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Author

Corporate Author USDA-States-EPA 2,4,5-T RPAR Assessment Team

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ALVIN L. YOUNG, Major, USAF
Consultant, Environmental Sciences

THE BIOLOGIC AND ECONOMIC ASSESSMENT OF 2,4,5-T

A REPORT OF THE
USDA-STATES-EPA
2,4,5-T RPAR ASSESSMENT TEAM

February 15, 1979

THE BIOLOGIC AND ECONOMIC ASSESSMENT OF 2,4,5-T

A Report of the
USDA-States-EPA
2,4,5-T RPAR Assessment Team

This report is a joint venture of the U.S. Department of Agriculture, the State Land Grant Universities, and the U. S. Environmental Protection Agency. It was prepared by a team of scientists from these organizatons and is an attempt to provide the best science available on the benefits of, and exposure to, 2,4,5-T.

The report is not intended to be a policy statement nor a position of advocacy for or against the use of a particular chemical. It is to be used in connection with other data as a portion of the total body of evidence in a final benefit/risk decision under the Rebuttable Presumption Against Registration Process in connection with the Federal Insecticide, Fungicide, and Rodenticide Act.

February 15, 1979

THE BIOLOGIC AND ECONOMIC ASSESSMENT OF 2,4,5-T

A REPORT OF THE USDA-STATES-EPA 2,4,5-T RPAR ASSESSMENT TEAM

ABSTRACT

USAGE AND IMPORTANCE

At least 10 million pounds of 2,4,5-T were identified by the Assessment Team as being used on 3.8 million acres annually in the United States to control weeds and brush on lands used for timber, grazing, rights-of-way, and rice. An additional but unknown amount of 2,4,5-T is used in these commodity areas and for some uses not analyzed in this report. Mechanical, hand labor, and fire alternatives for the control of plants currently controlled by 2,4,5-T generally are not sufficiently effective or economic when compared to 2,4,5-T.

TIMBER

About 3.2 million pounds of 2,4,5-T are currently used on about 1.2 million acres of forest land per year for reforestation and the release of conifers from competing vegetation. Approximately 0.2 percent of the commercial forest land in the U.S. may be treated in any one year.

Economic analysis of likely silvicultural alternatives to 2,4,5-T shows that canceling present uses of 2,4,5-T for timber production would result in management cost increases on all forest lands in the United States of $13.5 million the first year with a discounted cumulative increased management cost of $675 million after 50 years.

Reduced growth on all forest lands in the United States is estimated to be 15 million cubic feet per year the first year without 2,4,5-T and will continue to increase to 624 million cubic feet per year in the 50th year. The resulting cumulative reduced timber harvest is estimated to be 224 million cubic feet after 5 years and 18,250 million cubic feet

after 50 years. Increased management costs and reduced growth are combined by two methods in this analysis - present net worth and annual net income loss. Present net worth of U.S forests is expected to decrease $153 million the first year without 2,4,5-T with a cumulative present net worth loss of $4,421 million after 50 years. Annual net income loss, a sum of $9.6 million in reduced stumpage incomes and $13.5 million in increased stand management costs, is estimated to be $23.1 million the first year after cancellation of 2,4,5-T uses at present levels. Cumulative net income losses are estimated to total $801 million at the end of 10 years.

GRAZING LANDS

About 1.9 million pounds of 2,4,5-T are applied to 1.6 million acres annually to control mesquite and the post-blackjack oaks of the Southwest and in Oklahoma, Arkansas, and Missouri. 2,4,5-T is also important for control of several other pest and poisonous plants in other western states and on eastern pasture land, but on a more limited acreage. Expected income losses from the mesquite-infested rangelands, post-blackjack oak rangelands, and sand-shinnery oak rangelands are $871,800 the first year after 2,4,5-T is canceled but silvex and dicamba are available. Cumulative losses over the 16-year evaluation period are estimated to be $26.6 million. If both 2,4,5-T and silvex are canceled and dicamba is available, reductions in income to producers are expected to increase to $5.6 million the first year with a 16-year cumulative loss of $262.5 million. Losses on eastern and western pasture lands and from other brush, weed, and poisonous plants on all grazing and pasture lands would be a sizeable addition but can not be calculated from currently available data.

RIGHTS-OF-WAY

Control of brush is necessary for the safe, effective operation of the utility and transportation rights-of-way which crisscross the U.S. About 4.1 million pounds of 2,4,5-T are applied to 682,000 acres of the

31.3 million acres of rights-of-way each year. If 2,4,5-T registrations were canceled, current operating and maintenance expenses would increase an estimated 35 percent or about $35 million annually on these rights-of-way. About 74 percent of this increase would be incurred on electric rights-of-way.

RICE

Rice is grown on 2.5 million acres, mainly in four southern states (Arkansas, Louisiana, Texas, and Mississippi). Rice is a crop that is intensively managed and contributes significantly to these rural economies. About 300,000 pounds of 2,4,5-T are used on 300,000 acres each year for rice production. If 2,4,5-T registrations were canceled and the best alternate treatments (silvex, 2,4-D, and propanil) were substituted, rice farmers would lose $4.2 to $6.7 million annually. If both 2,4,5-T and silvex were canceled, the loss would range from $5.4 to $8.9 million annually.

CHEMICAL BEHAVIOR IN THE ENVIRONMENT

The movement, persistence, and fate of 2,4,5-T and TCDD in the environment are well known. Plants are the main receptors of both chemicals. Initial residues of 2,4,5-T immediately after application may be as high as 300 ppm, but residues decline rapidly thereafter due to plant growth and metabolism, photodegradation, volatilization, and rainfall. TCDD on vegetation and soil is rapidly photodecomposed by sunlight. In soils, 2,4,5-T does not persist in significant amounts from one year to the next. 2,4,5-T can occur in surface runoff water if heavy rainfall occurs soon after treatment. The percentage lost from treated areas is very small and 2,4,5-T dissipates rapidly in streams. Contamination of ground water by either chemical is highly unlikely because of limited leaching.

Residues of 2,4,5-T rarely occur in meat, milk, and other agricultural products. It does not accumulate in animal tissues and is rapidly excreted following ingestion by man and animals. TCDD is not bioaccumulating to detectable (10 ppt) levels from currently registered uses of 2,4,5-T.

EXPOSURE OF APPLICATORS

The 2,4,5-T Assessment Team used both correction factors and experimental data to estimate applicator exposure. Both methods show exposure is substantially less than estimated by EPA in Position Document 1 (PD-1). When calculated using the no-adverse-effect level from PD-1, the margins of safety are more than 1,000 for actual treatment situations. Adding a long-sleeved shirt and gloves to work apparel in place of a short-sleeved shirt reduces exposure 91 percent.

ACCIDENT RATE

A comparison of accident rates from spraying 2,4,5-T and alternate methods of vegetation control show that (1) the rate is lowest for aerial and ground application of herbicides on rangelands in Texas, (2) second for mechanical control of range brush, (3) third for all aerial application operations, and (4) highest for clearing brush manually.

Key Words: 2,4,5-T, TCDD, herbicide, biologic, economic, benefits, exposure, forest, timber, rice, pasture, range, rights-of-way, electric, highway, railroad, oil, gas, utilities, mesquite, pine, Douglas-fir, conifer, mixed hardwoods, brush, weeds, toxicity, persistence, post-blackjack oak, ecological, environmental, and Oregon.

MEMBERS OF THE 2,4,5-T ASSESSMENT TEAM

R. W. Bovey, Research Leader, Brush Control Research Group, SEA, AR, USDA, Texas A & M University, College Station, Texas (Group Leader, Assessment of 2,4,5-T Uses of Range and Pasture)

Boysie E. Day, Professor of Plant Physiology, University of California, Berkeley, California

Herman Delvo, Project Leader, Economics of Pesticide Regulation, Economics, Statistics and Cooperatives Service, USDA, Washington, D.C.

Garlyn O. Hoffman, Range Brush and Weed Control Specialist, Texas A & M University, College Station, Texas

Harvey A. Holt, Associate Professor of Forestry and Natural Resources, Purdue University, West Lafayette, Indiana
(Group Leader, Assessment of 2,4,5-T Uses on Rights-of-Ways)

Roger C. Holtorf, Economist, Economic Analysis Branch, Environmental Protection Agency, Washington, D.C.

Dayton L. Klingman, Chief, Weed Research Laboratory, SEA, AR, USDA Beltsville, Maryland
(Co-leader, 2,4,5-T Assessment Team)

B. Ted Kuntz, Research Economist, Economics, Statistics and Cooperatives Service, USDA, Corvallis, Oregon
(Leader, Economic Assessment of all Uses of 2,4,5-T)

Charles Lewis, Plant Pathologist, Plant Science Branch, Environmental Protection Agency, Washington, D.C.

Michael Newton, Professor of Forest Ecology, Oregon State University, Corvallis, Oregon
(Leader, Biological Assessment of all Uses of 2,4,5-T)

Logan A. Norris, Supervisory Research Chemist, Forest Service, USDA, Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon
(Leader, 2,4,5-T Assessment Team)

Robert N. Pearl, Silviculturist, Forest Service, USDA, Washington, D.C.

Paul F. Sand, Staff Officer, Pest Program Development Staff, APHIS, PPQ, USDA, Hyattsville, Maryland.

Charles Scifres, Professor of Range Science, Texas A & M University, College Station, Texas

Roy J. Smith, Jr., Research Agronomist, SEA, AR, USDA, Stuttgart, Arkansas
(Group Leader, Assessment of 2,4,5-T Uses on Rice)

Ronald E. Stewart, Research Silviculturist, Forest Service, USDA, Washington, D.C.
(Group Leader, Assessment of 2,4,5-T Uses on Timber)

Fred Tschirley, Professor and Head of Botany and Plant Pathology, Michigan State University, East Lansing, Michigan

James M. Witt, Professor of Agricultural Chemistry, Oregon State University, Corvallis, Oregon
(Leader, Environmental Assessment of all Uses of 2,4,5-T)

ADDITIONAL CONTRIBUTORS

John Benzie, Supervisory Research Forester, Forest Service, USDA, North Central Forestry Experiment Station, Grand Rapids, Minnesota

L. F. Bouse, Agricultural Engineer, SEA, AR, USDA, Texas A & M University, College Station, Texas

Ray Boyd, Research Forester, Forest Service, USDA, Inter-Mountain Forest and Range Experiment Station, Moscow, Idaho

William Bramble, Professor Emeritus of Forestry and Natural Resources, Purdue University, West Lafayette, Indiana

W. R. Byrnes, Professor of Forestry and Natural Resources, Purdue University, West Lafayette, Indiana

Ken Carvel, Professor of Forestry, University of West Virginia, Morgantown, West Virginia

William Chappell, Professor of Botany and Plant Physiology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

Jerome J. Chetock, Silviculturist, Oregon State Department of Forestry, Salem, Oregon

Ray Dalen, Range Specialist, Forest Service, USDA, Albuqerque, New Mexico

George Dutrow, Research Economist, Forest Service, USDA, Duke University, Durham, North Carolina

Robert Frank, Research Forester, Forest Service, USDA, Northeast Station, Orono, Maine

David A. Graham, Pesticide Use Specialist, Forest Service, USDA, Washington, D.C.

Robert D. Greaves, Resource Forester, Oregon State Department of Forestry, Salem, Oregon

C. H. Herbei, Research Leader, Jornada Experimental Range, SEA, AR, USDA, Las Cruces, New Mexico

Walter H. Knapp, Silviculturist, Forest Service, USDA, Region 6, Portland, Oregon

Robert E. Lee, II, Economist, Economic Analysis Branch, Environmental Protection Agency, Washington, D.C.

William Mann, Jr., Supervisory Research Forester, Forest Service, USDA, Southern Forestry Experiment Station, Alexandrea, Louisiana

C. Dudley Mattson, Economist, Economic Analysis Branch, Environmental Protection Agency, Washington, D.C.

Clark Row, Principle Research Economist, Forest Service, USDA, Washington, D.C.

Clara Roy, Economist, Economic Analysis Branch, Environmental Protection Agency, Washington, D.C.

Tom Russell, Research Forester, Forest Service, USDA, Southern Forestry Experiment Station, Sewanne, Tennessee

J. Stritzke, Associate Professor of Agromony, Oklahoma State University, Stillwater, Oklahoma

Phil Weatherspan, Research Forester, Forest Service, USDA, Pacific Southwest Forest and Range Experiment Station, Redding, California

SPECIAL TERMS AND ACRONYMS

ACE	-	allowable cut effect
ae	-	acid equivalent
aehg	-	pounds acid equivalent per 100 gallons
ai	-	active ingredient
amitrole-T	-	3-amino-s-triazole with ammonium thiocyanate
AMS	-	ammonium sulfamate
asulam	-	methyl sulfanilylcarbamate
atrazine	-	2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine
AU	-	animal units
bentazon	-	3-isopropyl-1H-2,1,3-benzothiadiazin-4(3H)one-2,2-dioxide
bifenox	-	methyl 5-(2,4-dichlrophenoxy)-2-nitrobenzoate
cacodylic acid	-	hydroxydimethylarsine oxide
ceteris peribus	-	all other things being equal or unchanged
Cunits	-	100 cubic feet of wood
dalapon	-	2,2 dichloropropionic acid
dbh	-	diameter breast height
dicamba	-	3,6 dichloro-o-anisic acid
2,4-D	-	2,4-dichlorophenoxyacetic acid
dichlorprop	-	2-(2,4-dichlorophenoxy)propiomic acid
EPA	-	U. S. Environmental Protection Agency
FIFRA	-	Federal Insecticide, Fungicide, and Rodenticide Act
Fosamine ammonium	-	ammonium ethyl carbamoylphosphonate
glyphosate	-	N-(phosphonomethyl)glycine
MAI	-	mean annual increment
MCPA	-	2-methyl-4-chlorophenoxyacetic acid
molinate	-	5-ethyl hexahydro-1H-azepine-1-carbothioate
MSMA	-	monosodium methanearsonate
oncogenic	-	tumor forming
picloram	-	4-amino-3,5,6-trichloropicolinic acid
pronamide	-	3,5-dichloro-N-(1,1-dimethyl-2-propynyl)benzamide

propanil	-	3',4'-dichloropropionanilide
R	-	R or Registered trademark
ROW	-	rights-of-way
RPAR	-	Rebuttable Presumption Against Registration
silvex	-	2-(2,4,5-trichlorophenoxy)propionic acid
simazine	-	2-chloro-4,6-bis(ethylamino)-s-triazine
teratogenic	-	fetus deforming
TCDD	-	2,3,7,8-tetrachlorodibenzo-p-dioxin
TSI	-	timber stand improvement
2,4,5-T	-	2,4,5-trichlorophenoxyacetic acid
USDA	-	U.S. Department of Agriculture

SUMMARY

The Environmental Protection Agency issued the Notice of Rebuttable Presumption Against Registration (RPAR) of 2,4,5-T in the Federal Register on April 21, 1978. Presumptions used in issuing the RPAR indicated that "registrations and applications for registration of pesticide products containing 2,4,5-T meet or exceed the 40 CFR 162.11(a)(3) risk criteria relating to oncogenic effects and teratogenic and/or fetotoxic effects in mammalian test species." 2,4,5-T is currently registered for use in forestry, grazing lands, rice, rights-of-way, and other noncroplands. The Assessment Team identified and analyzed vegetation control programs which use about 10 million pounds of 2,4,5-T on 3.8 million acres annually in the United States. There is some additional amount of 2,4,5-T used in these commodity areas and some minor uses which could not be quantified with current data. The biologic and economic analyses which evaluate the results of canceling 2,4,5-T are based on the management practices that would be used if 2,4,5-T is canceled. These practices include mechanical, fire, and hand labor alternatives applied singly or in combination.

TIMBER

There are about 500 million acres of commercial forest lands in the United States. Only about half of this acreage may actually be available for timber production. The United States presently is a net importer of wood. Significant increases in domestic production are possible through intensive forest cultural practices, including the control of competing vegetation with 2,4,5-T.

The herbicide 2,4,5-T is used to prepare areas for planting, for releasing desirable trees (from competing vegetation), for controlling quality and spacing of overstory trees (timber stand improvement), and for creating and maintaining fuel breaks. A wide variety of other vegetation-management practices such as mechanical clearing, prescribed

burning, other herbicides, manual cutting, and modified cultural practices are also used where applicable for these purposes.

Each practice has its own unique set of advantages and limitations. Prescriptions in forest management are site specific, and most practices are now being used where experience has proven them to be cost-effective and environmentally acceptable. Use of mechanical equipment as a replacement for 2,4,5-T is largely limited by rough terrain and likelihood of soil damage. Prescribed burning is limited by the narrow range of fuel conditions and weather requirements needed to obtain a satisfactory burn as well as legal air-quality restrictions. Use of other herbicides such as picloram plus 2,4-D, silvex, dicamba plus 2,4-D, fosamine ammonium, and glyphosate is limited by greater persistence or lack of selectivity, effectiveness, and registration. High treatment costs, inadequate labor supply, and hazard to workers limit the degree to which manual cutting can substitute for 2,4,5-T. Modified cultural practices that limit establishment of brush species or reduce their impact have been developed and are in use, but do not fully substitute for herbicides.

A survey of various landowners and states estimates a present use of 2,4,5-T on about 1.2 million acres per year, and a reasonable potential for use on 3.1 million acres per year. About 75 percent is aerially applied, 14 percent is applied by mistblower or broadcast ground spray, and 11 percent is applied as stem sprays or with tree injectors to individual stems.

An analysis of management costs and timber production resulting from use of alternative management regimes with and without 2,4,5-T was conducted for major timber type groups that account for 86 percent of the estimated use of 2,4,5-T in forestry in the United States. Regional panels of experts developed typical and alternative silvicultural prescriptions and timber harvests for three use patterns: (1) 2,4,5-T used for site preparation only, (2) 2,4,5-T used for release only, and (3) 2,4,5-T used for both site preparation and release.

Estimated impacts due to canceling the present uses of 2,4,5-T on management cost, timber growth, and present net worth are as follows:

End of year	Annual reduced timber yield	Cumulative Increased management cost	Cumulative Reduced timber harvest	Cumulative Reduced present net worth
	million cu. ft.	million dollars	million cu. ft.	million dollars
1	15.0	13.5	15.0	153.2
5	74.6	67.5	223.8	734.0
10	149.3	135.0	821.5	1,390.1
50	624.4	675.0	18,249.5	4,421.4

Increased management costs on all forest lands in the United States are estimated to be $13.5 million the first year without 2,4,5-T with a discounted cumulative increased management cost of $675 million after 50 years.

Reduced growth on all forest lands in the United States is estimated to be 15 million cubic feet per year the first year without 2,4,5-T and will continue to increase to 624 million cubic feet per year the 50th year. Cumulative reduced timber harvest resulting from the reduced timber growth is estimated to be 224 million cubic feet after 5 years and 18,250 million cubic feet after 50 years. Increased management costs and reduced growth are combined by two methods in this analysis - present net worth and annual net income loss. Present net worth of all forest lands in the United States is expected to decrease $153 million the first year without 2,4,5-T with a cumulative loss of $4,421 million after 50 years.

Assuming that reduced productivity would be reflected in reduced harvest under sustained yield management and adding cumulated reductions in stumpage incomes from all forest lands in the United States to cumulated increased management costs show the following total impact:

End of year	Cumulative increased management cost	Cumulative reduced stumpage income	Cumulative net income loss
	---million dollars---		
1	13.5	9.6	23.1
5	67.5	163.8	231.3
10	135.0	666.3	801.3

Forest land owners in the United States would spend $13.5 million more for stand management and received $9.6 million less in stumpage income for a net income loss of $21.8 million the first year after cancellation of 2,4,5-T uses at present levels. Cumulative net income losses are expected to total $801 million at the end of 10 years.

Further, conversion of less productive hardwood and nonstocked forest types to conifers on suitable sites using 2,4,5-T is presently adding about 4.2 million cubic feet of softwood production annually to the nation's timber supply. This is in addition to that which would be added by the conversion of the white-red-jack pine and oak-hickory types considered in the economic impact analysis.

RANGE AND PASTURE

The United States has approximately 1 billion acres of grazing land, one-third of which is infested with undesirable woody and herbaceous plants. These plants cause a loss of nearly $2 billion annually from decreased forage production, watershed yield, wildlife habitat, and recreational use. Cost of handling livestock, death and injury losses of livestock, and human injuries and allergies are greatly increased by stands of poisonous, thorny, or pollen-producing species. 2,4,5-T is an important management tool on grazing lands.

Pastures and rangeland require vegetation management to maintain the desired vegetation whether grazed or not. Aerial application of 2,4,5-T is the only economical and practical control measure available for some areas because of the steep, wet, or rocky nature of the land

and the height of the vegetation. Approximately 1.6 million acres of mesquite-infested rangelands, post-blackjack oak rangelands, and sand-shinnery oak rangelands are treated annually with 2,4,5-T. Treatment rates vary from 0.5 to 2 pounds per acre for a total use of about 1.9 million pounds of 2,4,5-T. Only minor quantities of silvex and dicamba are currently used.

Mesquite occurs on about 93 million acres of rangeland in the Southwest. It may reduce overall yield of range products by 30 percent. Mesquite and many other brush species are susceptible to low rates of 2,4,5-T. Alternative methods (chemical, mechanical, fire, or biological) cause greater environmental damage or are not as economical as 2,4,5-T in most situations. Mesquite control is practiced on about 600 thousand acres annually. The effects from a single application of 0.5 to 1.0 pounds per acre last from 5 to 16 years. Approximately 15 million acres of grazing land are managed with 2,4,5-T.

The post oak-blackjack oak savannah occupies more than 35 million acres of grazing land while nearly 14.3 million acres are infested with shinnery oaks. Post and blackjack oaks can be controlled by treating individual trees with 2,4,5-T, but the majority are treated by aircraft. Typically, 2,4,5-T is applied at 2 pounds per acre in the spring followed by 1 to 2 pounds per acre one or two years later. The 2,4,5-T treatment of mesquite and oaks has been practiced successfully for more than 25 years. Beef production on mesquite, post-blackjack oak and sand-shinnery oak-infested rangelands is estimated to decrease 2.1 million pounds the first year after 2,4,5-T is canceled if silvex is available. Cumulative losses over the 16-year evaluation period are estimated to be 147.6 million pounds of beef if 2,4,5-T is canceled and silvex is available.

If both 2,4,5-T and silvex are canceled but dicamba is available, beef production would be expected to decrease 21.5 million pounds the first year. Cumulative losses over the 16-year evaluation period are estimated to be 1.8 billion pounds of beef. If 2,4,5-T and silvex are canceled and dicamba is not used, beef production would be expected to decrease 27.7 million pounds the first year. Cumulative losses over the 16-year evaluation period are estimated to be 2.5 billion pounds.

A number of brush and weed species including cactus, hardwoods, yucca, poisonous plants, desert shrub, species in fence rows, pastures, and other woody plants are controlled effectively by 2,4,5-T, but data are not adequate for full economic analysis. However, these uses are very important to affected landowners.

2,4,5-T is used for woody plant control on over a million acres of pastureland in the eastern United States. Generally the same control methods are applied in the East as in the West. However, hand and ground application are more common than aerial application due to the smaller areas to be treated and the interspersion of the area with crops sensitive to small amounts of 2,4,5-T drift.

The lack of a historical data base on some of the uses of 2,4,5-T and other herbicides on pasture and range, especially the uses on eastern pastures, fence rows, cactus, yucca, hardwoods, poisonous plants, desert shrub, and miscellaneous woody plants limited the completeness of this analysis. Without these data a full economic impact of canceling 2,4,5-T uses on herbaceous and woody plant problems on more than 1 billion acres of pasture and range can not be estimated. The inability to estimate the full economic impact of canceling 2,4,5-T uses on the majority of pasture and range acres underscores the fact that the total impact of such action is understated in this document.

Expected income losses from the mesquite-infested rangelands, post-blackjack oak rangelands, and sand-shinnery oak rangelands are $871,800 the first year after 2,4,5-T is canceled, assuming that silvex and dicamba would be available. Cumulative losses over the 16-year evaluation period are estimated to be $26.6 million. If both 2,4,5-T and silvex are canceled and dicamba is available, reductions in income to producers are expected to be $5.6 million the first year with a 16-year cumulative loss of $262.5 million. Further, if 2,4,5-T and silvex are canceled and dicamba proves ineffective, income to producers would be expected to decrease $6.9 million the first year with a 16-year cumulative loss of $347.5 million.

RIGHTS-OF-WAY

Effective vegetation management is necessary for the safe and reliable functioning of the nation's complex and extensive system of rights-of-way.

The estimated total vegetated right-of-way acreage for the U.S. is 17.3 million including: railroads - 1.9 million acres; highways - 8.3 million acres, pipelines - 2.2 million acres, and electric utilities - 5 million acres. Acres treated annually with 2,4,5-T for each type are approximately 127,000 for railroads, 22,000 for pipelines, 68,000 for highways, and 465,000 for electric utilities. About 4.1 million pounds of 2,4,5-T are applied to these 682,000 acres, annually. 2,4,5-T is not usually applied alone, but in combination with other herbicides. Most of the right-of-way acreage is located in the eastern U.S. where deciduous woody species that are highly susceptible to 2,4,5-T predominate. Woody plant growth is less intensive in the drier climate of the Central Plains and Rocky Mountain regions and control measures are required less often and last longer. The rapid plant growth in the Pacific Northwest requires intensive vegetation-control programs.

Railroads and highways use mostly broadcast foliar ground application methods. Pipeline rights-of-way are predominantly treated with aerial methods. Aerial and selective basal are the dominant application methods for electric rights-of-way.

Control of a variety of plant species is an important criterion in the selection of any herbicide treatment. 2,4,5-T is more effective on more species than 2,4-D, dichlorprop, and silvex. 2,4,5-T is comparable to dicamba but is less costly and less persistent. It is not as corrosive to equipment as AMS nor as persistent as picloram, and is more selective than glyphosate.

Fire is essentially unused as a right-of-way management tool because of difficulty in controlling fire on such narrow tracts of land. Mechanical and manual methods generally are much more expensive than an application of 2,4,5-T and must be repeated more frequently. In many instances 2,4,5-T is used because mechanical and manual methods are impossible such as on boggy or extremely steep sites.

If 2,4,5-T use on all rights-of-way is canceled, use of alternative herbicides is expected to increase annual vegetation-management costs by $33.9 million. Additional costs of manually controlling species of woody plants that may not be controlled with alternative herbicides were not estimated. Electric utilities would have increased vegetation-management costs of $25.2 million followed by railroads at $6.3 million. Annual vegetation-management costs are estimated to increase about $1.0 million for highway and pipeline rights-of-way. For all rights-of-way, vegetation-management costs with alternatives would increase by 35 percent over the current 2,4,5-T vegetation-management program, ranging from a high of 55 percent for railroads to a low of 32 percent for electric and pipeline rights-of-way.

RICE

About 300,000 pounds of 2,4,5-T are applied annually on 300,000 acres of rice in the lower Mississippi Valley (Arkansas, Louisiana, Texas, and Mississippi). The principal weed pests for which 2,4,5-T use is most important include hemp sesbania, northern jointvetch, morningglory, ducksalad, and redstem.

The use of 2,4,5-T on rice accounts for about 5 percent of the 2,4,5-T used in the U.S. About 12 percent of total U.S. rice acres is treated with 2,4,5-T; however, in the Mississippi Valley where 2,4,5-T use is most important in rice production, about 28 percent of rice acres is treated with 2,4,5-T annually.

The most likely alternative to 2,4,5-T on rice is silvex, 2,4-D, and propanil on 33, 20, and 47 percent respectively, of the acres currently treated with 2,4,5-T. Silvex is comparable in effectiveness to 2,4,5-T, but yield and quality reductions would result on those acres treated with 2,4-D and propanil because these herbicides are less effective than 2,4,5-T. Other herbicides registered for use in rice include MCPA, molinate, bifenox, bentazon, and oxadiazon. However, these herbicides are only partially effective and their use on 2,4,5-T treated acres would be minimal. Cultural weed-control practices such as seedbed preparation, seeding method, water management, summer fallowing, and crop rotations are relatively ineffective for control of broadleaf-aquatic weed plant complexes.

Assuming that silvex would be available, cumulative yield and quality losses and control cost increases for the first 3-years following 2,4,5-T cancellation are estimated at $10.9 million. During the second 3-year cropping cycle, losses from weed competition would increase to make a total loss for the 6-year period of more than $25 million. If both 2,4,5-T and silvex were canceled, cumulative losses are expected to be about $14 million during the first 3-year period and total $33 million at the end of 6 years.

BEHAVIOR AND IMPACT ON THE ENVIRONMENT

2,4,5-T causes the greatest effect on the environment through alteration of the density and species composition of the vegetative community. This alteration is usually the intended purpose of weed and brush-control projects and will occur regardless of the technique used.

Spray drift may occur if herbicides are applied with improper equipment and/or during adverse weather. Damage to adjacent susceptible vegetation may occur from nozzle leakage. Close attention to formulation, weather, and application techniques will reduce offsite deposit of 2,4,5-T to insignificant amounts.

2,4,5-T does not persist in significant amounts in soils from one year to the next. Initial herbicide residues in or on vegetation may be as high as 300 ppm, but they decline rapidly through plant metabolism, photodegradation, volatilization, and removal by rainfall. A small percentage of the applied 2,4,5-T can move in surface runoff water if heavy rainfall occurs soon after treatment. 2,4,5-T in streams rapidly dissipates by dilution (and other processes) and is difficult to detect downstream. In impounded water, 2,4,5-T disappears rapidly, especially if adapted microorganisms are present. Groundwater contamination is unlikely.

When used in currently registered practices, residues of 2,4,5-T rarely occur in meat, milk, and other agricultural products. 2,4,5-T does not accumulate in animal tissues and is rapidly excreted in man and animals should intake occur. FDA national market basket surveys reveal insignificant quantities of 2,4,5-T in food products.

TCDD has a short half-life (< 1 day) when it is on vegetation in the presence of a hydrogen donor. Photochemical degradation also occurs on soil (half life about 50 hours). Groundwater contamination with TCDD has not been detected. Environmental monitoring indicates bioaccumulation of TCDD is not occuring (sufficient to produce residues in excess of 10 ppt in the majority of the population) in animals in or near areas treated with 2,4,5-T in current operational programs. Burning of 2,4,5-T treated vegetation is not expected to generate levels of TCDD greater than those which could be present immediately after the application of the herbicide.

Exposure levels for four scenarios used in Position Document No. 1 were recalculated using assumptions which reflect actual exposure situations. These adjusted exposure levels were used with the no-adverse-effect levels cited by EPA in PD-1 to calculate the following adjusted margins of safety:

Exposure scenario[a/]	Margin of safety			
	2,4,5-T		TCDD	
	PD-1[b/]	AT[c/]	PD-1[b/]	AT[c/]
2. Dermal exposure - backpack sprayer	3	$5.6x10^3$	43	$4.1x10^4$
3. Dermal exposure - tractor mounted boom	11	$1.1x10^6$	167	$8.8x10^6$
4. Dermal exposure - aerial application	312	$39x10^7$	$6.0x10^3$	$3.0x10^8$
5. Inhalation - aerial application	870	$7.2x10^5$	$1.5x10^4$	$1.2x10^7$

a/Numbered to correspond to order of criteria of risk cited in PD-1.

b/Margin of safety calculated from PD-1.

c/Adjusted margin of safety corrected by the Assessment Team using the factorial method.

Based on dermal exposure experiments, human absorption of 2,4,5-T is estimated to range from less than 0.001 mg/kg/hr to a maximum of 0.095 mg/kg/hr when exposed skin is wet with spray for the entire application period. An operational monitoring study showed human absorption of 0.0001 to 0.03 mg/kg/hr. Addition of a long-sleeved shirt and gloves to work apparel in place of a short-sleeved shirt reduces exposure 91 percent. Both the factorial and the absolute basis show that applicator exposure is substantially less than estimated in PD-1.

2,4,5-T is low-to-moderate in acute and subacute toxicity to a large number of mammals, birds, aquatic organisms, and insects. Dogs are more susceptible to 2,4,5-T than mice, rats, guinea pigs, rabbits, swine, sheep, cattle, chickens, and monkeys. Toxicity to fish and other aquatic organisms depends on formulation with the ester formulations being most toxic. When used according to label directions, acute or subacute toxic exposure levels are not likely to occur for domestic or wild animals.

ACCIDENT RATES

Accidents causing human injury and death result from the chemical, mechanical, fire, and hand labor methods for controlling weeds and brush in forests, grazing lands, rights-of-way, and rice. Chemical control has a lower accident rate than alternative nonchemical methods in a given commodity area.

During approximately 1.4 million man-hours of aerial application of all herbicides to brush in Texas, one accident occurred in which a flagger lost the sight in one eye which was diagnosed as being caused by diesel oil. During 75,000 hours of chemical application by ground equipment, no accidents occurred. During nearly 2 million man-hours of mechanical operation, it was estimated 201 accidents occurred or 6.7 accidents per 100,000 man-hours. Brush control on forest land in Oregon by chain saws resulted in 769 accidents per 100,000 man-hours. In hand-clearing operations the rate was 407 accidents per 100,000 man-hours.

The 1976 National Transportation Safety Board record of accidents involving the aerial application of herbicides shows the estimated annual number of accidents for spraying rangeland, rights-of-way, forests, and rice was 2.42, 1.73, 1.59, and 0.63, respectively. The estimated numbers of annual fatalities for these groups were 0.24, 0.16, 0.16, and 0.06, respectively.

Thirty-five states separated Workmen's Compensation rates into two categories--(1) tree trimming and brush cutting versus (2) chemical spray. These rates represent the percent of total labor cost spent for Workmen's Compensation. The average Workmen's Compensation rates for the 35 states that separated the two categories are 8.14 for tree trimming and brush cutting and 2.65 for chemical spray.

A comparison of accident rates shows that the rate is lowest for aerial and ground application of herbicides on rangeland in Texas, second lowest for mechanical control of range brush, third for all aerial application operations, and highest for clearing of brush in forests either manually or with a chain saw.

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INTRODUCTION

Part 40, Section 162.11, of the Code of Federal Regulations issued pursuant to the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) as amended (86 Stat. 971, 89 Stat. 751, 7 U.S.C. 136 et seq.), provides that a rebuttable presumption against registration (RPAR) shall arise if the Environmental Protection Agency (EPA) determines that the pesticide meets or exceeds any of the risk criteria relating to acute or chronic toxic effects set forth in the Regulation (Section 162.11 (a) (3)). A notice of RPAR is issued when the evidence related to risk meets the criteria set forth.

The RPAR may be rebutted by proving that:

(1) In the case of a pesticide presumed against pursuant to the acute toxicity or lack of emergency treatment criteria, "that when considered with the formulation, packaging, method of use, and proposed restrictions on the directions for use and widespread and commonly recognized practices of use, the anticipated exposure to an applicator or user and to local, regional or national populations of nontarget organisms is not likely to result in any significant adverse effects" and,

(2) In the case of a pesticide presumed against pursuant to the chronic toxicity criteria, " that when considered with proposed widespread and commonly recognized practices of use, the pesticide will not concentrate, persist or accrue to levels in man or the environment likely to result in any significant chronic adverse effects", or

(3) In either case, that "the determination by the Agency that the pesticide meets or exceeds any of the criteria for risk was in error."

The regulations also provide that evidence may be submitted as to whether the economic, social and environmental benefits of the use of the pesticide subject to the presumption outweigh the risk of use. If the risk presumptions are not rebutted, the Administrator (of EPA) will consider the information in determining the appropriate regulatory action.

In the Federal Register of April 21, 1978, the Environmental Protection Agency published a notice of a rebuttable presumption against registration and continued registration of pesticide products containing 2,4,5-T. EPA has determined that pesticide products containing 2,4,5-T and/or tetrachlorodibenzo-p-dioxin (TCDD) meet or exceed the following criteria related to (1) oncogenic effects and (2) other chronic or delayed toxic effects.

EPA has concluded that there is sufficient evidence to indicate that 2,4,5-T containing TCDD at levels as low as 0.05 ppm and TCDD alone can produce oncogenic effects in mammals. Based on their assumption that currently manufactured 2,4,5-T products contain up to 0.099 ppm TCDD, they state that a rebuttable presumption against registration has arisen.

EPA has concluded from several studies that 2,4,5-T containing TCDD, 2,4,5-T without detectable TCDD, and TCDD alone produce fetotoxic and teratogenic effects in mammals. Based on dermal and inhalation exposure scenarios and on cumulative oral, dermal, and inhalation exposure scenarios for 2,4,5-T and/or TCDD, EPA has concluded that an ample margin of safety does not exist for the population at risk (women of child-bearing age). They state that a rebuttable resumption against registration has arisen.

The USDA-States-EPA 2,4,5-T Assessment Team was formed in April, 1978 to prepare a biologic and economic assessment of 2,4,5-T in the United States. This is the report of that team effort. The purpose of this report is to provide biological, exposure, and economic information on the various uses of 2,4,5-T to EPA. The data and discussions of uses, exposures, and benefits accruing from currently registered uses of 2,4,5-T are based on data and experience accumulated over more than 25 years.

The report has six major sections: one each on four commodity groups (timber, range and pasture, rights-of-way, and rice), one on behavior and impact of 2,4,5-T in the environment, and one on accident statistics from the use of 2,4,5-T and alternative methods for weed and brush control. There are generally two major subdivisions within each commodity section. The biological assessment subdivision describes the commodity, the nature and extent of use of 2,4,5-T, the effects on commodity production of using 2,4,5-T or alternative practices, and their costs. The economic assessment integrates data on commodity production and costs to quantify the economic benefits or effects of using 2,4,5-T or alternative practices for the production of a specific commodity. The environmental section contains a review of the movement, persistence, and fate of 2,4,5-T and TCDD in the environment. It also includes an extensive discussion of the exposure domestic and wild animals and humans (applicators and others) are likely to receive as a result of the use of 2,4,5-T in the four commodity areas. The report has three appendices, (1) a 2,4,5-T RPAR Assessment Report for timber production in Oregon, (2) an analysis of recent correspondence received by USDA regarding 2,4,5-T and (3) extracts from the Federal Register which give the EPA exposure analyses.

CHAPTER 1: THE BIOLOGIC AND ECONOMIC ASSESSMENT OF 2,4,5-T USE IN TIMBER PRODUCTION IN THE UNITED STATES

SUMMARY

There are about 500 million acres of commercial forest land in the United States. Only about half of this acreage may actually be available for timber production because of changing ownership objectives and land classifications. The United States presently is a net importer of wood--1.6 billion cubic feet or about 11 percent of total U.S. consumption in 1972. Low net energy requirements in the extraction and manufacturing of forest products coupled with the renewable nature of the forest, will increase the importance of wood in relation to more energy-intensive, nonrenewable materials. Significant increases in domestic production will be needed to meet projected increases in demand and to avoid increased reliance on wood imports. Production increases are possible by applying existing intensive forest cultural practices, including controlling competing vegetation with 2,4,5-T.

The herbicide 2,4,5-T is used to control competing vegetation for: preparing existing brushfields, new burns, and harvested areas for planting; releasing existing stands of desirable trees (usually conifers); controlling quality and spacing of overstory trees, or timber stand improvement (TSI); and creating and maintaining fuel breaks. A wide variety of other vegetation-management practices, such as mechanical clearing, prescribed burning, other herbicides, manual cutting, and modified cultural practices are available and in use on forest lands.

Each management practice has its own unique set of advantages and disadvantages. Prescriptions in forest management are site specific and most practices are now used where experience has proven them to be cost-effective and environmentally acceptable. Use of mechanical equipment as a replacement for 2,4,5-T is largely limited by lack of suitable terrain and likelihood of soil damage. Additional use of

prescribed burning is limited by the narrow range of fuel conditions and weather requirements needed to obtain a satisfactory burn as well as increased air quality restrictions. Use of other herbicides such as picloram plus 2,4-D, silvex, dicamba plus 2,4-D, fosamine ammonium, and glyphosate is limited by greater persistence or lack of selectivity, effectiveness, and registration. High treatment costs and inadequate labor supply will limit the use of manual cutting as a substitute for 2,4,5-T. Modified cultural practices that limit establishment of brush species or reduce their impact have been developed and are in use, but additional practices are not available as substitutes because of the lack of ecological information on desirable species and their competitors.

In the North, both 2,4-D and manual treatments would be likely substitutes for conifer release, but each would require three or four separate applications to obtain equivalent effects to one application of 2,4,5-T. Hand cutting or injection of 2,4-D amine, picloram plus 2,4-D, MSMA, and cacodylic acid would likely replace the small present use of 2,4,5-T for TSI.

In the South, picloram plus 2,4-D, or chopping or shearing mechanical treatments combined with windrowing and burning would be substituted for 2,4,5-T for site preparation in the loblolly, shortleaf, and longleaf-slash pine types. At least one manual cutting would be needed to release pines on most sites.

Management intensity in the Rocky Mountains has been low and few herbicides have been used. As existing young stands are managed more intensively, however, the need for 2,4,5-T, especially in the northern Rocky Mountains, will increase. The probable substitute for 2,4,5-T would be 2,4-D applied at higher application rates or applied more frequently (1.5 to 2 times more often).

In the Pacific Coast, 2,4,5-T is a major silvicultural tool for vegetation management. About 6 percent of site preparation on new cuttings and 10 percent in brushfields is accomplished with 2,4,5-T. Use of mechanical site preparation on areas now treated with 2,4,5-T is often limited by steep, rough topography. Broadcast burning, spraying, or spraying plus burning using 2,4-D, or picloram plus 2,4-D are the most likely substitutes. Amitrole-T, fosamine ammonium, or glyphosate may be used on some sites in western Oregon and Washington. About 78 percent of all release treatments use 2,4,5-T applied alone or in combination with 2,4-D. Herbicides such as 2,4-D, silvex, amitrole-T, fosamine ammonium, or glyphosate would be used as substitutes if 2,4,5-T were unavailable. None of these herbicides would be a complete substitute for 2,4,5-T because each has a different spectrum of effectiveness. Even a considerable increase in manual cutting of brush would not maintain current production in all cases.

The most important use of 2,4,5-T is for release of conifers, especially pine species. A survey of various landowners and states estimates 2,4,5-T is presently used on about 1.2 million acres per year with a reasonable potential of 3.1 million acres per year. About 75 percent is aerially applied, 14 percent by mistblower or broadcast ground spray, and 11 percent as stem sprays or with tree injectors to individual stems.

An analysis of costs and timber yields resulting from use of alternative management regimes with and without 2,4,5-T was conducted for major timber type groups in the United States. Regional panels of experts developed typical and alternative silvicultural prescriptions and timber harvests for three use patterns: (1) 2,4,5-T used for site preparation only, (2) 2,4,5-T used for release only, and (3) 2,4,5-T used for both site preparation and release. The alternatives included chemical, mechanical, manual, fire, and various combinations of these.

The timber types included in the analysis account for the following portions of the estimated present use of 2,4,5-T on forests: North, 79 percent; South, 87 percent; Pacific Coast, 86 percent; or 86 percent for the United States as a whole. Estimated impacts due to canceling the present uses of 2,4,5-T on management cost, timber growth, and present net worth are as follows:

Section and end of year	Annual reduced timber growth	Cumulative Increased management cost	Cumulative Reduced timber harvest	Cumulative Reduced present net worth
	million cu. ft.	million dollars	million cu. ft.	million dollars
North				
1	1.1	1.2	1.1	7.3
5	4.8	6.0	13.7	37.4
10	9.6	12.0	50.2	72.2
50	38.9	60.0	1,125.7	238.7
South				
1	8.2	11.0	8.2	89.3
5	41.4	55.5	124.2	430.6
10	82.8	111.0	455.7	821.2
50	300.8	555.0	9,813.6	2,679.5
Pacific Coast				
1	5.7	1.2	5.7	56.2
5	28.5	6.0	85.9	266.0
10	56.9	12.0	315.6	496.7
50	284.6	60.0	7,310.2	1,503.2
United States				
1	15.0	13.5	14.9	153.2
5	74.7	67.5	223.8	734.0
10	149.3	135.0	821.5	1,390.1
50	624.4	675.0	18,249.5	4,421.4

Increased management costs on all forest lands in the United States are estimated to be $13.5 million the first year after cancellation of 2,4,5-T with a discounted cumulative increased management cost of $675 million after 50 years. Reduced growth on all forest lands in the United States is estimated to be 15 million cubic feet per year the first year without 2,4,5-T and will continue to increase to an estimated 624.4 million cubic feet per year the 50th year. Cumulative reduced timber harvest resulting from the reduced timber growth is estimated to be 224 million cubic feet after five years and continue to increase to 18,250 million cubic feet after 50 years. Increased management costs and reduced growth are combined by two methods in the analysis - present net worth and annual net income loss. Present net worth on all forest lands in the United States is expected to decrease $153 million the first year without 2,4,5-T with a cumulative loss of $4,421 million after 50 years.

Assuming that reduced productivity would be reflected in reduced harvest under sustained yield management, and adding cumulated reductions in stumpage incomes from all forest lands in the United States to cumulated increased management costs show the following impacts by region and for the U.S.:

Section and end of year	Cumulative increased management cost	Cumulative reduced stumpage income	Cumulative net income loss
	----------million dollars------------		
North			
1	1.2	0.3	1.5
5	6.0	3.6	9.6
10	12.0	14.0	26.0
South			
1	11.0	4.2	15.2
5	55.5	75.2	130.7
10	111.0	311.5	422.5

Pacific Coast			
1	1.2	5.1	6.3
5	6.0	85.0	91.0
10	12.0	340.8	352.8
United States			
1	13.5	9.6	23.1
5	67.5	163.8	231.3
10	135.0	666.3	801.3

Forest land owners in the United States would have $13.5 million in increased management costs and $9.6 million in reduced stumpage income for a net income loss of $23.1 million the first year after cancellation of 2,4,5-T uses at present levels. Cumulative net income losses are estimated to total $801 million at the end of 10 years.

The present use of 2,4,5-T in the Rocky Mountains is limited to 180 acres treated for conifer release and 20 acres for site preparation and release, mostly on an experimental basis. Because of the lack of use experience, an economic analysis of impacts was not attempted. However, rising stumpage values, past reforestation failures, and predicted timber shortages all suggest an increased intensity of forest management and use of 2,4,5-T. A reasonable potential of 10,600 acres annually for release alone and 5,200 acres for both site preparation and release is projected for the Douglas-fir, ponderosa pine, western white pine, hemlock-spruce, fir-spruce, and nonstocked forest type groups in the Rocky Mountains.

Further, conversion of less productive hardwood and nonstocked forest types to conifers on suitable sites using 2,4,5-T is presently adding about 4.2 million cubic feet of softwood production annually to the nation's timber supply. This is in addition to that which would be added by the conversion of the white-red-jack pine and oak-hickory types.

CHAPTER 1: PART 1

THE BIOLOGIC ASSESSMENT OF 2,4,5-T USE IN TIMBER PRODUCTION

INTRODUCTION

This report describes the forest resource and forest management, vegetation management principles and needs, specific methods for accomplishing desired silvicultural objectives, estimates present and potential use of 2,4,5-T by treatment purpose and application method, discusses probable alternatives to 2,4,5-T including the costs, limitations, and environmental effects of each, and assesses the potential impacts of canceling the registration of 2,4,5-T on forest productivity and economic efficiency.

THE FOREST RESOURCE AND ITS MANAGEMENT

THE FOREST RESOURCE

The forests of the United States occur on a wide variety of climatic, soil, and topographic conditions ranging from hot, dry sites on shallow soils to cool, moist sites on deep soils. This diversity in environments combined with regional differences in geologic and glacial history results in a complex mosaic of forest communities. For this report, the United States has been divided into four sections on the basis of similar forest communities, environments, and economic conditions as shown in figure 1. The Society of American Foresters lists 106 forest cover types in the eastern United States and 50 types in the Western United States (Society of American Foresters 1954). These types can be grouped into four softwood (conifer) and six hardwood type groups in the East, and eight softwood and one hardwood type group in the West, and distributed as shown in table 1. Hardwood types, especially oak-hickory, predominate in the East while softwoods, especially Douglas-fir and ponderosa pine, are more common in the West. The loblolly-shortleaf pine type group is the most important softwood type in the East.

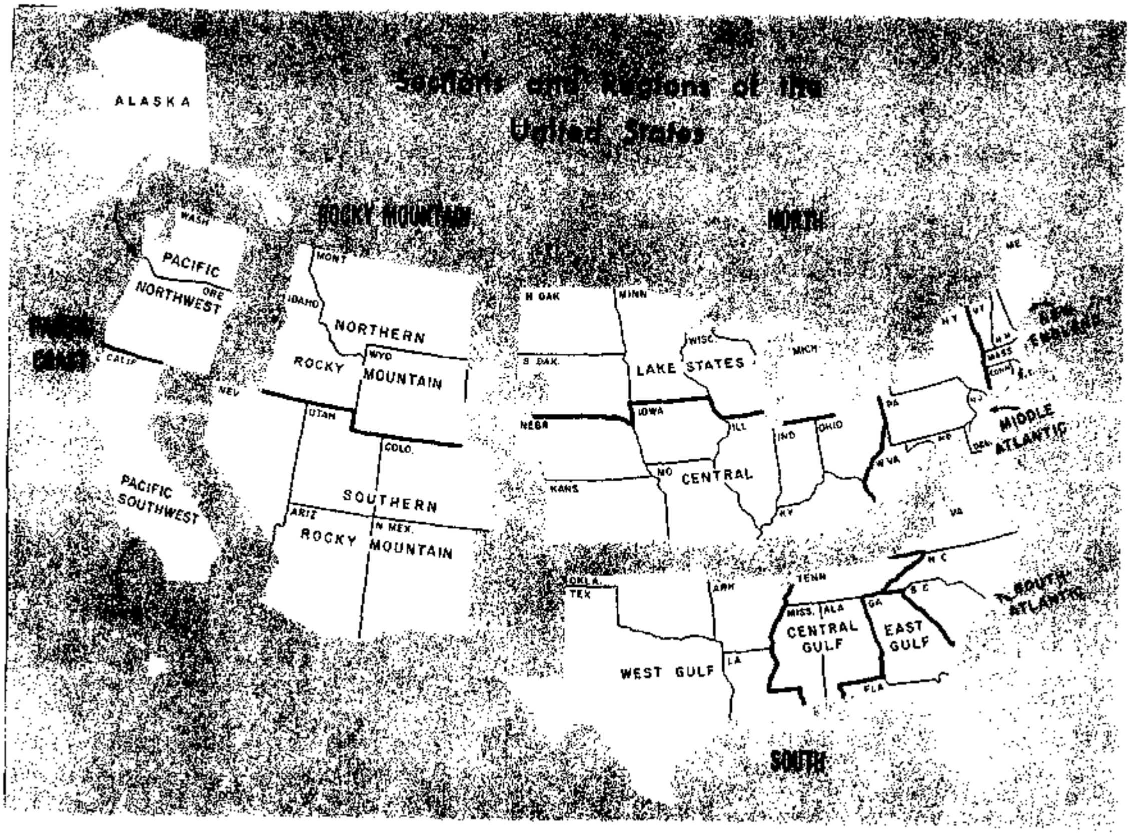


Figure 1. Sections and regions of the United States used in the timber commodity assessment.

Table 1--Area of commercial forest land in the United States by forest type group and section in 1970 a/

Type group	North	South	Rocky Mountains	Pacific Coast	Total
	-----	-----	million acres	-----	-----
EASTERN TYPE GROUPS					
Softwood types:					
Loblolly-shortleaf pine	3.4	49.4	0	0	52.8
Longleaf-slash pine	0	18.3	0	0	18.3
Spruce-fir	18.9	trace	0	0	18.9
White-red-jack pine	11.9	0.2	0	0	12.1
Total	34.2	67.9	0	0	102.1
Hardwood types:					
Oak-hickory	55.5	56.3	0	0	111.8
Oak-pine	4.1	30.9	0	0	35.0
Oak-gum-cypress	1.4	29.3	0	0	30.7
Maple-beech-birch	30.6	0.5	0	0	31.1
Elm-ash-cottonwood	22.0	2.8	0	0	24.8
Aspen-birch	20.5	0	0	0	20.5
Total	134.1	119.8	0	0	253.9
Nonstocked	9.6	4.8	0	0	14.4
Total East	177.9	192.5	0	0	370.4

continued

Table 1—Area of commercial forest land in the United States by forest type group and section in 1970 a/ (Continued)

Type group	North	South	Rocky Mountains	Pacific Coast	Total
	million acres				
WESTERN TYPE GROUPS					
Softwood types:					
Douglas-fir	0	0	11.9	18.9	30.8
Ponderosa pine	0	0	14.4	13.5	27.9
Spruce-fir	0	0	9.8	8.0	17.8
Lodgepole pine	0	0	9.9	3.3	13.2
Hemlock-Sitka spruce	0	0	0.9	9.9	10.8
Larch	0	0	2.0	0.7	2.7
White pine	0	0	0.6	0.2	0.8
Redwood	0	0	0	0.8	0.8
Total	0	0	49.5	55.3	104.8
Hardwood Types	0	0	4.3	8.5	12.8
Nonstocked	0	0	2.7	3.7	6.4
Total West	0	0	56.5	67.5	124.0
Total U.S.	177.9	192.5	56.5	67.5	494.4 b/

a/ From USDA, Forest Service (1974), Tables 45-48, pp. 302-309.

b/ Not including 5 million acres of "unregulated" commercial forest lands in National Forests in the Rocky Mountain States.

About one-third (754 million acres) of the 2.3 billion acres of the United States was classified as forest land in 1970. Forest lands vary from highly productive areas intensively managed for timber production to areas incapable of yielding wood economically because of adverse climate, soil, or elevation, or because of their reserved status in wilderness and other nontimber-producing classifications. About two-thirds of the nation's forest land (about 500 million acres) was classed as commercial forest land both available and suitable (capable of growing in excess of 20 cubic feet of wood per acre per year) for growing continuous crops of industrial wood products. The regional distribution of commercial forest land is shown in table 2; relative distribution by individual states is shown in figure 2.

The productive capacity of these commercial forests varies widely depending on local climate, soils, and timber types. Productivity tends to be higher in the South and Pacific Coast sections, intermediate in the North section, and lowest in the Rocky Mountain section (table 3). Furthermore, the available acreage for commercial timber production continues to decline because of shifts of public lands to reserved or deferred status; increased use of forest lands for roads, utility rights-of-way, and urban expansion; and conversion to croplands and pastures. Between 1962 and 1970, total commercial forest lands increased 2 percent in the North, but declined 4 percent in the South, 5 percent in the Rocky Mountains, and 1 percent in the Pacific Coast section (USDA, Forest Service 1974). A continuing reduction of 5 million acres per decade is projected. Only about half of the 500 million acres of commercial forest may actually be available for full timber production because of changes in land use and ownership objectives. These downward trends are expected to continue and will contribute to predicted shortages in softwood timber supplies in the United States. Softwood supply may be 2 billion cubic feet less than demand by the year 2000 if relative wood prices increase, and 4.3 billion cubic feet less if prices remain at 1970 levels.

Table 2--Area of commercial forest land in the United States by section and region in 1970 a/

Section and region	Total area
	million acres
NORTH	
New England	32.4
Middle Atlantic	49.7
Lake States	50.8
Central	45.0
Total North	177.9
SOUTH	
South Atlantic	48.5
East Gulf	41.3
Central Gulf	51.4
West Gulf	51.3
Total South	192.5
ROCKY MOUNTAINS	
Northern Rocky Mountains	36.7
Southern Rocky Mountains	25.0
Total Rocky Mountains	61.7
PACIFIC COAST	
Pacific Northwest	49.7
Pacific Southwest	17.9
Total Pacific Coast	67.6
Total All Sections	499.7

a/ From USDA, Forest Service (1974) Table 2, p. 10.

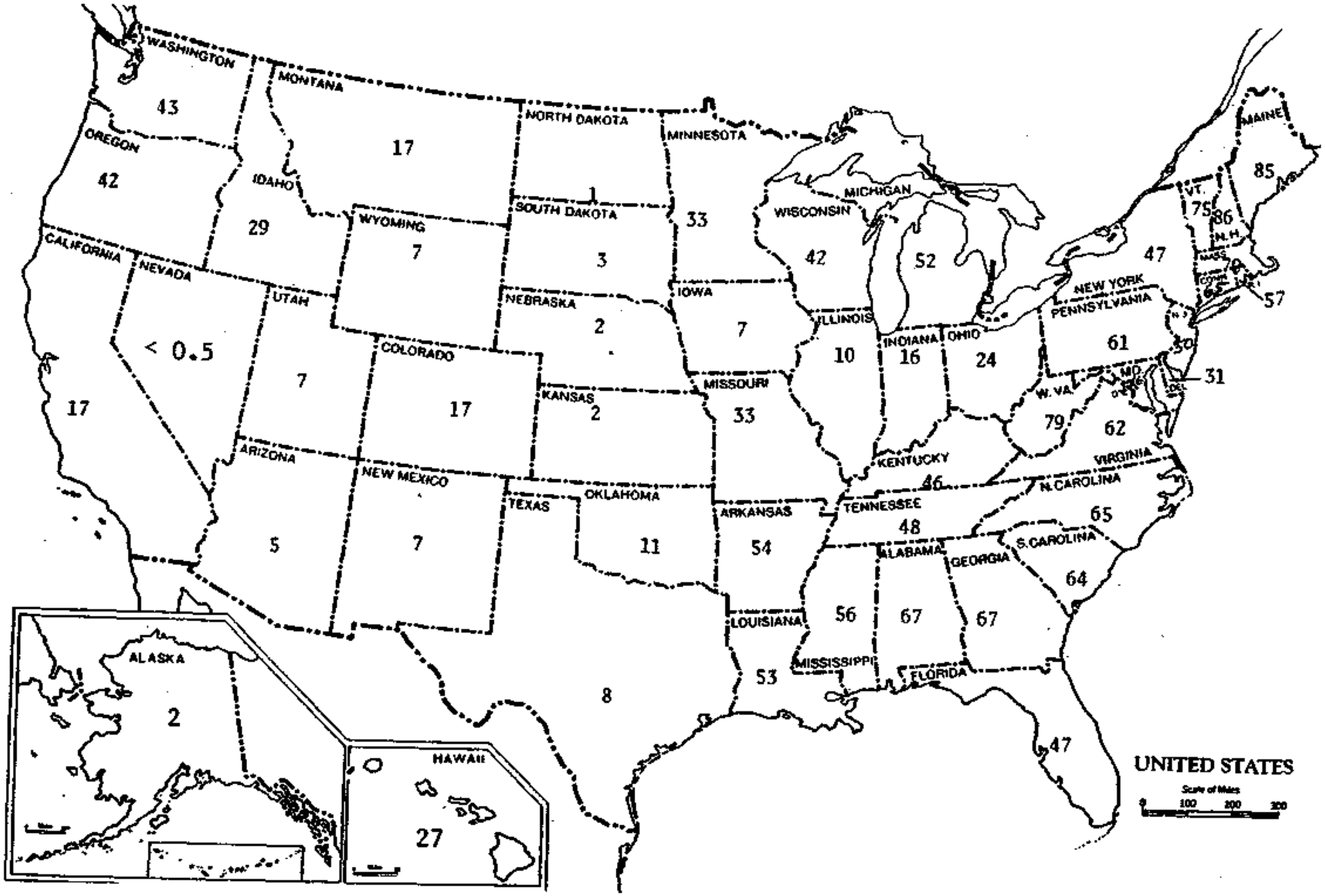


Figure 2. Commercial forest land by State as a percentage of total land area.

Table 3--Area of commercial forest land in the United States by section, site productivity class, and timber type group in 1970[a]

	North				South				Rocky Mountains				Pacific Coast			
	120 or more cf/A [b]	85 to 120 cf/A	50 to 85 cf/A	20 to 50 cf/A	120 or more cf/A	85 to 120 cf/A	50 to 85 cf/A	20 to 50 cf/A	120 or more cf/A	85 to 120 cf/A	50 to 85 cf/A	20 to 50 cf/A	120 or more cf/A	85 to 120 cf/A	50 to 85 cf/A	20 to 85 cf/A
	million acres															
Eastern forest:																
White- red-jack pine	1.1	2.4	5.0	3.4	0.1	c	0.1	c	—	—	—	—	—	—	—	—
Spruce-fir	1.9	4.0	6.2	6.7	—	—	c	c	—	—	—	—	—	—	—	—
Longleaf-slash pine	—	—	—	—	0.8	5.5	8.8	3.1	—	—	—	—	—	—	—	—
Loblolly-shortleaf pine	0.1	1.8	1.3	0.2	4.9	16.3	23.1	5.2	—	—	—	—	—	—	—	—
Oak-pine	0.3	1.4	1.4	1.0	2.6	8.2	15.4	4.7	—	—	—	—	—	—	—	—
Oak-hickory	2.6	15.4	21.0	16.5	1.9	9.3	28.5	16.7	—	—	—	—	—	—	—	—
Oak-gum-cypress	c	0.5	0.6	0.3	2.4	12.8	10.9	3.1	—	—	—	—	—	—	—	—
Elm-ash-cottonwood	1.2	3.9	8.7	8.2	0.7	1.0	0.8	0.2	—	—	—	—	—	—	—	—
Maple-beech-birch	1.9	5.8	11.6	11.4	c	0.1	0.3	0.1	—	—	—	—	—	—	—	—
Aspen-birch	0.5	3.3	10.2	6.5	—	—	—	—	—	—	—	—	—	—	—	—
Nonstocked	0.1	0.8	3.1	5.5	c	0.3	1.7	2.8	—	—	—	—	—	—	—	—
Total Eastern	9.8	39.3	69.0	59.8	13.5	53.5	89.6	36.0	—	—	—	—	—	—	—	—
Western forest:																
Douglas-fir	—	—	—	—	—	—	—	—	1.1	2.0	3.6	5.2	7.9	3.6	6.5	1.0
Ponderosa pine	—	—	—	—	—	—	—	—	0.3	0.7	3.2	10.3	1.7	3.3	6.2	2.3
Western white pine	—	—	—	—	—	—	—	—	0.4	0.1	0.1	c	c	0.1	c	c
Fir-spruce	—	—	—	—	—	—	—	—	0.8	1.9	3.1	4.0	2.3	2.0	2.9	0.7
Hemlock-Sitka spruce	—	—	—	—	—	—	—	—	0.2	0.3	0.2	0.2	5.2	2.8	1.7	0.2
Larch	—	—	—	—	—	—	—	—	0.8	0.5	0.6	0.1	0.1	0.2	0.3	0.1
Lodgepole pine	—	—	—	—	—	—	—	—	0.8	1.8	2.1	5.2	c	0.9	2.0	0.3
Redwood	—	—	—	—	—	—	—	—	—	—	—	—	0.7	0.1	c	—
Western hardwoods	—	—	—	—	—	—	—	—	0.1	0.2	0.6	3.3	4.2	1.9	2.0	0.4
Nonstocked	—	—	—	—	—	—	—	—	0.2	0.3	0.5	1.7	1.5	0.7	1.1	0.4
Total Western	—	—	—	—	—	—	—	—	4.7	7.8	13.9	30.2	23.6	15.6	22.9	5.5
Total U.S.	9.8	39.3	69.0	59.8	13.5	53.5	89.6	36.0	4.7	7.8	13.9	30.2	23.6	15.6	22.9	5.5

a/ From USDA, Forest Service (1974) Tables 45-48, pp. 302-309.

b/ A measure of the net annual productivity attainable in cubic feet per acre (CF/A) in fully stocked natural stands.

c/ Less than 50,000 acres.

Effects on hardwood supplies are estimated to be less than for softwoods. There is, however, a severe shortage of high quality hardwoods.

The projections in this study assume full availability of all harvestable timber on all commercial forest land. Anticipated future land withdrawals, especially on public lands, would considerably reduce supply. The United States will continue to be an importer of wood unless domestic timber production is increased--the U.S. imported a net 1.6 billion cubic feet, or about 11 percent of total consumption in 1972 (USDA, Forest Service 1974).

Insects, diseases, fires, and storms cause an annual loss of 4.5 billion cubic feet of growing stock (trees above 5.0 inches in diameter), with the majority of the losses occurring in softwood timber stands primarily in the West (USDA, Forest Service 1974). Additional losses from understocking and weed competition are sizeable. Despite these losses, 14 billion cubic feet of growing stock were harvested in 1970, mostly from the Pacific Coast and South sections (U.S. Forest Service 1974). About one-third of all softwood removals came from forest industry lands, nearly 40 percent from farm and miscellaneous private ownerships, and about 30 percent from public lands.

The wood harvesting and processing industry generated employment for nearly 25 million persons in 1972 and produced forest products valued at $200 billion (table 4). Forestry and the forest industry contributed about 5 percent of the Gross National Product. Maintaining a productive commercial forest base is vitally important to the economic well-being of the nation. It is especially important in the Pacific Northwest and South and to rural communities in forested areas throughout the United States.

Low net energy requirements in the extraction and manufacturing of forest products, coupled with the renewable nature of the forest, will increase the importance of wood in relation to more energy-intensive,

Table 4—Estimated value of product of service, value added, and employment for the timber-based economy in 1972 a/

Type of timber-based economic activity	Value of product or service	Value added		Employment	
		Total	Attributed to timber	Total	Attributed to timber
	million dollars	million dollars	million dollars	thousand employees	thousand employees
Forest management	2,864	2,864	2,864	117	117
Harvesting	6,360	3,065	3,065	190	190
Primary manufacturing	23,018	10,069	8,797	488	427
Secondary manufacturing	—	—	12,504	—	900
Construction	168,000	79,601	11,947	5,278	795
Transportation and marketing	—	194,171	9,287	18,707	835
Total	200,242	289,770	48,464	24,780	3,264

a/ From Robert Phelps, USDA, Forest Service, Division of Forest Resources Economics Research, Washington, D.C.

nonrenewable materials. Significant increases in domestic production will be needed to meet projected increases in demand and to avoid increased reliance on wood imports. Such increases are possible by applying existing intensive forest-management practices, including controlling competing vegetation with 2,4,5-T.

FOREST MANAGEMENT

Forest management is the planned manipulation of forest communities to achieve desired objectives. Depending on successional status of the tree species and management objectives, forests may be managed using one of two silvicultural systems: (1) even-aged silviculture that by use of clearcut, seed tree, or shelterwood harvesting reproduces even-aged stands often of high-value, fast-growing, subclimax, shade-intolerant species; or (2) uneven-aged (all-aged) silviculture that by use of individual tree or small group selection harvesting reproduces multiple-aged stands often of climax, shade-tolerant species. Selecting specific management techniques depends on the biology of the tree species and on the goals and objectives of the forest landowner. Forest land ownership patterns, management objectives, forest management methods, and both current and potential forest yields are described below.

Forest Land Ownership Pattern and Management Objectives

About 73 percent of all commercial forest lands was privately owned in 1970; 26 percent was owned by farmers, 33 percent by miscellaneous nonfarm owners, and 14 percent by forest industry (table 5). Many of the farm and miscellaneous private holdings include highly productive timber sites (table 6) and most are close to markets for timber products. About 96.3 million acres of the total farm and miscellaneous private land can produce in excess of 85 cubic feet per acre per year based on fully stocked natural stands. Potential growth under intensive management would be considerably higher. These ownerships consequently have been an important source of supply for wood-using

Table 5--Area of commercial forest land by type of ownership and section in 1970 a/

Type of ownership	North	South	Rocky Mountain	Pacific Coast	Total
	thousand acres				
Federal:					
National Forest	10,458	10,764	39,787	30,915	91,924
Bureau of Land Management	75	11	2,024	2,652	4,762
Bureau of Indian Affairs	815	220	2,809	2,044	5,888
Other Federal	963	3,282	78	211	4,534
Total Federal	12,311	14,277	44,699	35,822	107,109
Other public:					
State	13,076	2,321	2,198	3,828	21,423
County and city	6,525	681	71	312	7,589
Total other public	19,601	3,002	2,269	4,140	29,012
Private:					
Forest industry	17,563	35,325	2,234	12,219	67,341
Farm	51,017	65,137	8,379	6,602	131,135
Miscellaneous	77,409	74,801	4,051	8,840	165,101
Total private	145,989	175,263	14,664	27,661	363,577
Total all ownerships	177,901	192,542	61,632	67,622	499,697

a/ From USDA, Forest Service (1974) Table 3, p. 11.

Table 6--Area of commercial forest land by section, type of ownership, and productivity class in 1970 a/

Section and ownership type	165 cf/A b/ or more	120 to 165 cf/A	85 to 120 cf/A	50 to 85 cf/A	Less than 50 cf/A
	thousand acres				
North:					
National Forest	1	224	773	6,890	2,568
Other public	5	714	2,239	8,863	9,630
Forest industry	0	1,795	4,311	5,694	5,760
Other private	57	6,972	32,022	47,570	41,803
South:					
National Forest	112	456	2,217	5,228	2,750
Other public	143	317	1,470	2,863	1,720
Forest industry	593	2,876	11,798	15,568	4,488
Other private	1,872	7,106	37,966	65,967	27,025
Rocky Mountains:					
National Forest c/	1,018	2,930	5,844	8,085	16,861
Other public	13	201	726	2,024	4,215
Forest industry	38	200	370	920	703
Other private	47	294	848	2,865	8,373
Pacific Coast:					
National Forest	1,895	4,890	8,701	12,518	3,001
Other public	1,862	2,273	1,569	2,856	486
Forest industry	3,489	3,173	2,345	2,740	472
Other private	2,479	3,656	2,957	4,790	1,559

a/ From USDA, Forest Service (1974 Table 5, pp. 237-239).

b/ A measure of the net annual productivity attainable in cubic feet per acre in fully stocked, natural stands.

c/ Area does not include 5 million acres of National Forests that are not included in the allowable cut base because of such factors as unstable soils, small size of isolated stands, or special use constraints.

industries--about 40 percent of the softwood harvest in 1970 came from farm and miscellaneous private ownerships (USDA, Forest Service 1974). Management objectives vary considerably among individual owners. Some attempt to maximize wood production and minimize costs; some rely on occasional sale of forest products to pay taxes, make special purchases, or otherwise supplement their main source of income; and some own the land for recreational or other purposes and do not plan to harvest timber.

The 67 million acres of commercial forest land owned by forest industry in 1970 included some of the most productive and accessible timber-growing areas in the nation (table 6). About 52 percent was in the South, 26 percent in the North, and most of the remaining 22 percent was in the Pacific Coast section.

About 31.0 million acres of industrial forests can produce at least 85 cubic feet per acre per year in fully stocked natural stands; considerably more is actually produced in intensively managed stands. About one-third of all softwood removals in 1970 came from forest industry ownerships (USDA, Forest Service 1974).

Forest industry lands are usually managed to maximize both forest growth and return on investment. Various intensive cultural practices, as described later, are used to attain as near the biological growth potential as possible without impairing long-term site productivity. Forest stands are often managed for specific products, such as pulpwood, lumber, or a combination of these depending on the associated manufacturing facilities. Cultural practices tend to be more intensive and rotations[1/] are generally shorter on forest industry lands than on other ownerships. Other forest-related uses that are compatible with management objectives are usually encouraged, but not at the expense of timber production.

[1/] The planned number of years between regeneration and final cutting at a specified stage of maturity.

Of the 27 percent of commercial forest land in public ownership, some 92 million acres, or 18 percent of the total, were in National Forests in 1970 (table 5). Most of these forests are located in the Rocky Mountains and Pacific Coast sections. Much of the land is relatively low in site quality and is located at higher elevations, but it contains a substantial part of the nation's timber inventory. About 17 million acres of public forest lands are capable of producing at least 85 cubic feet of wood per acre per year (table 6). National forests, other Federal, State, county, and municipal forests contributed 30 percent of all softwood removals in 1970 (USDA, Forest Service 1974).

Most public lands, by law, are managed to produce multiple benefits such as timber, water, wildlife, grazing, and recreation. Some of these represent competing uses that are not always compatible with intensive forest management. Therefore, tradeoffs are necessary and less intensive cultural techniques are often used. Moreover, end products for the trees produced are not clearly defined. A product mix of sawtimber and pulpwood is usually preferred.

Forest Management Methods

Forest management blends the disciplines of economics, applied ecology, engineering, and silviculture[2/] to produce continuous crops of forests and other benefits. This involves selecting an appropriate harvest practice and logging system and applying cultural treatments to insure adequate regeneration and growth of desired tree species.

[2/] The theory and practice of controlling the establishment, composition, constitution, and growth of forests.

Harvest practices for regeneration of even-aged stands include clearcutting, shelterwood, and seed tree systems. Uneven-aged stands are regenerated by single-tree or small group selection systems. Logging may be accomplished using crawler tractors, self-propelled feller-bunchers, or rubber-tired skidders on gentle terrain. Cable logging such as high-lead and skyline systems is necessary on slopes greater than 35 percent. Balloons and helicopters have been used to remove trees on unstable or easily compacted soils.

The regeneration phase of stand management involves a series of interdependent cultural treatments including selection of proper harvest method, slash disposal, site preparation, planting or seeding, protection from animal damage, and control of competing vegetation (fig. 3). The dependability of reforestation is closely tied to the planning and timing of harvest and other reforestation operations (Cleary and Greaves 1978). The longer the process is drawn out, the more likely it becomes that biological problems will occur in establishment of the new stand. Weed problems are especially important if reforestation is delayed.

Precommercial thinning and other timber stand improvement (TSI) measures may be used in young stands to control stocking density and remove low value or poorly formed trees and to improve both stand growth and quality. In practice, these two operations are often combined and classified as TSI. Thinning of commercial-size trees may be used to reduce crowding, maximize growth on selected crop trees, and salvage expected mortality. Fertilizers can be applied where necessary to accelerate growth of thinned stands and correct identified nutrient deficiencies.

Selection of specific practices and methods depends on local site conditions--site quality, terrain, soil type, tree species, and microclimate--regeneration method, and management objective. All operations are not required on every forested acre managed for wood production. Common silvicultural practices for major forest types

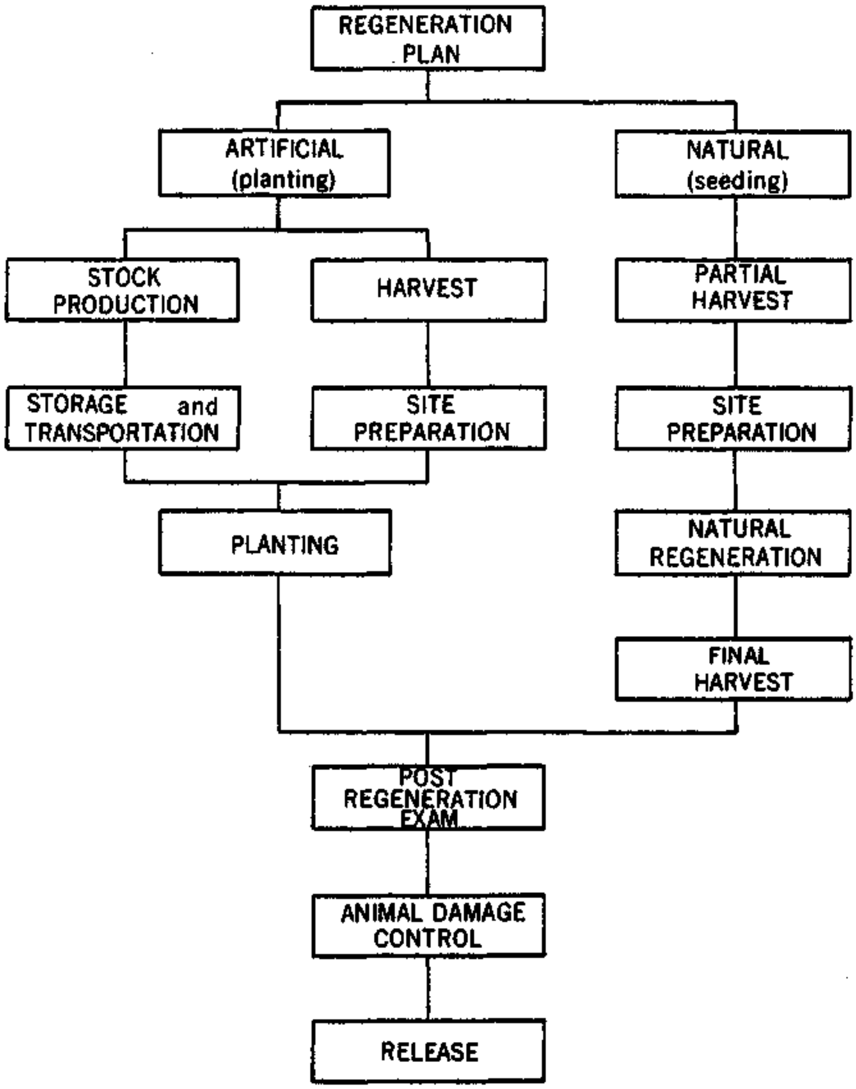


Figure 3. Sequence of steps before and after harvest operation to obtain either natural or artificial regeneration (from Cleary and Greaves 1974).

throughout the United States have been summarized in recent publications (McDonald et al. 1977, USDA, Forest Service 1973) and will not be repeated here. Intensive timber culture, designed to maximize wood production and produce merchantible products in the shortest possible time at least cost, usually consists of the following sequence (further illustrated in fig. 4).

Clearcut

↓

Site Preparation
(machine, herbicide, fire, or combination)

↓

Plant
(hand or machine planting of genetically-improved stock)

↓

Release from competing vegetation
(herbicides)

↓

Precommercial thinning
(chainsaw or herbicide injection)

↓

Fertilization
(once or at periodic intervals)

↓

Commercial thinning
(once or at periodic intervals)

Yields and Potentials

Average net annual growth in 1970 varied widely by section and ownership (table 7). High growth rates in the South reflect both high site quality and the presence of thrifty young stands resulting from protection and other intensive management practices. Despite the large amount of slow-growing, old-growth timber in the Pacific Coast section, growth rates are also relatively high because a large proportion of the

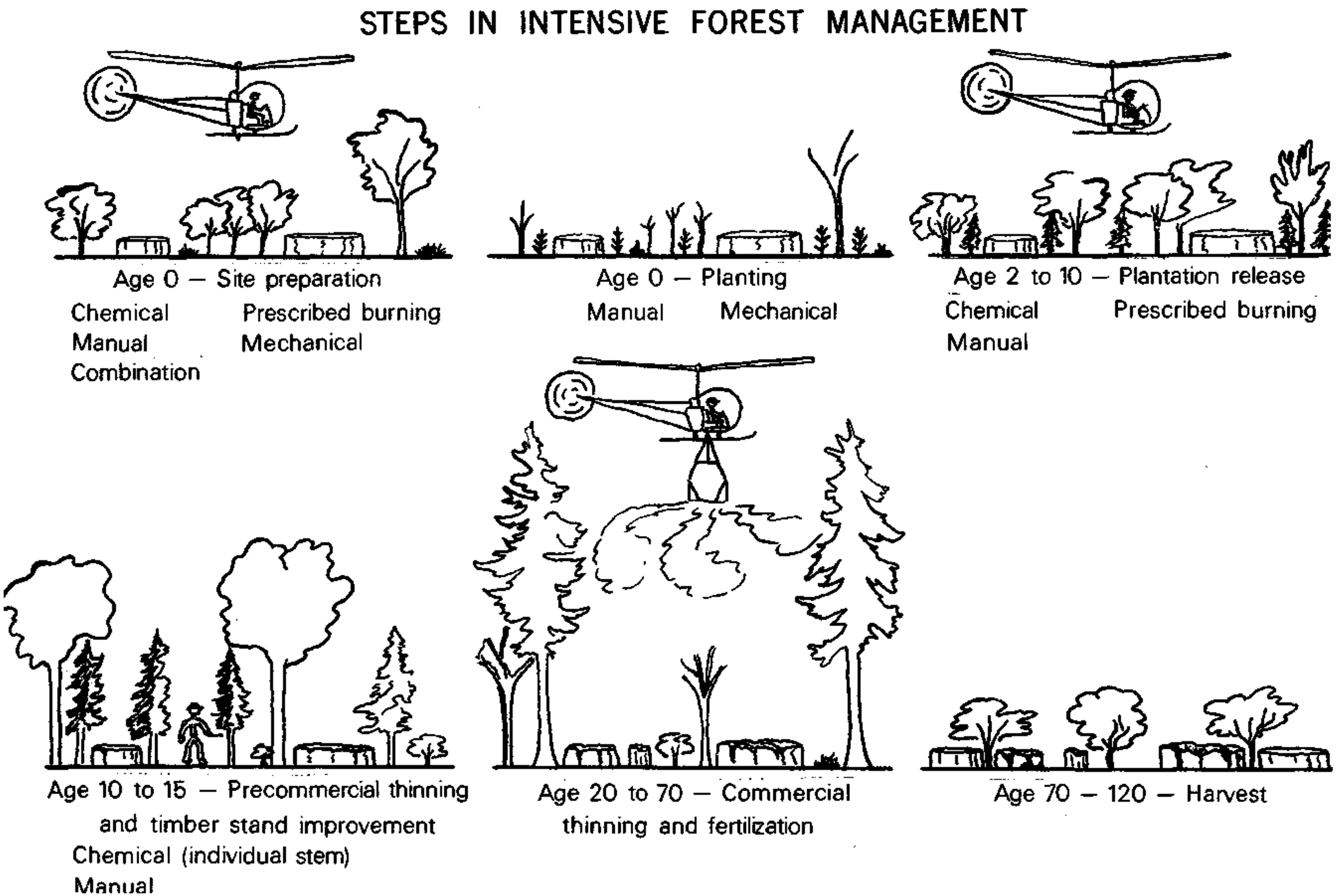


Figure 4. Steps in intensive forest management--not all steps may be necessary on every acre.

Table 7--Average net annual and potential stand growth per acre, by type of ownership and section a/

Section	National Forest	Other public	Forest industry	Farm and miscellaneous private
	cubic feet per acre			
North:				
Current	38	33	40	29
Potential b/	66	59	72	69
South:				
Current	55	45	53	42
Potential	70	71	81	75
Rocky Mountain:				
Current	23	23	47	25
Potential	65	54	70	50
Pacific Coast:				
Current	27	60	65	58
Potential	88	100	107	96
Total:				
Current	30	39	52	36
Potential	73	68	83	72

a/ From USDA, Forest Service (1974) Table 10, p. 17.

b/ Based on growth in fully stocked natural stands.

land is high site productivity and young stands on private lands have high growth rates. Slower growth in the North section results from a high proportion of land in lower productivity classes, predominance of slow-growing hardwood stands, and the large amount of rough and rotten timber. Average growth in the Rocky Mountains is also low, reflecting the combined effect of many slow-growing, old-growth stands, stagnation of younger stands because of overstocking, relatively low average site productivity, and regeneration problems following logging and wildfire.

Potential growth rates in fully stocked natural stands are about twice the current rate (table 7), and growth in intensively managed stands is even greater (up to twice that in fully stocked natural stands). For example, an analysis of selected intensive management opportunities in the Northcentral, Southeast, and Pacific Northwest regions projects the following increases in softwood timber harvest (USDA, Forest Service 1974):

	Increased harvest by year				
	1980	1990	2000	2010	2020
	billion board feet				
Nonindustrial private	0.1	0.2	1.0	3.9	6.8
National Forests	1.5	2.5	3.7	5.0	6.3
Total	1.6	2.7	4.7	8.9	13.1

This analysis assumes 5 percent or more return on investment, wood prices 30 percent above 1970 levels, and an allowable cut effect in estimating increased yields from National Forests. The potential harvest with intensive management is 3 percent more than projected supplies by 1980 and 25 percent more by 2020 compared with 1970 levels of management.

VEGETATION MANAGEMENT ON FOREST LANDS--PRINCIPLES AND NEEDS

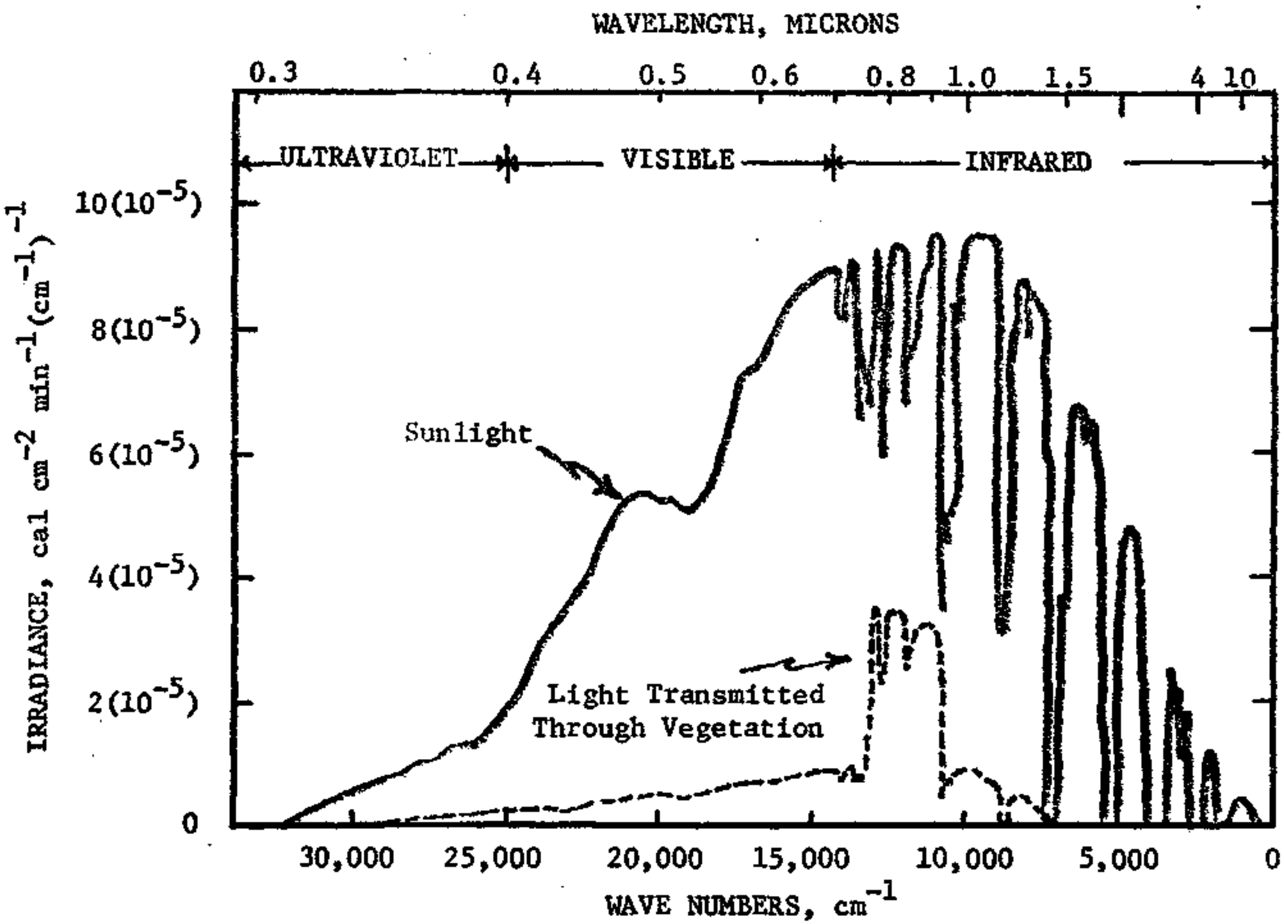
Studies of growth in fully stocked natural and intensively managed stands confirm that measures to insure prompt regeneration and use of intensive cultural practices on suitable highly productive sites can markedly increase future timber supplies. Control or modification of competing vegetation is an important, often critical, step in establishing and managing young forests. The following discussion describes the ecological principles involved and the need for vegetation management on forest lands.

ECOLOGICAL PRINCIPLES

Effects on the Tree Seedling Environment

The purpose of vegetation control in management of young forests is to improve the seedling or young tree environment. The supply of essential environmental factors--sunlight, soil moisture, temperature, and soil nutrients--are fixed for any given site by climatic and edaphic conditions largely beyond the control of forest managers. The manager can, however, affect the distribution of these factors through manipulation of forest vegetation. Competition for light, soil moisture, and nutrients between and among species can be intense (Gratkowski 1967) if they occupy the same or closely related niches. For example, both light quality and quantity needed for photosynthesis and growth are markedly less under a vegetative canopy (fig. 5). Soil moisture in the zone occupied by roots of young trees is rapidly depleted by shrubs and other competing vegetation (fig. 6); moisture depletion by the dense, fibrous roots of grasses can be even more rapid (Newton 1964).

Reduced sunlight and soil moisture combined with lower ambient temperatures under plant canopies result in reduced photosynthesis, growth, and vigor of small trees (fig. 7). Control of shrubs, weed trees, and herbaceous species increases survival and growth of important



SPECTRAL DISTRIBUTION OF SOLAR RADIATION AT SEA LEVEL ON A CLEAR DAY AND TRANSMITTED THROUGH VEGETATION (FROM GATES)

Figure 5. Spectral distribution of solar radiation at sea level on a clear day in the open and under a vegetative canopy.

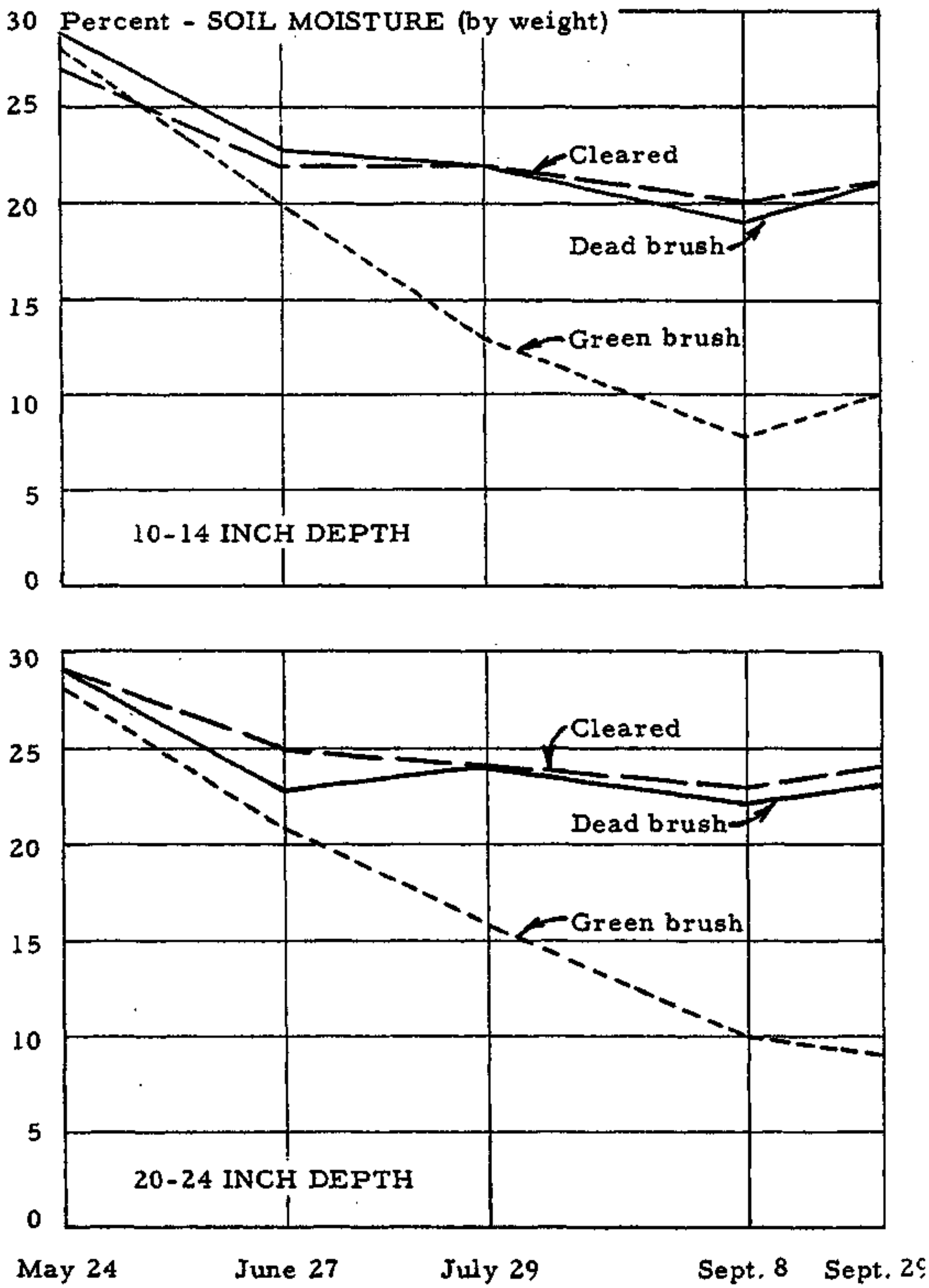


Figure 6. Trend of soil moisture at depths of 10 to 14 and 20 to 24 inches in cleared, sprayed and untreated greenleaf manzanita brushfields in central Oregon (from Tarrant 1957).

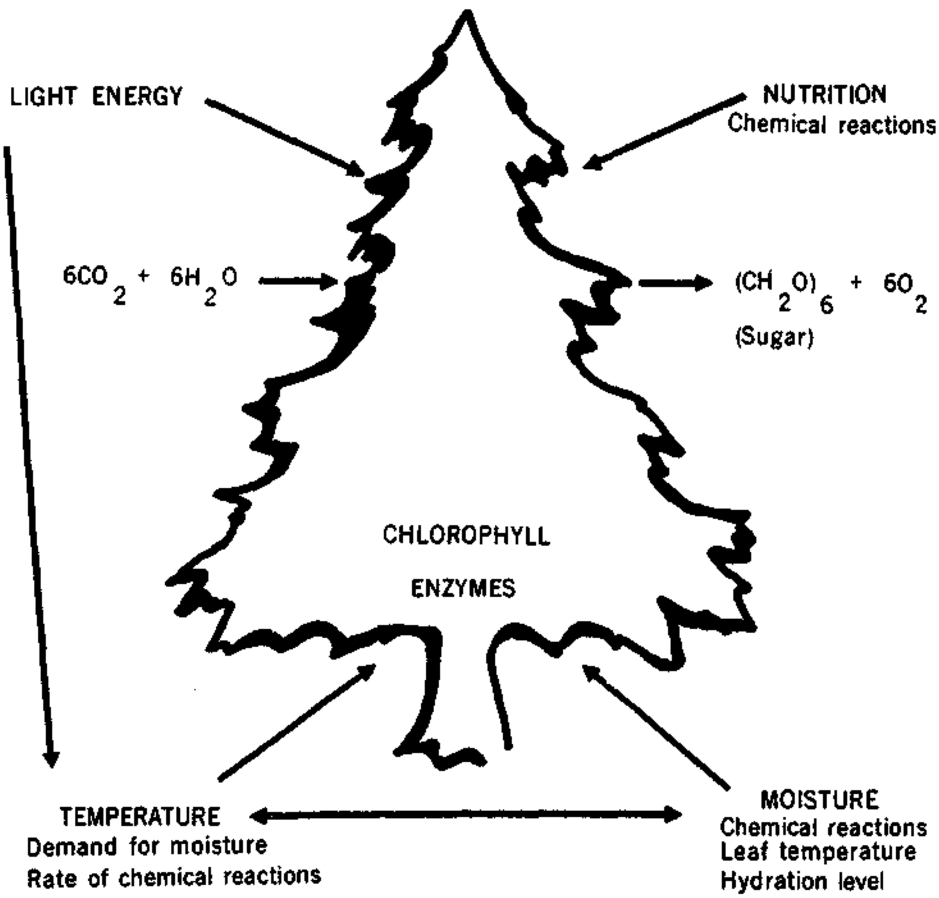


Figure 7. Interaction among four factors in the seedling environment that affect the rate of seedling photosynthesis (from Cleary et al. 1978).

commercial species such as Douglas-fir (Bickford et al. 1965, Gratkowski and Lauterbach 1974, Lauterbach 1967, Newton 1964 and 1967a, Radosevich et al. 1976, Ruth 1956 and 1957, Zavitkowski et al. 1969, Zavitkowski and Newton 1967), ponderosa pine (Baron 1962, Barrett 1973, Bentley et al. 1971a, Crouch and Hafenstein 1977, Dahms 1950, Hall 1971, Heidmann 1968 and 1969, Stewart and Beebe 1974), and redwood (Boe 1971) in the West. Similar responses have also been shown for southern pines (Brady 1972, Burns 1974, Johansen 1975, Langdon and Trousdell 1974, Russell 1963, Smith and Smith 1963, Walstad 1976), northern conifers (Freeman and van Lear 1977, Jacin 1972, Lambert et al. 1972, McCormack 1977, Roe and Black 1957, Sterrett and Adams 1977), and eastern hardwoods (Bey et al. 1975, Fitzgerald et al. 1975, Fitzgerald and Selden 1975). Selective removal of competition redistributes the available light, soil moisture, and nutrients, which results in improved vigor and growth of the remaining species.

Selective control of vegetation can also be used to indirectly increase tree survival through alteration of animal habitat. For example, removal of herbaceous vegetation can reduce the carrying capacity of plantations for pocket gophers, a major cause of reforestation failure in some western areas. This can reduce damage and markedly improve seedling survival (Crouch and Hafenstein 1977).

Effects of Manipulation on Plant Communities

Unlike highly artificial agricultural crop communities, managed forest stands are more like natural ecosystems. Natural processes controlling ecosystem stability, function, and organization are normally operating. Disturbance of the forest community sets a secondary plant succession sequence in motion. The nature of this sequence depends on the kind and degree of disturbance, soil conditions, climate, and availability of plant species for colonization. The system tends toward stability by rapidly filling voids (niches) created by manipulation of the vegetation. Return to a more stable condition is more rapid in mesic (moist) environments and following light disturbance such as removal of individual species or selected trees. Manipulation of the overstory canopy results in greater changes and delays in attaining a stable condition than does manipulation of the understory.

Disturbance always favors species that are adapted or resistant to the particular type of disturbance (Newton 1967b)—that is, fire adapted species following wildfire, or herbicide resistant species following spraying. These species will make up a greater proportion of the early successional community and tend to remain dominant longer than in natural stands. Fire was the most common natural disturbance factor in North American forests followed by insects, windstorms, and diseases. Many species have evolved specific adaptations to fire, such as resprouting or induced germination of buried seed by heating in soils.

Many pioneer species produce abundant crops of light-weight, wind-blown seed; others become established from seed buried in the soil. Still others rapidly occupy the site by sprouting from well-established root systems, rhizomes, or root crowns. The most important competitors and their methods of establishment following disturbance are shown in table 8 for major timber type groups where vegetation management is presently necessary. Pioneers and early successional dominants are shade intolerant, grow best in full sunlight, and have rapid initial growth rates. Some have the capacity to fix nitrogen or to improve soil conditions through accumulation of soil organic matter, thus creating conditions suitable for more stable communities. Life spans of early successional stage species often are short, and voids created by mortality are rapidly filled by more persistent species that are able to regenerate in their own shade (shade tolerant species) (Newton 1967b). If seed sources for later dominant tree species have been eliminated, such as by extensive and repeated wildfire, natural succession can be arrested, resulting in establishment of semipermanent brushfields. Selective removal of more tolerant, climax species can also be used to delay succession and maintain dominance of high value subclimax species, such as Douglas-fir and many pine species.

Table 8—Important competitors on forest lands in the United States listed by section, type group, and method of establishment following disturbance a/

	Most important method of establishment		
	Residual species	Invading species	
Section and type group	Resprouting	Buried seed	Introduced seed
North			
Spruce-fir	raspberry, bigtooth aspen, quaking aspen, red maple	raspberry, pin cherry	bigtooth aspen, quaking aspen, white and grey birch, herbs
White-red-jack pine	aspen, paper birch red maple, sugar maple, oaks, hazel willow, mountain maple, sweet fern, raspberry, bracken fern	raspberry	willow paper birch
Oak-hickory	wild grape, white oak, red oak, hickories, yellow-poplar, back gum sugar maple, red elm, birches, sweet gum, white ash sycamore, rhododendron, black cherry, pin cherry, beech, sourwood, serviceberry, cucumbertree, blacklocust, sassafras, dogwood, hawthorn, witch hazel, greenbriar striped maple, Dutchman pipe, spice bush, pokeweed, quaking aspen, chestnut oak, Fraser magnolia, blueberry, elderberry, nettle, bigtooth, aspen, eastern hophornbeam	wild grape, yellow-poplar black cherry, pin cherry, blacklocust, sassafras	wild grape, white oak, red oak, hickories, yellow-poplar, black gum, sugar maple, red elm, birches, sweet gum persimmon, white ash, sycamore mountain laurel, black cherry, pin cherry, beech, American hophornbeam, blackberry, eastern redcedar, sourwood serviceberry, cucumbertree, blacklocust, sassafras, dogwood, redbud, hawthorn, witch hazel, greenbriar, sumac, devils walking-stick, striped maple, Dutchman pipe, spicebrush, pokeweed, quaking aspen,

continued

Table 8—Important competitors on forest lands in the United States listed by section, type group, and method of establishment following disturbance a/ (continued)

	Most important method of establishment		
	Residual species	Invading species	
Section and type group	Resprouting	Buried seed	Introduced seed
North			
Oak-hickory (continued)			chestnut oak, Fraser magnolia, blueberry, elderberry, nettle, bigtooth aspen
Oak-pine	scrub oaks, aspen, red maple, blackberry, bracken fern, hazel sweetgum, blackgum, mountain laurel, hickories, alder, American hophornbeam, serviceberry	blackberry	Japanese honeysuckle, scrub oak, aspen, red maple, sweetgum, blackgum, hickories, alder, elderberry, American hophornbeam, serviceberry, hawthorn, jack pine, red pine
Elm-ash-cottonwood	alder, willow		willow
Maple-beech-birch	red maple, sugar maple raspberry, hobblebush, striped maple, beech, hay scented fern, yellow birch, bracken fern, cucumbertree, blackcherry, paper birch, pin cherry, white ash, willow	raspberry, pin cherry, spring elderberry, blackcherry, white ash	spring elderberry, yellow-birch, cucumbertree, striped maple, hemlock, paper birch, pin cherry, red maple, herbs
Aspen-birch	white ash, sugar maple, red maple, red oak, aspen		willow
South			
Loblolly-shortleaf pine	American beautyberry, blackgum, blueberries, flowering dogwood, gallberry, hickories, oaks (black, post, scarlet, southern red, water, willow), red maple, sumacs, sweetbay, sweetgum, waxmyrtle, winged elm, yaupon	American beautyberry, blackgum, blueberries, flowering dogwood, gallberry, hickories, sumacs, waxmyrtle, yaupon	American beautyberry, blackgum, blueberries, flowering dogwood, gallberry, red maple, sumacs, sweetgum, waxmyrtle, winged elm, yaupon

continued

Table 8—Important competitors on forest lands in the United States listed by section, type group, and method of establishment following disturbance a/ (continued)

	Most important method of establishment		
	Residual species	Invading species	
Section and type group	Resprouting	Buried seed	Introduced seed
South (continued)			
Longleaf-slash pine	blackgum, buckwheat tree, flowering dogwood, gallberry, oaks (blackjack, bluejack, live, myrtle, post, dwarf sand live, turkey), cabbage and saw palmetto, pineland threeawn, swamp, cyrilla, sweetbay, sweetgum, waxmyrtle, yaupon, bluestem grasses	blackgum, buckwheat tree, flowering dogwood gallberry, cabbage and saw palmetto, pineland threeawn, swamp cyrilla, waxmyrtle, yaupon, bluestem grasses	blackgum, flowering dogwood, gallberry, pineland threeawn, sweetgum, waxmyrtle, yaupon, bluestem grasses
Oak-hickory	blackjack oak, black locust, blueberry, flowering dogwood, American and winged elm, blackgum sweetgum, hawthorns, red maple, sassafras, sourwood, wild plum, viburnums, sugar maple, yaupon	black locust, blueberry, flowering dogwood, blackgum, hawthorns, sassafras, sourwood, wildplum, viburnums, yaupon	blueberry, flowering dogwood, American and winged elm, blackgum, sweetgum, hawthorns, red maple, sassafras, viburnums, sugar maple, yaupon
Oak-pine	blueberry, flowering dogwood, blackgum, sweetgum, hickories, blackjack and post oak, red maple, sassafras, sourwood, viburnums, winged elm	blueberry, flowering dogwood, blackgum, hickories, sassafras, sourwood, viburnums	blauberry, flowering dogwood, blackgum, sweetgum, red maple, winged elm
Oak-gum-cypress	nuttall oak, willow oak, water oak, American elm, green ash, sugarberry, overcup oak, water hickory, bald cypress, tupelo gum, sweetgum, red maple	sugarberry	American elm, green ash, sugarberry, bald cypress, tupelo gum, sweetgum, red maple
Elm-ash-cottonwood	American elm, green ash, eastern cottonwood, American sycamore, boxelder, silver maple,		American elm, green ash, eastern cottonwood, American Sycamore, boxelder,

continued

Table 8--Important competitors on forest lands in the United States listed by section, type group, and method of establishment following disturbance a/ (continued)

Section and type group	Most important method of establishment: Residual species: Resprouting	Invading species: Buried seed	Invading species: Introduced seed
South			
Elm-ash-cottonwood (continued)	sweetgum, sweet pecan, red maple, black willow		silver maple, sweetgum, red maple, black willow
Rocky Mountains			
Douglas-fir	schooler's willow, ninebark, ocean spray, snowberry, thimbleberry, mountain maple, spirea, mock orange, pinegrass, Canada thistle	snowbrush ceanothus	schooler's willow, ninebark, thimbleberry, mountain maple, spirea, bluegrass, Canada thistle
Ponderosa pine	ninebark, snowberry, gamble oak, alligator juniper, New Mexican locust, pinegrass, Canada thistle, sedges	snowbrush ceanothus	ninebark, bluegrass, grasses, forbs, Canada thistle
Fir-spruce	Sitka alder, false huckleberry, huckleberry, schooler's willow, thimbleberry pachistima, mountain ash, pinegrass, sedges, beargrass bracken fern		Sitka alder, schooler's willow, thimbleberry, mountain ash, fireweed
Lodgepole pine	snowberry		fireweed
Larch	thin-leaf alder, false huckleberry, schooler's willow, ninebark, ocean spray, snowberry, thimbleberry, mountain maple, pachistima, spirea, honeysuckle, elderberry, mountain ash	redstem ceanothus, pin cherry, choke cherry	thin-leaf alder, schooler's willow, ninebark, thimbleberry, mountain maple, spirea, elderberry, mountain ash, fireweed, Canada thistle
White pine	thin-leaf alder, Sitka alder, huckleberry, schooler's willow, thimbleberry, mountain maple, pachistima, honeysuckle, elderberry, mountain ash	redstem ceanothus, snowbrush, ceanothus, pin cherry, choke cherry	thin-leaf alder, Sitka alder, schooler's willow thimbleberry, elderberry, mountain ash, bluegrass, fireweed, Canada thistle

continued

Table 8—Important competitors on forest lands in the United States listed by section, type group, and method of establishment following disturbance a/ (continued)

	Most important method of establishment		
	Residual species	Invading species	
Section and type group	Resprouting	Buried seed	Introduced seed
Pacific Coast			
Douglas-fir	salmonberry, vine maple, California hazel, red elder, blue elder, tanoak, madrone, hairy manzanita, hoary manzanita, Howell manzanita, serviceberry, greenleaf manzanita, evergreen chinkapin, canyon live oak, bear clover, sword fern, grasses, forbs	salmonberry, snowbrush ceanothus, varnishleaf ceanothus, redstem ceanothus, mountain whitethorn ceanothus, blueblossom ceanothus, deerbrush ceanothus, Scotchbroom, greenleaf manzanita, buckbrush ceanothus	thimbleberry, vine maple, red alder, red elder, blue elder, tanoak, madrone, serviceberry, bearclover
Ponderosa pine	greenleaf manzanita evergreen chinkapin, serviceberry, creambrush rockspirea, pinegrass, fescue	snowbrush ceanothus, greenleaf manzanita, redstem ceanothus	
Fir-spruce	Sitka alder, pachistima, willow, beargrass, huckleberries, sedges		Sitka alder
Lodgepole pine	greenleaf manzanita, pinegrass, fescue	snowbrush ceanothus	
Hemlock-Sitka spruce	salmonberry, salal, swordfern		red alder, red elder
Redwood	tanoak, salmonberry, red huckleberry, evergreen, huckleberry		red alder, red elder

a/ Information provided by John Benzie (USDA, Forest Service, Northcentral Forest Experiment Station, Grand Rapid, MN), Bill Wendel (USDA, Forest Service Northeastern Forest Experiment Station, Parsons, WV), Carl Tubbs (Northeastern Forest Experiment Station, Durham, NH), and Bart Blum (Northeastern Forest Experiment Station, Orono, ME) for the North section; Bill Mann, Jr. (Southern Forest Experiment Station, Alexandria, LA) and Bob Johnson (Southern Forest Experiment Station, Stoneville, MS) for the South section; Ray Boyd (Intermountain Forest and Range Experiment Station, Moscow, ID) and Frank Ronco, Jr. (Rocky Mountain Forest and Range Experiment Station, Flagstaff, AZ) for the Rocky Mountains section; and Hank Gratkowski (Pacific Northwest Forest and Range Experiment Station, Corvallis, OR) for the Pacific Coast section.

Overstory trees with a shrub or small tree understory tend to dominate mesic sites in the temperate forests of the United States. On drier sites, overstory density decreases and grasses and forbs tend to dominate the understory. Here, grasses may intensify the droughty condition and reduce chances for establishment of small tree seedlings. Grasses become established and emerge as dominants on disturbed sites more rapidly than shrubs. Emergence of trees as dominants is slower yet (Newton 1967b). More modal sites (intermediate between wet and dry) tend to be dominated by hardwood species, except in the western United States where hardwood species have been largely eliminated by past climatic changes and fires. Conifers are climax species on cold and moist or on hot and dry sites. In most forest types, removal of overstory species results in a rapid growth of understory species. Some evidence suggests that communities tend toward a constant leaf area for a given environment. Reductions in leaf area by removal or control of one component of the community result in corresponding increases in other components, especially species resistant to the specific type of disturbance.

The response and persistence of understory species following thinning, an increasingly common management practice, are proportional to the amount of overstory removed (Agee and Biswell 1970, Anderson et al. 1969, Brown 1959, Halls and Schuster 1965, McConnell and Smith 1970, Ruth 1970). This suggests that thinning may increase grazing and browse potential, but will likely increase vegetation management problems at the time of final harvest. Moreover, the increased understory may actually reduce growth of the overstory trees on drier sites unless controlled (Barrett 1973).

THE NEED FOR VEGETATION MANAGEMENT

An estimated 38 percent of all commercial forest land is dominated by weeds and requires some type of vegetation control to assure dominance by desirable trees (table 9). Brush problems tend to be more severe on high site land, reflecting that much of this land is highly productive.

Table 9--Area of commercial forest land dominated by weeds in the United States (excluding Alaska and Hawaii)

Section	Commercial timberland	Commercial timberland presently dominated by weeds a/	
	million acres	million acres	percent
North	178	35.0	20
South	192	134.0	70
Rocky Mountains	62	15.5	25
Pacific Coast	67	6.5	10
Total United States	499	191.0	38

a/ Defined as commercial timberlands which are either nonstocked or poorly stocked with appropriate timber species because of weed competition. From Walker et al., Benzie et al., Fitzgerald et al., Gratkowski et al., and Johnsen et al. 1973. Rehabilitation of forest land. J. Forestry 71(3):136-158. Sections adjusted to Forestry Survey units.

Except for extensive brushfields in the West that originated after wildfire (fig. 8), much of the nonstocked and poorly stocked land resulted from past land clearing and use of inadequate reforestation practices, especially site preparation, seeding or planting, and control of competing vegetation.

A long history of "high-grading" (i.e. selective harvesting of high quality trees) of the most valuable trees from stands in the North has resulted in reduced quality of the remaining growing stock. Marginal quality wood is prevalent in many hardwood forests that are regarded as adequately stocked. Presence of dominant low-grade trees reduces growth and regeneration of desirable trees on these areas.

Prompt reforestation, control of competing vegetation, and conversion of brushfields to valuable tree species are essential to meet the growing demand for wood. Conversion of brushfields alone can have sizeable impacts on future softwood supplies. For example, conversion of 83,700 acres of brushfields to Douglas-fir in five national forests in Oregon and Washington could increase annual harvest by 7.5 million cubic feet (40 million board feet) (USDA, Forest Service 1978). Similar benefits are possible from reforesting most of the 6.4 million acres in the Rocky Mountains and Pacific Coast sections that are presently nonstocked. Additional major increases in softwood supplies are possible by converting many oak-hickory stands to southern pines, improving pine stocking on 35 million acres of oak-pine type in the South, and converting 8 to 10 million acres of selected aspen-birch and jack pine stands to red pine in the Northcentral region.

VEGETATION MANAGEMENT ON FOREST LANDS--OBJECTIVES AND METHODS

As previously described, vegetation management is used to increase available sunlight, soil moisture, and nutrients, and thereby increase survival and growth of desirable tree species. Specific objectives and methods are defined and described below.

Figure 8. Extensive 100 year old brushfield originating from repeated wildfires in the Cascade Mountains of Oregon.

OBJECTIVES

Measures to control vegetation are undertaken to achieve specific objectives in five silvicultural practices. In order of decreasing degree of disturbance or vegetation control needed to attain the objective, these practices and related objectives are:

(1) Rehabilitation or species conversion to allow establishment of desirable tree species in existing stands of weed trees, shrubs, or herbaceous vegetation.

(2) Site preparation to allow establishment of desirable tree species on new cuttings dominated by residual vegetation.

(3) Tree release to increase survival and growth of seedling to sapling size[3/] trees overtopped by competing vegetation.

(4) Precommercial thinning to control spacing of trees and increase diameter and height growth in sapling-size stands.

(5) Timber stand improvement to concentrate growth on more desirable species by removing low value and poorly formed trees.

More thorough, complete control of vegetation is needed to establish small seedlings in well-developed brushfields. Less disturbance may be required when larger planting stock and/or more shade tolerant species are used (Newton 1973). A high degree of root kill of competing species is also desirable for establishing trees on new cuttings. Here, though, competing vegetation is often less vigorous and satisfactory control can be achieved using less drastic measures. The most significant changes in the ecosystem usually result from timber harvest operations rather than subsequent site preparation practices.

[3/] A seedling-size tree is less than 3 feet tall and 2 inches in diameter; a sapling-size tree is 2 to 4 inches in diameter.

In addition to being required by law in many jurisdictions, rehabilitation and site-preparation practices to control competing vegetation often must accomplish other objectives including: rid areas of logging slash or other debris; reduce habitat for tree damaging animals; prepare mineral soil seedbeds; reduce compaction or improve drainage of surface and upper soil horizons; create more favorable microsites on harsh sites; control disease; or provide access for planting crews or planting machines. Secondary succession usually proceeds rapidly following this type of disturbance; competition is intense and niches are quickly filled by resprouting residual species and invading species established on bare mineral soil.

The objective of tree release is not to kill brush or other vegetation, but to increase the amount of light reaching young trees in the understory and to decrease competition for soil moisture and nutrients. Often, it is necessary only to obtain a high percentage of defoliation, a fair amount of topkill, and minimum resprouting (Gratkowski 1961c). Actually, a complete topkill without root kill may stimulate development of basal sprouts on many species and result in rapid recovery and greater competition than if some of the original crown remains alive. Given 3 to 5 years of improved light and moisture, young trees on many sites will outgrow the damaged competitors and be permanently released. On other sites where recovery of vegetation may threaten to once again overtop the trees, a second treatment may be necessary. Reducing the vigor of competitors favors resistant species and hastens the process of secondary succession. Trees attain dominance more rapidly and other species are relegated to their natural position in the understory.

Removal of overstory tree species during precommercial thinning or timber-stand improvement results in some increase in understory shrubs and herbs. In the case of precommercial thinning, overstory composition changes little. Significant shifts in species composition can occur during timber stand improvement operations only if the stands contain several tree species of widely different value or form. The total impact of either practice on ecosystem structure and function is relatively minor compared with rehabilitation and site preparation.

METHODS

Vegetation can be controlled using mechanical equipment, prescribed burning, herbicides, manual cutting, insects and diseases, grazing, or a combination of methods. Problems can also be prevented or minimized in some situations by proper selection of cultural practices that discourage establishment of competitors or increase the competitive ability of the desirable trees.

Selection of individual practices depends on the objective of treatment; the species, size, and stocking of desirable trees; the composition and structure of the ground cover; physical factors, such as terrain, exposure, soil type, erosion hazard, size of treatment area and access; availability of manpower and equipment, and external constraints, including government rules and regulations, proximity to sensitive areas (i.e., waterways and dwellings), and attitudes of adjacent landowners. Because of these factors and the complex mosaic of vegetation, topography, soils, and climate that are characteristic of most forest lands, treatment prescriptions must be site specific. Often, the chosen practice is uniquely suited to the local combination of site conditions. Substitutes may not exist or will result in increased environmental impact, reduced effectiveness, or higher cost. Cost effectiveness is especially critical in forestry where investments must be carried for long periods of time. Investments such as vegetation management practices and reforestation, made early in the rotation are compounded longer and have a higher degree of risk than investments made later in the rotation.

Individual methods, their advantages and limitations, and suitability for rehabilitation, site preparation, tree release, precommercial thinning, and timber-stand improvement are described below.

Mechanical

Mechanical vegetation control ranges from use of logging equipment during harvesting to use of tractor-drawn or self-propelled equipment that will disc, furrow, terrace, trench, strip, rip, punch, slit, drag, chop, till, churn, or crush the ground and vegetation on it (Stewart 1978b). Despite the myriad of crawler tractor attachments and specialized machines available (Harrison 1975, Roby and Green 1976), relatively few have found regular use in forestry including: angle blades, brush rake blades, shearing blades, rolling brush cutters, and shredders. Offset discs and integral disc plows are also used for some situations.

Standard crawler tractors equipped with angle blades may be used to crush shrubs and small trees or to clear land down to mineral soil. The area can be treated with implements that are towed at the same time. Tractors may be used to pile and windrow debris (fig. 9). The blade is usually operated 6 to 12 inches above ground to minimize topsoil loss and to crush brittle-stemmed brush species.

Because the blade cannot be used to uproot vegetation without severe soil disturbance, profuse resprouting can be expected following treatment. This practice is usually more effective on mature brush than on young shrubs; effectiveness can be increased and costs reduced if shrubs are killed with herbicides before crushing. Production rates vary from 0.6 to 2.5 acres per hour.

Brush rakes (fig. 10) are the most common attachments for piling and windrowing debris, clearing and grubbing brush, and soil scarification. Soil displacement is minimized because dirt filters through the rake teeth. This results in less dirt in windrows and more complete burning of debris piles. Tractors can operate with the rake teeth in the soil to uproot sprouting species and produce more complete vegetation control. Brush rakes offer less resistance to tractor movement than angle blades thereby allowing safer, more efficient operation on steeper

Figure 9. Brush is often cleared and windrowed using crawler tractors.

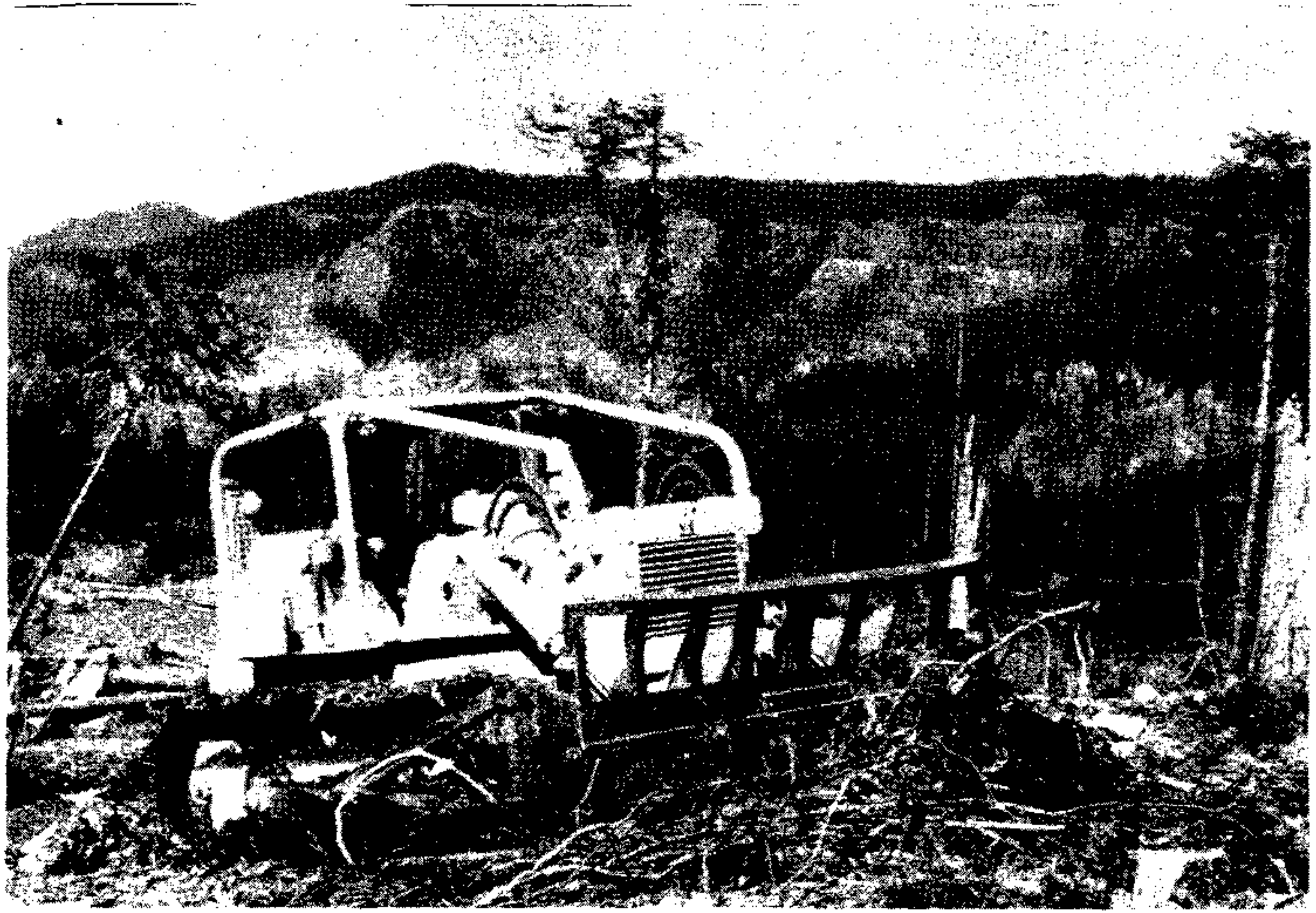


Figure 10. Tractors equipped with toothed brush rakes are best for clearing and piling logging slash and brush.

(30 to 35 percent) slopes. Production rates average about 1.2 acres per hour.

Tree cutters or shearing blades (fig. 11) remove trees and large shrubs by clearing them at the ground line. They may have straight or V-shaped blades with straight or serrated cutters along the bottom edge; some are equipped with stump splitters to aid clearing of large trees and stumps. The blade must be operated above ground level to prevent soil displacment; therefore, resprouting is likely. Shearing blades are not effective on rough or rocky terrain, or on large woody vegetation.

Rolling brush cutters (fig. 12) are large, weighted drums with chopping blades or spikes welded or bolted onto the surface. They are usually towed behind a tractor, but some are mounted on the dozer blade. Others such as the 80,000 pound LeTourneau Tree Crusher, are self-propelled. All types roll over the brush, crushing and chopping it into smaller pieces. Choppers are most effective on hard ground and small-diameter, brittle material. Unless vegetation is killed with herbicides prior to chopping, sprouting will occur. Rolling cutters with blades should be operated up and down slope to avoid erosion in the blade depressions. Towed brush cutters can operate on slopes up to 25 to 30 percent. They cover about 1.5 acres per hour under average conditions. Large, self-propelled units can operate on slopes up to 45 percent and cover 3 to 4 acres per hour.

Shredders cut brush or slash near the ground and shred the material into mulch. They are large, self-powered machines of either rotary blade or rotobeater design. Use experience shows that rotobeaters are safer and do a better job of mulching. Shredders can handle heavy brush on slopes up to 35 percent, and the mulch prevents soil erosion and helps conserve soil moisture. Shredders will not control resprouting and should be operated only in areas that are relatively free of rocks. Dust often becomes highly objectionable and reduces operator visibility. Production rates of 0.4 to 3.7 acres per hour have been reported for heavy brush and logging slash treatments.

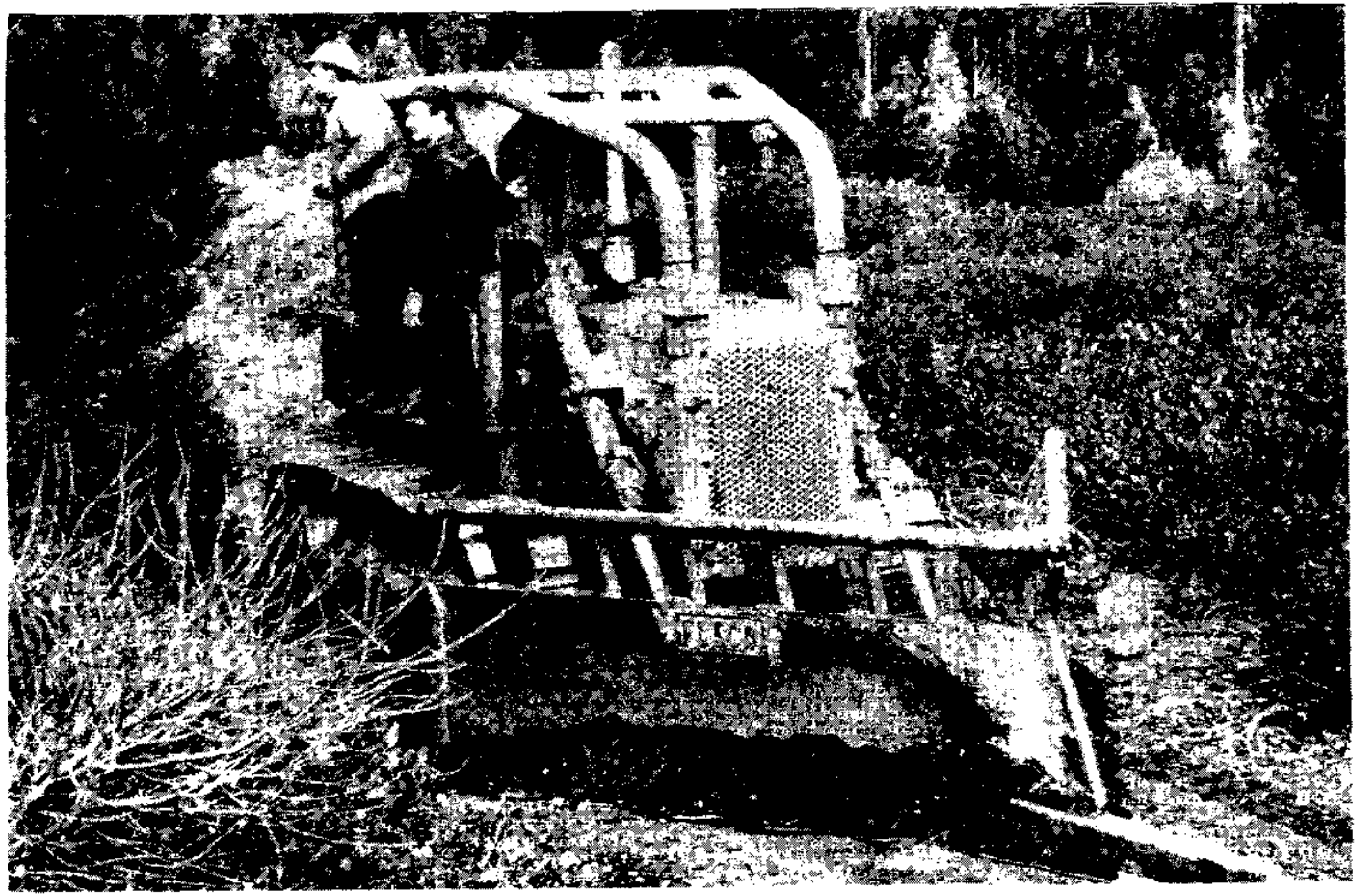


Figure 11. Shearing blades mounted on crawler can be used to clear brush and weed trees.

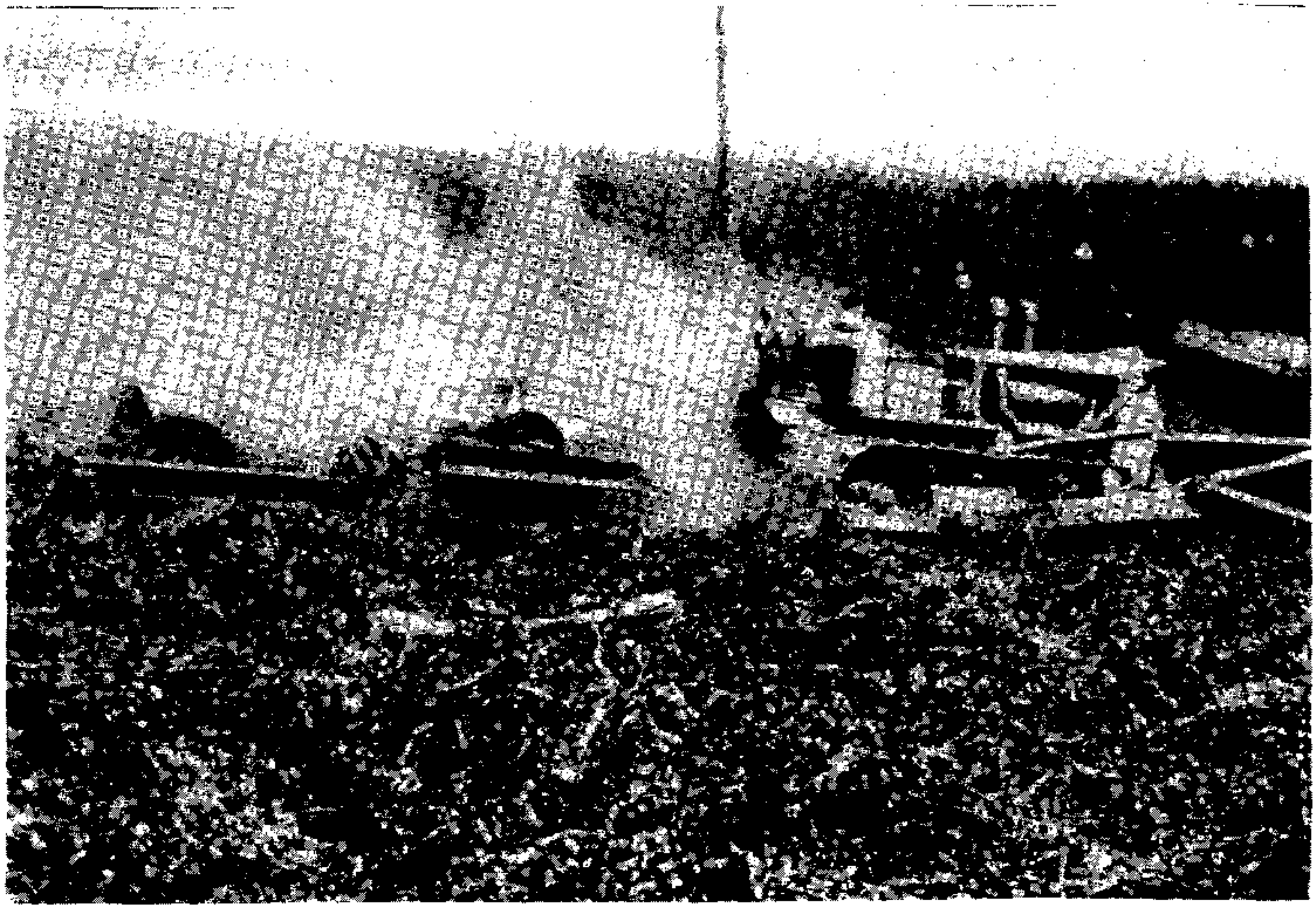


Figure 12. Rolling choppers are commonly used to prepare brushfields and new cuttings for reforestation.

Offset discs (two rows or gangs of discs set at an angle to each other) can be used to control moderate brush, loosen surface soil, and chop up and turn under surface debris. The tilling action can effectively control shallow-rooted sprouting species, and erosion hazard is partially reduced by incorporating debris into the soil as mulch. Offset discs are limited to slopes under 30 percent and to soils that do not have large rocks.

Integral disc plows are short gangs of large discs mounted directly on a tractor. They are used to loosen the soil and turn under debris. They can be used to produce contour strips of bare ground in which seedlings are planted. Competition from untreated brush, however, may severely limit seedling growth. Integral disc plows are more maneuverable than offset discs, but are not well suited for brush control.

The variety available of attachments and specialized machines makes mechanical methods versatile on gentle terrain. By careful selection of equipment, mechanical methods can be used to achieve all rehabilitation and site preparation objectives--that is, remove debris, reduce competition, prepare seedbeds, reduce soil compaction resulting from logging, or create favorable microsites--on suitable soils and terrain.

Mechanical methods can also be used for precommercial thinning of very dense stands where only clearing of regularly spaced strips and no selection of individual leave trees is required. Such methods are not suitable for tree release where small trees are hidden by brush, or for precommercial thinning and timber-stand improvement where individual tree selection is needed. However, in dense, very young stands, mechanical clearing of alternate strips may later be combined with selective removal by manual or chemical means.

Equipment moving and operating costs are relatively high, so treatment units must be fairly large and readily accessible. Costs can be reduced if equipment is kept moving forward and around obstacles; complete eradication or clearing is not desirable or cost-effective. The major limitations to use of mechanical vegetation control are steep terrain and likelihood of soil erosion. Safe operation of most equipment is limited to slopes of less than 35 percent. Using specialized techniques for steeper slopes, such as using two tractors yo-yo fashion or high-lead scarification (Ward and Russell 1975), sharply increases costs and aggravates soil erosion potential. Improper use of equipment can compact soils, disrupt normal drainage patterns, and remove significant amounts of nutrients (Gutzwiler 1976, Stewart 1978b). Increased use of mechanical treatments is sharply constrained by three factors: lack of suitable terrain in the mountainous West, lack of suitable soils, and increasing water quality restrictions and standards.

In general, mechanical vegetation control has the following advantages and disadvantages:

Advantages	Disadvantages
Excellent vegetation control is assured if species are nonsprouting or are uprooted.	Difficult to use where desirable trees exist.
Planting on mechanically prepared sites may be less costly	More expensive in many situations than other methods.
Manpower requirements are low (an operator and helper).	Equipment can only be used on gentle slopes.
	Scheduling of equipment can be difficult, treatment season limited.
	Soil compaction can be a problem.

Clearing loosens topsoil and removes organic matter, increasing erosion hazard and fostering germination of buried and introduced weed seed.

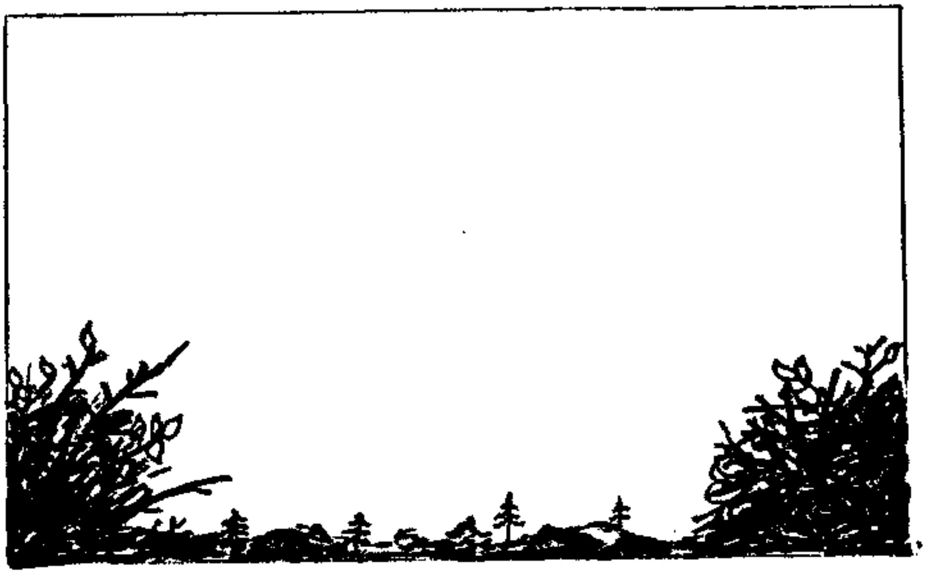
Mechanical brush control removes most of the protective cover and maximizes sunlight, soil moisture, and temperature extremes near the ground (fig. 13). Except on dry, hot sites, most of these changes are beneficial for seedling establishment (fig. 14).

Prescribed Burning

Fire is nature's principal method of preparing sites for a new stand. In fact, many of our most valuable commercial timber species are pioneers or subclimax species that owe their present abundance to wildfires. Prescribed burning can be properly timed to minimize the adverse effects of fire on soils. Fuel moisture must be low enough to permit burning, but surface litter and soil moisture must be high enough to prevent damage. Atmospheric conditions must also be suitable for safe burning and rapid dispersal of smoke.

Where vegetation is dense, it may be necessary to desiccate the plant cover with herbicides prior to burning (fig. 15) (Stewart 1978b). Fires in sprayed brush are easier to control and spread more rapidly and uniformly than fires in unsprayed brush. Because fire is a common natural disturbance, many species are well adapted to burning. Development of a plant cover from resprouts or from germination of buried seed and light-seeded pioneers proceeds rapidly after burning (Gratkowski 1961a, Stewart 1978a). Sprouting can be significantly decreased, thereby reducing future brush problems, if the vegetation

Figure 13. Mechanically cleared areas can be planted easily but soil disturbance can be severe unless sites are carefully selected and equipment properly operated.



Factor	Change
Solar radiation	
Intensity	+
Spectral quality	+
Air	
Temperature	
Day	+
Night	−
Diurnal variation	+
Relative humidity	-
Frost	+
Precipitation	
Interception	−
Reaching crop	+
Soil	
Temperature	
Surface	+
Subsurface	+
Diurnal variation	+
Moisture	
Total	+
Evaporation	+
Use by competitors	−
Available for trees	+
Nutrients	
Structure	-
Erosion	+
Air movement	+

Figure 14. Environmental changes due to use of mechanical equipment to clear vegetation (positive signs indicate increasing levels of the environmental factor; negative signs indicate decreases).

Figure 15. Dense brush left after logging may need to be sprayed to permit burning.

is sprayed with systemic herbicides prior to burning and if burning is delayed until these chemicals have been translocated into the roots.

Prescribed burns may be started with diesel- or gasoline-fed drip torches, flame throwers, or back-firing fusees. Burning may also be accomplished using helicopters. The fire may be set in progression or several points ignited at once. For some conditions, multiple ignition using electronically-fired containers of jellied gasoline that simultaneously ignite all or parts of an area may be necessary.

Prescribed burning can be used to accomplish several rehabilitation or site preparation objectives--reducing debris, reducing competition, and exposing mineral soil seedbeds--but it is not as versatile for this purpose as mechanical brush control. Because fire is nonselective in effect, it is difficult to use for tree release, precommercial thinning, or timber stand improvement. It is used to control brown-spot needle blight during the grass stage of longleaf pine, a very fire-resistant species. Repeated ground fires are also used to control understory vegetation (often hardwoods; included as TSI) in southern pines. Repeated ground fires also are being tested in red pine in the Northcentral region and in ponderosa pine in the Pacific Northwest.

A back pack torch has also been used experimentally to control individual hardwood stems (Cavanagh and Weyrick 1978). Girdling with heat is as effective as mechanical girdling or cutting, but torch-girdled trees often resprout, whereas use of herbicides usually limits sprouting.

The major limitations to expanded use of fire are its lack of selectivity, the narrow range of fuel and climatic conditions required for safe use, and restrictions imposed by state and federal air quality standards (figure 16). Air quality standards are becoming more restrictive in all parts of the United States. Even with existing regulations and weather requirements, many areas planned for broadcast

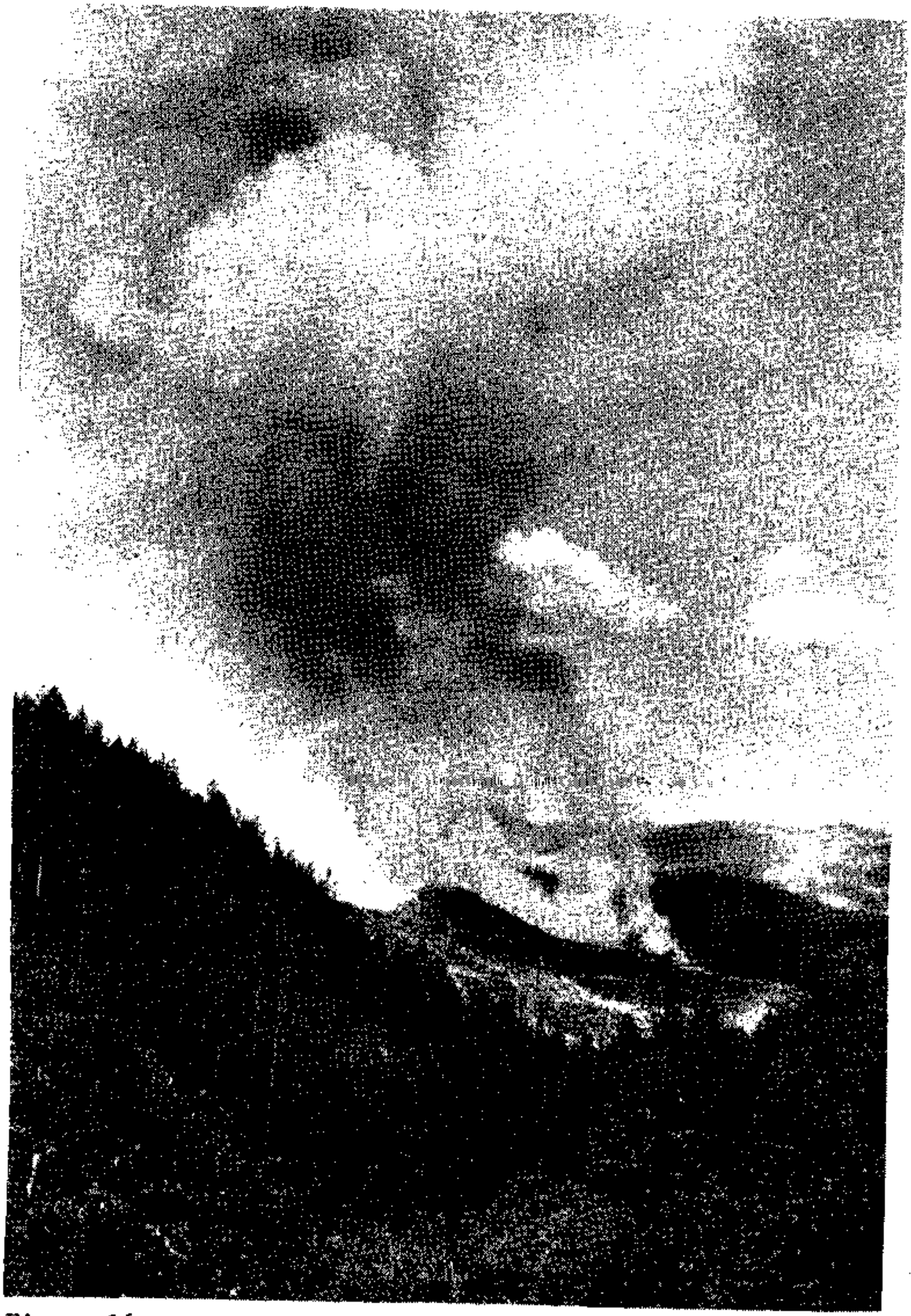


Figure 16. Fire is a natural and useful tool in forestry but air quality standards may reduce its availability.

burning, i.e., burning slash and residual vegetation on an entire unit, cannot be treated. Prescribed burning has the following advantages and disadvantages:

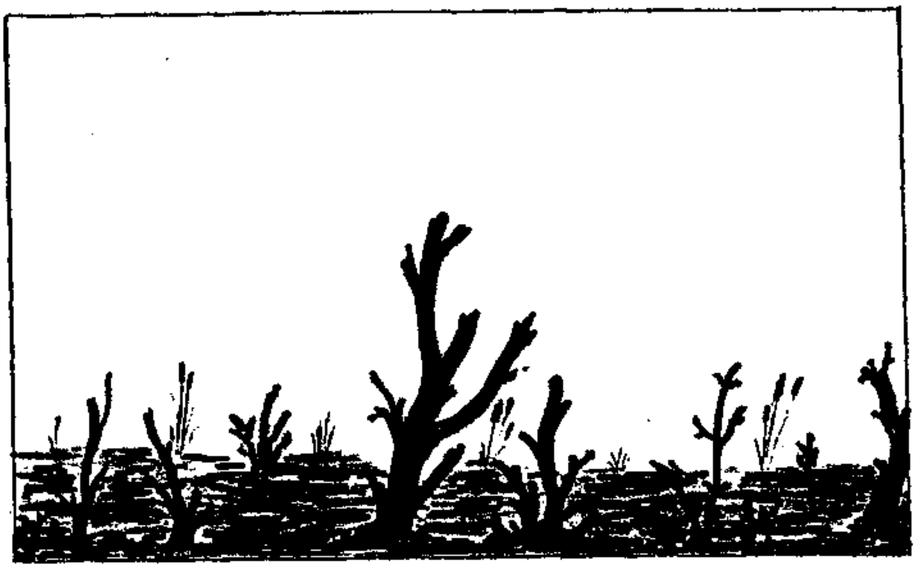
Advantages	Disadvantages
Can be used on steep terrain	Fire control can be difficult and expensive
Produces large, easily planted areas	Desired effects are difficult to achieve
Reduces fire hazard	A large complement of well-trained personnel is needed
Often costs less than mechanical treatment	Smoke pollution can be a problem
	Not suitable for highly erodible soils
	Many shrubs resprout and fire may induce germination of some species
	Results in loss of soil nutrients, especially nitrogen and organic matter
	Timing of fuel preparation is difficult to coordinate with atmospheric conditions

Where fuel conditions and air quality restrictions permit, prescribed burning is the best alternative for reducing vegetative cover for site preparation on steep terrain. Herbicides or manual felling of weed trees may be necessary to obtain proper fuel conditions on some sites. Burning temporarily provides maximum light and soil moisture for new tree seedlings (fig. 17), but the blackened surface may result in lethal soil temperatures on exposed south-facing slopes. Environmental changes caused by understory burning are minimal.

Herbicides

Herbicides may be used to control competing vegetation if the most abundant species are susceptible. In contrast to most agricultural crops, there are few herbicides registered for use in the production of timber. Each has different characteristics and each varies in the spectra of species controlled. Important uses of the most common herbicides in silviculture are listed below (Norris et al. 1979):

Herbicide	Vegetation Controlled	Use Pattern
Amitrole-T	Salmonberry, elderberry, and poison oak	Site preparation and release
Atrazine	Annual grasses and some forbs	Site preparation and release
Dalapon	Annual and perennial grasses	Site preparation or release (with atrazine)
Dicamba	Deciduous shrubs and trees, conifers, forbs	Site preparation
Fosamine ammonium	Deciduous shrubs and trees	Site preparation
Glyphosate	Deciduous shrubs and trees, grasses and forbs	Site preparation



Solar radiation
- Intensity............ +
- Spectral quality...... +

Air
- Temperature...........
  - Day............... +
  - Night............. −
  - Diurnal variation.. +
- Relative humidity..... −
- Frost............... +

Precipitation
- Interception.......... −
- Reaching crop......... +

Soil
- Temperature............
  - Surface............ +
  - Subsurface.......... +
  - Diurnal variation... +
- Moisture
  - Total............... +
  - Evaporation......... +
  - Use by competitors.. −
  - Available for trees. +
- Nutrients............. +
- Structure............. −
- Erosion............... +

Air movement.............. +

Figure 17. Environmental changes due to broadcast burning (positive signs indicate increasing levels of the environmental factor; negative signs indicate decreases).

MSMA	Hardwoods and conifers	Precommercial thinning and TSI (injection)
Picloram	Deciduous shrubs and trees, conifers, forbs	Site preparation, precommercial thinning, and TSI by injection
Silvex	Evergreen and deciduous shrubs, weed trees, forbs	Site preparation and release
2,4-D	Evergreen and deciduous shrubs, weed trees, forbs	Site preparation, release, precommercial thinning, and TSI (injection)
2,4,5-T	Evergreen and deciduous shrubs, weed trees, forbs	Site preparation, release, precommercial thinning, and TSI (injection)

Other properties and a comparison of all important herbicides used in forestry are displayed in table 10.

Determining the prescription is not usually difficult, but several factors must be considered. These include selection of the most effective herbicide or combination of herbicides, the rate or amount of active ingredient to be applied, the carrier or diluent, total volume of spray per unit area, season of application, and type of equipment to be used (Gratkowski 1975). The choice of herbicide depends on species composition of the vegetation and is keyed to control from one to five

Table 10--Properties of herbicides used in forestry

Herbicide	Formulation	Season of application	Carrier and volume	Application[b] rate	Selectivity	Relative persistence[a]	Use precautions	Route of uptake	Cost[b]
									($/lb ai or $/gal)
Fosamine	Krenite-water soluble liquid	Late summer to early fall	10-40 gal/A aerial, 50-300/gal/gal/A ground in water	1-1/2 to 3 gal/A	Deciduous species for site preparation	Short	Applied in 2 month period before fall leaf coloration; LD_{50}-24,000 mg/kg	Foliage	$32/gal
Amitrole-T	Amino triazole + ammonium thiocyanate liquid	May-July	10-15 gal/A in water	1/2 to 1 gal/A	Salmonberry and elderberry; will damage Douglas-firs if applied too early or late	Short	LD_{50}-750 mg/kg	Foliage	$13/gal
Asulam	Asulam-sodium salt liquid	June-August after full flood development	10-20 gal/A in water	1 gal/A	Bracken fern; use on Christmas trees when not actively growing	Short	Apply when conifers are not actively growing; LD_{50}-2000 mg/kg	Foliage	$38/gal
Atrazine	80% wettable powder	Late winter	10 gal/A in water	3 to 4 lb ai/A[b]	Annual grasses and some forbs does not damage conifers when properly applied	Short	Requires at least 2 inches of rain after application; LD_{50}-3080 mg/kg	Root	$2.80/lb
Dalapon	74% sodium and magnesium salts-water soluble	Late winter to early spring grasses emerge	5 to 10 gal/A aerial, 10 to 100 gal/A ground in water	3 to 11 lb ai/A	Annual and perennial grasses for site preparation; use with atrazine or directed sprays for release	Short	Use 1/2 to 4 pints surfactant per 100 gal; delay planting 2 weeks if rate over 8 lb; apply when grasses are actively growing; LD_{50}-6500 mg/kg	Foliage and root	$1.96/lb

continued

Table 10—Properties of herbicides used in forestry (continued)

Herbicide	Formulation	Season of application	Carrier and volume	Application rate[b/]	Selectivity	Relative persistence[a/]	Use precautions	Route of uptake	Cost[b/]
									($/lb ai or $/gal)
Dalapon (continued)	Triisopropano-lamine salts of picloram & 2,4-D (Tordon 101R and Tordon 101)	All	None	Undiluted	Hardwoods and conifers by injection	Long	May damage untreated conifers ("flash-back"); Tordon 101R contains half the picloram of Tordon 101	Cut surface	$10/lb for Tordon 101R and and $17.50/gal for Tordon 101
Picloram	Triisopropano-lamine salts of picloram & 2,4-D (Tordon 101) with or without low volatile esters of 2,4,5-T or silvex	Spring to mid-summer	10 to 25 gal/A in water	1 to 4 gal/A	Shrubs and weed trees for site preparation	Long	Must use application methods that reduce drift	Foliage	$17.50/gal
	Isooctyl ester of picloram & PGBE ester of 2,4,5-T (Tordon 155)	Dormant to budbreak	20 to 40 gal/A in diesel	1/2 to 1 gal/A	Shrubs and weed trees for site preparation	Long	For use in California, Oregon, and Washington only; delay planting 3 to 6 months	Stem	$49/gal
Pronamide	50% wettable powder	October to December	10 gal/A in water	1 to 2 lb/A	Grasses only for site prep-aration or releases in Christmas trees	Moderate	Christmas trees only; LD_{50}-5620 mg/kg	Root	$13/lb
Dicamba	Dimethylamine salt	All	Water or undiluted	Undiluted or or 1:4 in water	Hardwoods and conifers by injection	Moderate	LD_{50}-1040 mg/kg	Cut Surface	$34/gal

continued

Table 10--Properties of herbicides used in forestry (continued)

Herbicide	Formulation	Season of application	Carrier and volume	Application rate[b/]	Selectivity	Relative persistence[a/]	Use precautions	Route of uptake	Cost[b/] ($/lb ai or $/gal)
Dicamba	Dimethylamine salts of dicamba & 2,4-D or 2,4,5-T	Spring to midsummer	15 to 300 gal/A in water	1 to 3 gal/A	Shrubs and weed trees for site preparation	Moderate	Not as effective as picloram or as oil-soluble formulation	Foliage	$13 to $18/gal
	Oil-soluble acid of dicamba and isooctyl esters of 2,4-D or 2,4,5-T	Dormant (fall to late winter)	30 gal/A in diesel	1 gal/A	Shrubs and weed trees for site preparation	Moderate	More effective than water-soluble formulation	Stem	$17 to $20/gal
DNBP	Emulsifiable dinitrophenol	Spring to late summer	10 to 20 gal/A water or oil	1 to 2 gal/A	Nonselective, nontranslocated desiccant used to prepare herbaceous and woody vegetation for burning	Short	Must burn within 1 month of treatment; will not control resprouting; highly toxic; LD_{50}-58 mg/kg; absorbed through skin	Foliage	$8/gal
MSMA	Monosodium acid methanearsonate	Fall and winter	None	Undiluted	Hardwoods and conifers by injection	Short	Wear protective clothing; LD_{50}-700 mg/kg	Cut surface	$12.35/gal
Picloram	Potassium salt + invert emulsions of 2,4-D or 2,4,5-T	Spring to mid-summer	15-25 gal/A invert emulsion	1 to 4 quarts picloram + 1 to 4 gal of phenoxy invert	Shrubs and weed trees for site preparation	Long	Delay planting 8 months; must be used with Dow invert emulsions; LD_{50}-8200 mg/kg	Foliage	$60/gal + invert

continued

Table 10—Properties of herbicides used in forestry (continued)

Herbicide	Formulation	Season of application	Carrier and volume	Application rate[b]	Selectivity	Relative persistence[a]	Use precautions	Route of uptake	Cost[b] ($/lb ai or $/gal)
Silvex	Low-volatile esters (BEE, PGBE)	Late winter to summer	10 gal/A in diesel, water or oil-in-water emulsion	1/4 to 3/4 gal/A	Shrubs, weed trees, and forbs; slightly more damaging to conifers than 2,4-D or 2,4,5-T	Moderate	Silvex is not a direct substitute for 2,4,5-T; LD_{50}-375 mg/kg	Stems and foliage	$18/gal at 4 lb ae/gal
Simazine	80% wettable powder	Fall	10 gal/A in water	3 to 4 lb/A	Annual grasses and some forbs for site pre-aration and release in Christmas trees	Moderate	Actively similar to atrazine; requires rainfall to activate; LD_{50}-5000 mg/kg	Root	$3.06/lb
2,4-D	Amine	Spring and summer	None	Undiluted or 1:1 with water	Hardwoods except cherry and bigleaf maple by injection	Short	LD_{50}-375 mg/kg	Cut surface	$6.50 at 4 lb ae/gal
	Low volatile ester (Isooctyl, BEE, PGBE)	Late winter to summer	5 to 20 gal/A in diesel, water, or oil-in-water emulsions	1/4 to 3/4 gal/A	Shrubs, weed trees, and forbs for site preparation and conifer release (except pines)	Short	May be used in combination with 2,4,5-T as brush-killer; LD_{50}	Stem and foliage	$8/gal at 4 lb ae/gal

continued

Table 10--Properties of herbicides used in forestry (continued)

Herbicide	Formulation	Season of application	Carrier and volume	Application rate[b/]	Selectivity	Relative persistence[a/]	Use precautions	Route of uptake	Cost[b/] ($/lb ai or $/gal)
2,4,5-T	Low-volatile ester (Isooctyl, BEE, PGBE)	Late winter to late summer	5 to 20 gal/A in diesel, water, or oil-in-water	1/4 to 3/4 gal/A	Shrubs, weed trees, and forbs, for site preparation and release	Short	Can be used to release pines in late summer; also available combined with 2,4-D as a brushkiller mix; LD_{50}-300 mg/kg	Stem and foliage	$17/gal at 4 lb ae/gal
	Amine	Spring to late summer	None	Undiluted of 1:1 with water	Hardwoods by injection	Short		Cut surface	$19/gal at 4 lb ae/gal
Glyphosate	Isopropylamine salt water soluble	Late summer to early fall	10 gal/A aerial, 20 to 100 gal/A ground in water	1/4 to 3/8 gal/A	Deciduous woody species and herbs for site preparation and release	Short	Registered in Oregon and Washington only, LD_{50}-4320 mg/kg	Foliage	$60/gal

a/ Short 1/2 life 4 months; moderate - 12/ life 5-8 months; long - 1/2 life 8-12 months.

b/ ae - acid equivalent; ai - active ingredient.

SOURCE: Norris, L. A. et al. 1979. USDA-States-EPA 2,4,5-T RPAR Assessment Team.

dominant species on the site. Susceptibility of the most important brush species to 2,4,5-T and other herbicides is well-documented (Brady 1972, Bovey 1977, Dahms 1961, Gratkowski 1975, McCormack 1977, Romancier 1965, Stewart 1978b, Williston et al. 1976).

The phenoxy herbicides 2,4-D, 2,4,5-T, and silvex control a broad spectrum of evergreen and deciduous shrubs and hardwood trees. The herbicide 2,4,5-T is more effective on many brush species and is less damaging than 2,4-D on most pine species (Gratkowski 1961b and 1977). Silvex is effective on fewer species and is more damaging to conifers than either 2,4,5-T or 2,4-D. Picloram and dicamba are also broad-spectrum herbicides that tend to be more effective on deciduous species and less effective on evergreen chaparral species than the phenoxy herbicides. They are also more persistent and will severely damage existing conifers. Picloram and dicamba are usually most effective for site preparation when combined with 2,4-D or 2,4,5-T. Asulam, atrazine, dalapon, pronamide, and simazine are effective on herbaceous species only and do not overlap the spectrum of species susceptible to the other herbicides.

Fosamine ammonium and glyphosate are new herbicides with limited registration for forest uses in the Pacific Northwest. Both show promise for site preparation and release of conifers from deciduous but not evergreen species. Triclopyr also shows promise for site preparation to control both evergreen and deciduous species in the Northeast and West. Triclopyr is not registered for forest use and the other two are registered for use only in Oregon and Washington.

Low-volatile emulsifiable esters of the phenoxy herbicides are preferred for broadcast foliage and stem sprays. Amine formulations are most useful for injection and cut surface treatments. Amine and metallic salt formulations of the more phytotoxic herbicides, such as picloram, have proven effective as foliage sprays, especially when combined with an emulsifiable low-volatile ester of 2,4-D or 2,4,5-T. Oil-soluble combinations of dicamba or picloram plus 2,4,5-T show promise for control of multiple layer, multiple species brushfields in the Pacific Northwest (Stewart 1974).

The effective dosage of the phenoxy herbicides varies from 0.5 to 4 pounds acid equivalent (ae) per acre for broadcast sprays. Concentrations in basal sprays may approach 16 pounds ae per 100 gallons of carrier (3 to 4 percent active). More phytotoxic herbicides, such as picloram and dicamba, are usually applied at 0.5 to 1 pound ae per acre combined with 1 to 4 pounds ae of 2,4-D or 2,4,5-T. Rates in excess of 4 pounds active ingredient (ai) per acre for broadcast herbicide application are seldom required in any one application.

Carriers are used as diluents to increase spray volume, to improve distribution of the herbicides, and to enhance herbicidal uptake. Choice of carrier is determined by the route of herbicidal uptake and solubility of the formulation (Gratkowski 1975, Stewart 1978b). The following is a rough guide to carrier selection:

	Spray season		
Vegetation type	Budbreak	Early foliar	Mid-summer
Deciduous	oil	water	oil-in-water
Evergreen	oil-in-water	oil-in-water	oil-in-water
Evergreen	oil	oil-in-water	oil-in-water
Herbaceous	water	water	water

Diesel oil is also used for basal and stump sprays to improve penetration through the bark.

Carrier volume (diluent) must be sufficient to obtain adequate coverage of the vegetation and is highly dependent on structure, height, and density of the vegetation and on spray droplet size distribution. Aerial spray volumes vary from 3 gallons per acre in open stands to 20 gallons per acre in dense brushfields or when applying drift-reducing formulations with large median droplet diameters. Field experience suggests that in dense brush, an increase in carrier volume produces equivalent or better effect than an increase in herbicidal dosage. Volumes for broadcast applications using mistblowers usually vary between 3 and 10 gallons per acre depending on the height and density of the brush.

Season of application is chosen to correspond with the period of maximum herbicidal susceptibility of the dominant weed species and, if trees are present, minimum susceptibility of desirable tree species. Susceptibility is usually low during winter dormancy, increases at time of budbreak, and reaches a maximum during late spring or early summer when soil moisture is readily available and plants are actively growing. Four spray seasons are ordinarily defined: budbreak, early foliar, mid-summer, and late foliar (Gratkowski 1975). Dicamba and picloram may be effective earlier and later in the year than are the phenoxy herbicides; both fosamine ammonium and glyphosate are most effective in the Pacific Northwest in late summer or early fall prior to leaf abscission.

Unfortunately, no herbicide is truly selective--that is, one that will kill all undesirable species and leave conifers unharmed. To use them effectively for release, the forest manager must utilize small differences in herbicidal effects and growth stages of weeds and trees. Effect varies considerably depending on carrier, rate of application, and season (Gratkowski 1961c). For example, early foliar (April to June) sprays of 2,4,5-T applied in water are used to release southern pines; late foliar (September to October) sprays applied in water are used to release western pine species. Phenoxy herbicides are applied in a water carrier after full-leaf expansion (mid-July to mid-August) to release pines in the Lake States and New England.

Broadcast sprays may be applied by helicopter or fixed-wing aircraft, or by tractor-mounted mistblowers. Helicopters are preferred for treating areas in rugged, mountainous terrain (fig. 18). Production rates under

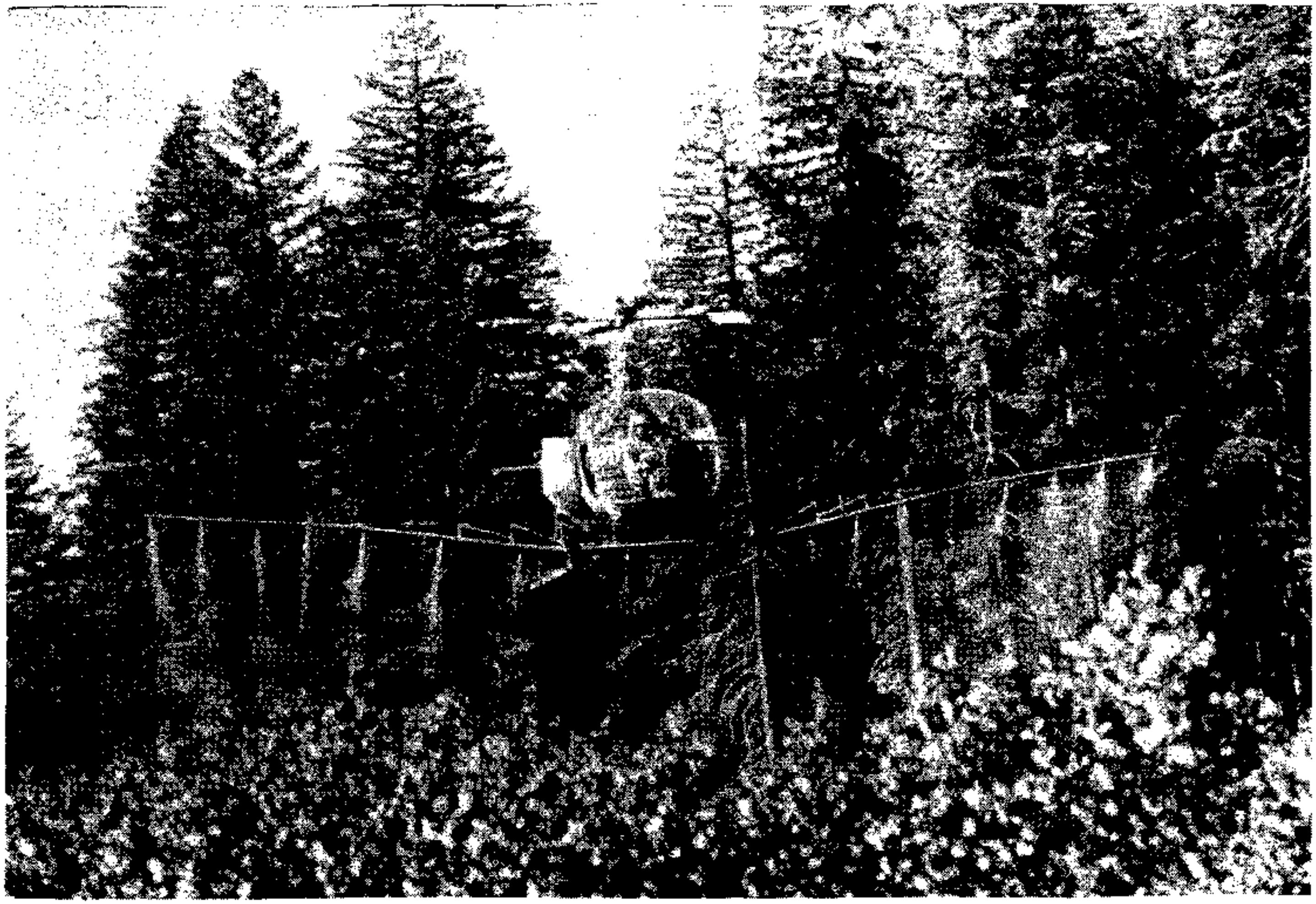


Figure 18. Helicopters are most often used to aerially apply herbicides to forest lands.

favorable weather conditions vary from 60 to 120 acres per hour. Actual flying time averages 1 to 3 hours or 60 to 360 acres per day. Mistblowers are useful for treating smaller areas on gentle terrain but are only effective on weeds less than 25 feet high. Individual stem and spot treatments may be applied using backpack sprayers or mistblowers (foliage and basal sprays), tree injectors, hypo hatchets, axes and squeeze bottles, or metered squirt cans (fig. 19). Overstory weed trees can be economically treated on small areas using amine or metallic salt formulations of 2,4-D, 2,4,5-T, or picloram applied in notches or frills made 2 or 3 inches apart completely around each stem. Cuts can be made with a tree injector at the base of the tree or with an axe at any convenient height. Production rates of 1 to 6 acres per day per worker are possible with injection treatments.

Herbicides alone only control competing vegetation and do not accomplish any of the other possible objectives of rehabilitation or site preparation. Even when composed of susceptible species, the dense, interwoven stems of chemically-killed brush may make it impossible for areas to be planted at reasonable cost (fig. 20) (Gratkowski 1961c). Herbicides alone are an effective method of rehabilitation and site preparation only when either the brush species are very susceptible to herbicides, and when litter is light enough to allow a reasonable chance of success for natural or direct seeding, or if the stand is sparse enough to permit planting. Even then, seeds and young trees are jeopardized by rabbits, mice, and other tree- and seed-eating animals that move about freely under the standing dead brush. Therefore, herbicides are most useful for rehabilitation and site preparation when combined with other methods, such as mechanical clearing or prescribed burning, to remove cover and physical barriers to planting, and prepare the seedbed (Stewart 1978b).

Herbicides, especially 2,4-D and 2,4,5-T, are most useful for tree release using broadcast sprays. They are also used successfully for precommercial thinning and timber-stand improvement using individual stem treatments. By far, the most common use of herbicides is the application of 2,4,5-T alone or in combination with 2,4-D for release.

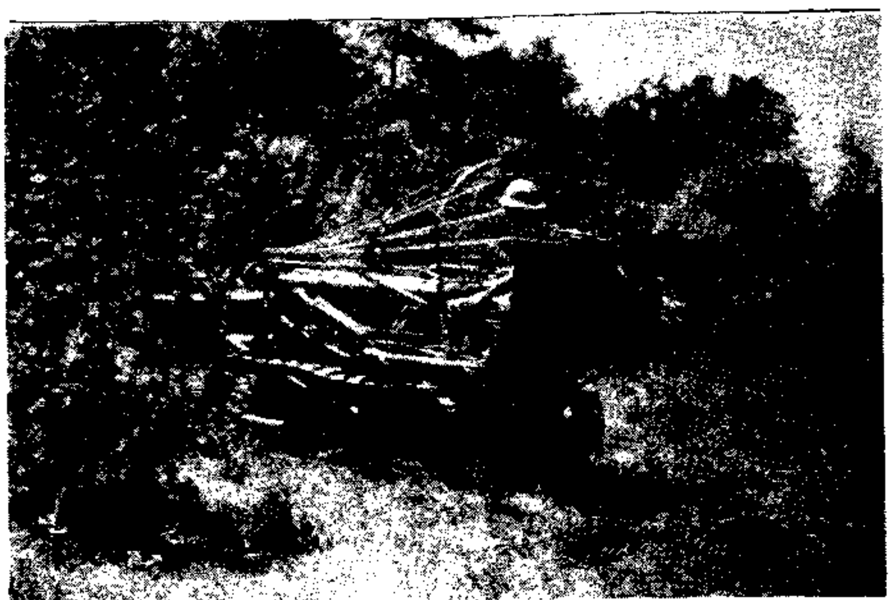


Figure 19. Tree injectors, tractor-mounted mistblowers, and pressurized sprayers are commonly used to apply herbicides in the South.

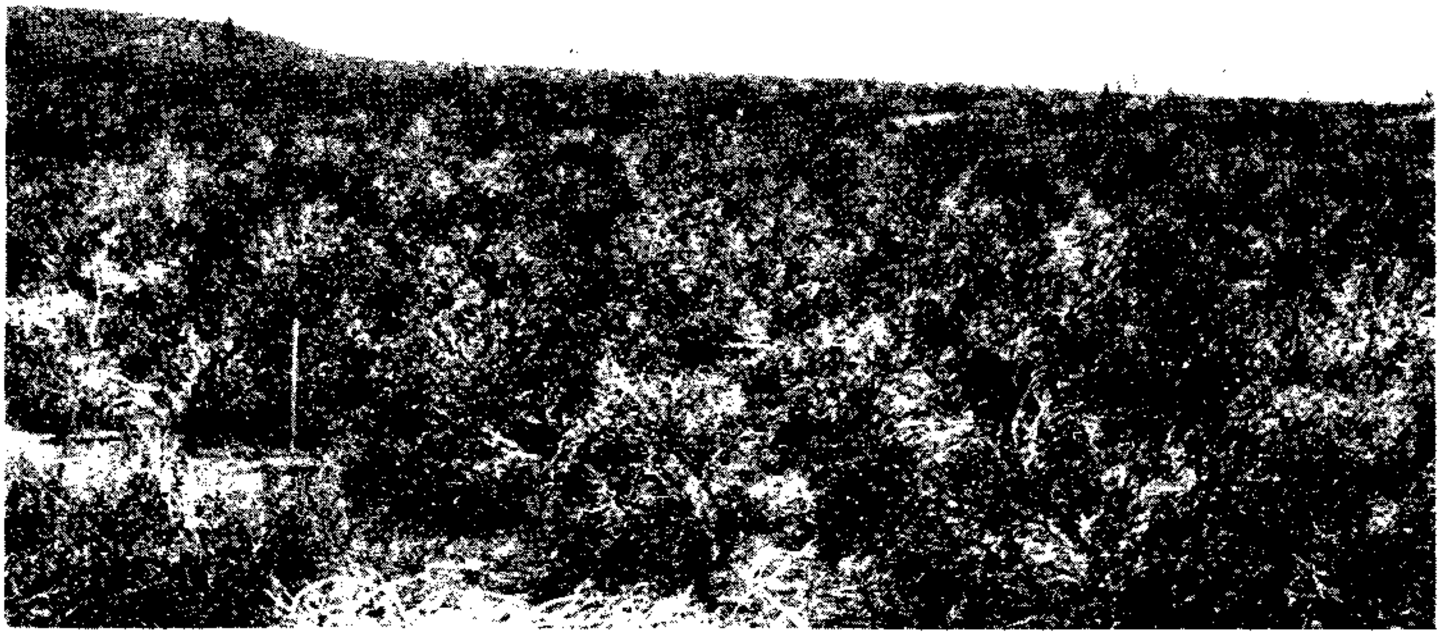


Figure 20. Planting can be difficult amid dense, chemically killed brush.

The herbicide 2,4,5-T is especially important for releasing pine species because of its greater selectivity (Gratkowski 1961b); no proven substitute for pine release is presently registered. It is also preferred for releasing other conifers wherever it is the most effective herbicide. In mixed stands of brush the two herbicides may be combined to improve control and reduce cost since 2,4-D is less expensive than 2,4,5-T. However, no registered or currently available herbicide has the same combination of broad-spectrum effectiveness and conifer selectivity as 2,4,5-T.

The major limitations to expanded use of herbicides are the high development cost and small market potential for new products, lack of registration for potential chemicals, and litigation resulting from environmental concerns. Except for fosamine ammonium and glyphosate, which show potential for replacing some uses of 2,4,5-T in the Pacific Northwest (site preparation and perhaps conifer release from deciduous species), substitute new herbicides are not likely to be developed in the near future. Despite these problems, control of competing vegetation with herbicides has some very attractive attributes. Herbicides do not disturb the soil and they leave treated vegetation and litter intact. Thus, erosion hazard is less following chemical treatment than following mechanical clearing or prescribed burning. Because herbicides restrict resprouting and do not expose mineral soil, reinvasion of competing vegetation from sprouts and seedlings is often slower.

Because of the sensitive nature of pesticide use, more precautions are taken in planning and conducting herbicidal spray applications than many other activities in forestry. For example, individuals who prescribe or apply herbicides are trained and licensed as certified applicators if the chemical used is a restricted use pesticide. Untreated buffer zones are usually left along water courses. In addition, proper weather conditions, such as air temperature, relative humidity, and wind speed and direction are specified for each application. These conditions are usually monitored on the spray site. Operations are suspended when conditions would result in unacceptable drift or volatilization. To further confine effects to the spray site, helicopters are almost always specified because of their greater maneuverability, slower flying speed, and lower flying height. When necessary, additional precautions, such as use of special drift-reducing spray equipment or adjuvants, are also specified.

Use of herbicides has the following advantages and disadvantages:

Advantages	Disadvantages
Often the least expensive treatment	Planting can be more expensive amid chemically killed brush
Large areas can be treated quickly with moderate manpower and supervision	Does not expose mineral soil necessary for natural or artificial seeding
Produces the least disturbance; does not compact, loosen, or move topsoil, or expose surface to erosion	Herbicides can be used only where the dominant species are susceptible
Can be used on all terrain	Herbicides may not be acceptable near sensitive areas
Leaves vegetation and litter intact to protect soil surface	Tree-damaging animals move about freely under sprayed brush where they are protected from predators
	A rapid resurgence of difficult to control vegetation may require respraying to assure continued dominance of planted trees

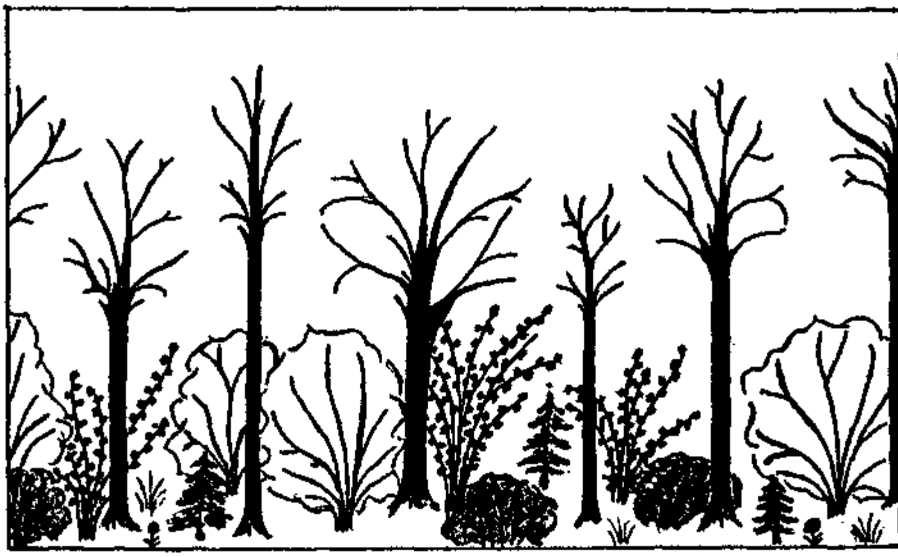
Environmental conditions are less extreme amid chemically killed brush. Removal of selected overstory trees using individual stem treatment results in slight increases in light and soil moisture near the ground (fig. 21). This is accompanied by a small increase in understory species. Removal of the canopy by spraying causes greater increases in light, soil moisture, temperature, and wind speed near the ground (fig. 22 and 23). These increases, however, are less than changes occurring following clearing by mechanical, fire, or manual methods.

Manual

Competing vegetation can be removed by hand using chainsaws, axes, hoes, or other cutting and grubbing equipment. Scalping, or hand clearing of planting spots in herbaceous communities using the side or end of the planting hoe, is one of the most common site preparation practices. Size of scalp varies from a narrow slit to a cleared spot several feet square depending on rooting habits, capacity of the competing plants to reinvade openings, and difficulty in removing vegetation. Effectiveness of scalping is highly variable; herbicides may be better because of more complete vegetation control and creation of a mulch that conserves soil moisture (Heidmann 1968 and 1969, Stewart and Beebe 1974).

Manual cutting is effective when species to be cut are not overly dense and do not resprout. Rapid sprouting from established root systems markedly reduces the effectiveness of treatment and requires repeated application to attain the desired duration of control (fig. 24). In fact, manual cutting may lead to increased abundance of the undesirable species (Lewis and Higdon 1977, Roberts 1977). In the Oregon Coast Range, sprouts grew 2 to 5 feet, some as much as 10 feet, and the number of stems increased during the first growing season after cutting (Roberts 1977).

Most conifers do not resprout and are easily controlled by felling. Eastern hardwoods can also be controlled with an axe notch or power-machine girdle, but a low axe frill using 2,4,5-T is more

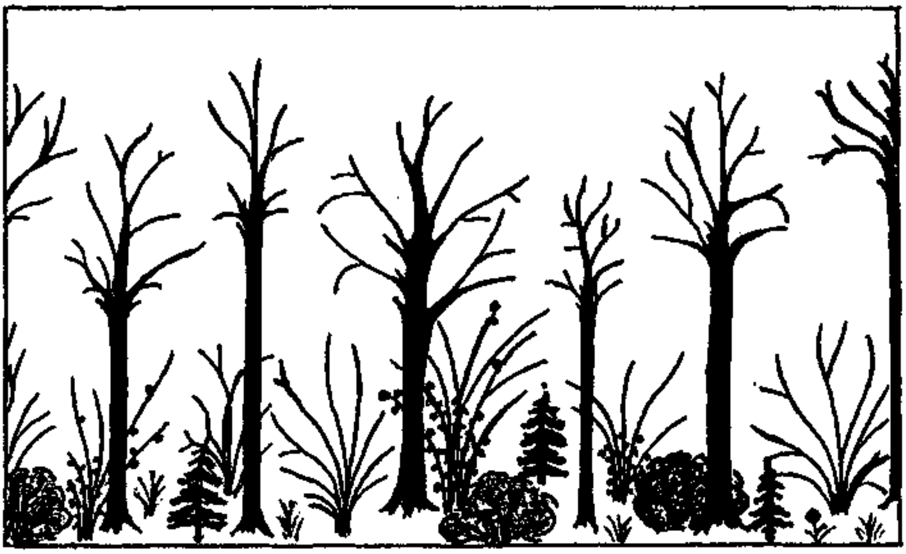


Solar radiation	
Intensity	+
Spectral quality	+
Air	
Temperature	
Day	+
Night	-
Diurnal variation	+
Relative humidity	-
Frost	
Precipitation	
Interception	-
Reaching crop	+

Soil	
Temperature	
Surface	+
Subsurface	+
Diurnal variation	+
Moisture	
Total	+
Evaporation	+
Use by competitors	-
Available for trees	+
Nutrients	+
Structure	
Erosion	
Air movement	+

Figure 21. Environmental changes due to use of an individual stem herbicide application that removes overstory weed trees (positive signs indicate increasing levels of the environmental factor; negative signs indicate decreases).

Figure 22. Aerial spraying to release conifers does not often eliminate species but results in increased light, soil moisture, and nutrients for the trees.



Solar radiation	
Intensity	**+**
Spectral quality	**+**
Air	
Temperature	
Day	**+**
Night	−
Diurnal variation	**+**
Relative humidity	−
Frost	+
Precipitation	
Interception	**−**
Reaching crop	**+**

Soil	
Temperature	
Surface	+
Subsurface	+
Diurnal variation	+
Moisture	
Total	+
Evaporation	+
Use by competitors	−
Available for trees	**+**
Nutrients	+
Structure	
Erosion	
Air movement	+

Figure 23. Environmental changes due to use of a broadcast aerial spray that removes all overstory and most understory weed species (positive signs indicate increasing levels of the environmental factor; negative signs indicate decreases).

Figure 24. Varnishleaf sprout height one growing season after the shrubs were lopped 6 inches above ground.

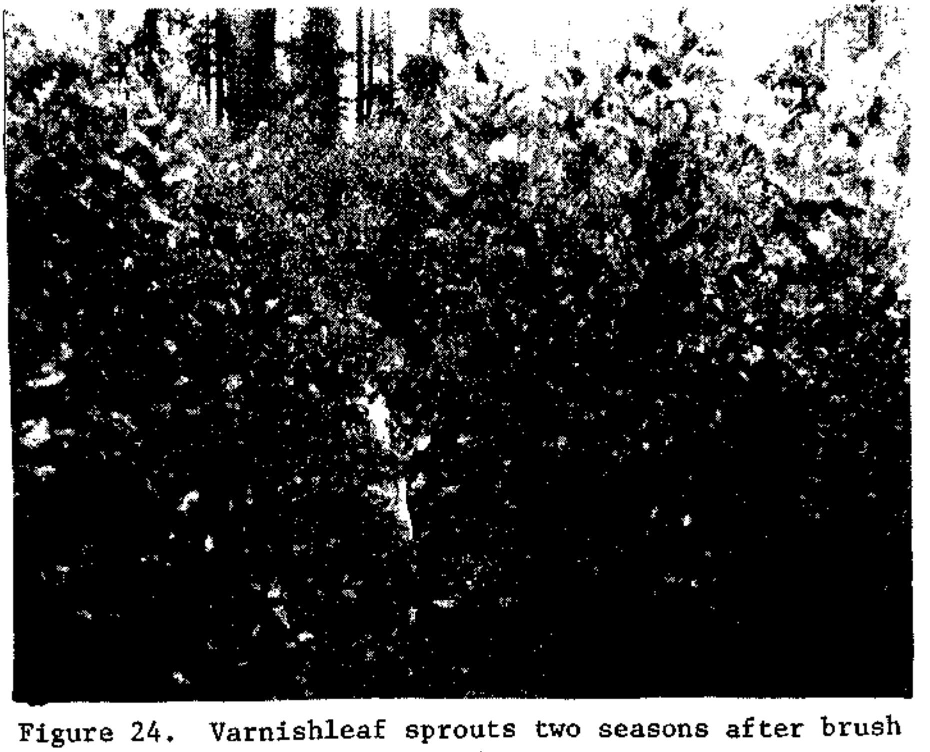


Figure 24. Varnishleaf sprouts two seasons after brush was cut 6 inches above ground.

cost-effective (Ryker and Minckler 1962). Production rates vary from one-fourth to 1- or 2-acres per worker per day depending on terrain, size and density of the vegetation, and number of stems to be treated. Production rates are lower and accidents more likely when working on steep slopes. As with all methods, more complete treatment of vegetation is needed for rehabilitation and site preparation than for tree release. Production rates for manual brush cutting are low; costs are high; and accidents are more likely--as much as twice that of manual precommerical thinning (Bernstein 1977 and 1978). Production rates are highest and cost is lowest when treating individual trees for precommercial thinning or timber-stand improvement operations.

Manual treatments are not well suited for rehabilitation, site preparation, or release in dense brush or in stands of sprouting species unless used with herbicides. Cutting for release also can damage desired trees from the cutting tools themselves or falling brush (Bernstein 1977 and 1978, Roberts 1977). At a production rate of one-half acre per day, it would take 80 worker days to treat a 40-acre unit. In addition, two or more retreatments may be needed to achieve the desired results.

Manual cutting is often the preferred practice for precommercial thinning of conifers because it increases selectivity and visual control of results. Manual cutting may also be combined effectively with herbicide treatment of stumps for controlling scattered, undesirable overstory trees left after harvest.

The major limitations to increased use of manual brush control are the high treatment costs, lack of manpower, predominance of resprouting species, and safety considerations. Manual cutting will continue to be a major precommercial thinning practice for conifers. Need for this treatment will sharply increase in the near future as large acreages of existing stands reach precommercial thinning age. The manpower required for manual cutting will compete with that needed for other manual treatments.

Manual brush control has the following advantages and disadvantages:

Advantages	Disadvantages
Can be highly selective	Stimulates resprouting and necessitates repeated treatment
Can treat small, isolated areas	Requires intensive labor at high cost, but low productivity
Can treat sensitive areas	Finding all trees in need of release is difficult
Provides employment	Damages trees to be released
Can be used on all terrain, but more dangerous on steep slopes	Limited work force available; high accident potential
	Creates a high fire hazard unless slash is scattered or removed; slash limits access and wildlife movement

Environmental changes from manual rehabilitation, site preparation, or release are nearly identical to those produced by mechanical clearing (fig. 14), but are much shorter in duration where sprouting species have been treated. Manual precommerical thinning and timber stand improvement effects are similar to those produced by individual stem herbicide treatments (fig. 21).

Biological Control

Insects and Disease

Woody and herbaceous plants are not always undesirable on forest lands; they protect the soil, add to scenic beauty, and serve as wildlife cover and food. Therefore, use of control agents whose effects cannot be confined to the site of need have not generally been considered practical on forest lands. Existing efforts to locate, test, and use plant insects and diseases have focused on economically important, widespread weeds found in agricultural crops or on rangelands (Bartlett et al. 1978, Bendixen 1974, Goeden et al. 1974).

Endemic populations of defoliators and stem borers and diseases have been examined and reported on many forest species. Repeated defoliation or killing of resprouting stems in successive years is needed to produce adequate control. Life cycles and mass rearing methods for these organisms are largely unknown. Further, proper timing, intensity, and distribution of outbreaks and confinement of effects to the treated areas are difficult to achieve. These factors largely limit the usefulness of biological control agents now and in the near future.

Grazing

Carefully regulated grazing by domestic livestock can be used to control competing vegetation. Goats are most effective on brushlands; sheep and cattle may be used where the primary competitors are herbaceous species (Green 1977a and 1977b, McKinnell 1974, Murphy et al. 1975, Skovlin et al. 1976). Grazing intensity and season of use must be carefully controlled to maximize benefits and minimize adverse impacts. Fencing and other measures to control herds may also be necessary. Field experience suggests that where vegetation is well established, the grazing intensity needed to prepare a site or release a plantation in a reasonable time period may result in compaction or stream contamination.

At present, browsing by goats seems feasible for maintaining fuelbreaks (Green 1977a and 1977b). National forests in California and Oregon are also evaluating use of goats and sheep in new cutting and plantations. These studies should provide information on the cost, effectiveness, and site impacts of regulated grazing. A potential use sequence is: 1- or 2-years of grazing by either goats to reduce brush or sheep and cattle to reduce herbs prior to planting; this is followed by periodic grazing by cattle to control herbs after trees are well-established. Benefits to the plantation, however, may be marginal (Edgerton 1971).

Soil compaction, poor control of competition, the long time period needed to obtain control, and damage to desirable species are major deterrents to widespread use of grazing. Other potential limitations are predators, unseasonable cold weather, lack of qualified herders, low return on investment in livestock, and the fact that treatment units may not be economic browsing or grazing units. Because it lacks selectivity, grazing is not suited for precommercial thinning or timber stand improvement.

Combinations

Several individual methods are frequently combined to produce a more effective practice. Most of these have been mentioned previously. These may be classified according to the method used for removing vegetation and slash as mechanical, prescribed burning, or manual. Herbicides alone do not remove physical barriers; therefore, they are often best used in combination with one of the other methods.

For site preparation, crushing or clearing is commonly combined with spraying or burning to achieve more complete control of vegetation and better access. Spraying cost can often be offset by reduced costs of subsequent mechanical site preparation. Herbicides may also be used to prepare brushfields or new cuttings for prescribed burning. Sprayed areas can often be burned under marginal conditions, making fire control easier (Stewart 1978b). Desiccation by herbicides also markedly influences fire behavior--more than can be attributed to changes in fuel moisture content alone. Fires in sprayed brush increase in intensity and spread over an area more rapidly and uniformly than do fires in unsprayed brush. However, if weather conditions are not favorable for drying or if burning is done too soon after spraying, even a spray that kills the brush cannot assure a good burn (Ryker 1966).

Combinations of herbicides with mechanical clearing or burning seem especially effective for rehabilitation of extensive brushfields in the West (Dimock et al. 1976, Gratkowski et al. 1973, Gratkowski and Philbrick 1965). Herbicides may also be used on cut surfaces to reduce resprouting following manual cutting of weed trees for site preparation, release, or timber-stand improvement.

Of the various factors influencing choice of method, combination treatments are most limited by physical site factors, available manpower and equipment, and environmental impacts. Just as combining methods builds on their individual strengths, it also results in combining the limitations of each. From a practical standpoint, the limitations on mechanical clearing and prescribed burning are most critical. Environmental changes would be similar to those encountered with either of these individual techniques (figs. 14 and 17), although control of resprouting by prior treatment with herbicides would tend to prolong the effects.

Cultural

Modifying silvicultural practices to minimize the extent or impact of future brush problems is a viable and useful option where sufficient ecological knowledge exists. For example, thorough site preparation and large vigorous planting stock may reduce the need for plantation release (Newton 1973). Planting more shade-tolerant species, such as western hemlock, in place of Douglas-fir can reduce site-preparation requirements and the need for release. Changing species, however, often involves tradeoffs in growth rates, log values, or product requirements.

In the Western United States on certain habitat types, disposal of slash by methods other than burning can reduce or eliminate establishment of shrub species that have seeds that are induced to germinate by high soil temperatures. Such species include deerbrush, redstem, varnishleaf, wedgeleaf, whitethorn, and snowbrush ceanothus and scotchbroom (Gratkowski 1962, 1973a, 1973b, 1974a, 1974b). Other promising cultural techniques include use of desirable species to limit establishment of competitors and regulation of overstory density to reduce vigor of understory species. For example, interplanting with autumn olive or European alder in black walnut plantations has been used to force height growth, hasten natural pruning, provide wind protection, or provide nitrogen fixation (Burke and Williams 1973). Manipulation of overstory density of northern Appalachian hardwoods has been experimentally combined with manual cutting to control grape vines[4/].

Cultural methods are not widely used at present because of a lack of basic ecological information about the major commercial tree species and their competitors.

This lack of information severely restricts use of modified silvicultural practices as a substitute for 2,4,5-T. The practices previously described are all used operationally, however. Information on ecesis, relative growth rates, and competitive ability of individual species and species mixtures is needed before cultural control methods can be fully implemented. Current research results suggest that vegetation management needs in some parts of the United States may be lessened in the future. Other than effects on wildlife habitat and perhaps soil nutrient cycling, cultural controls should have minimal impact on the environment and may often cost less than present practices.

[4/] Clay Smith. Personal communication. Data on file, Timber and Watershed Laboratory, USDA, Forest Service, Parsons, West Virginia.

Vegetation management with 2,4,5-T or its substitutes has a multitude of impacts on flora and fauna of a forest. As Newton and Norris (1976) pointed out, the principal effects on nontarget biota from using herbicides are the indirect effects associated with changes in plant community structure. In the absence of evidence that concentrations of 2,4,5-T reaching food chains are having detectable influences on population dynamics of animals directly, postulated changes in animal and plant welfare must be dealt with in terms of habitat change.

Forests subjected to herbicide treatment are generally those in some state of disrepair because of human activity. Within a forest stand, microenvironment is determined in large measure by the overhead cover produced by trees.

Numerous investigators have reported the very considerable changes that take place in microenvironment and animal habitat when overstory is removed, as with clearcut logging. Physical changes resulting from removal of cover included: increased temperature fluctation, increased soil moisture, and increased moisture demand by herbaceous plants in response to increased sunlight. The biotic response includes rapid increase in abundance of pioneer plant species and the animals that depend on them. Species that grow in deep shade are likely to decrease in abundance and vice versa. Succession in plants brings about succession in animals as habitats shift.

Terrestrial Environment

Changes in Vegetation With Time

Forests are treated with herbicides for one purpose, i.e., to increase survival and growth of desirable trees. In most instances, the trees being released or planted are very small, and successful vegetation control requires suppressing associated vegetation until the small trees are dominant. This necessarily entails developing vegetation of low stature for a prolonged period. Applications of phenoxy herbicides, especially 2,4,5-T, can maintain this condition without eradicated grown cover. In contrast, if the control operation is done with a bulldozer, the effects on associated vegetation are very striking. Vegetation, food, and cover for wildlife are virtually eliminated for short periods of time. Further, habitats created by plant succession following such drastic disturbances are markedly different than those created following spraying.

The killing of an overstory has very different impacts on habitat, depending on whether it is done with chemicals, fire, or by mechanical methods. When the forest is left physically intact, there is no impact on soils or on perches for birds. Selectivity of herbicides always leaves forage and cover (Carter et al. 1976). When the overstory is burned, much of the cover is removed, with no major dislocations of soil. When it is removed with heavy equipment, the impact on wildlife habitat is total. All vegetation is removed, soil surfaces are torn up, burrows are crushed, and silt may be deposited in creeks. Recovery of primary forage species may be delayed severely. In contrast, when done with phenoxy herbicides, there is a tendency for stems to sprout, maintaining the compositional integrity of the community. There are no other treatment regimes that can accomplish this.

After brush or weed tree control, there is rapid recovery of the plant community. Recovery rates are dependent on the degree of physical disturbance and the abundance of sprouting species surviving the disturbance. If goals are to be met, however, all methods must lead to a conifer-dominated cover, which itself constitutes a total environmental change. Kelpsas (1978) reported that bulldozing, glyphosate and a mixture of 2,4,5-T, and picloram all gave satisfactory site preparation so that planted transplant Douglas-fir were likely to become and remain dominant in the various types.

In the interim before canopy closure, Kelpsas did not observe the extinction of any plant species and recorded large increases in many. Some pioneer species invaded all treated areas.

No disturbance that changes a forest with a 90-ft canopy height into a plantation 2 feet tall can be regarded as short term in its effects. In no instance do the herbicides persist beyond the first few months or perhaps a year. Yet the community responds quickly to the reduction in cover following treatment. This in turn sets a long-term pattern of succession in motion. The nature of this pattern determines if the operation was a success and if the intermeded habitats created by succession are beneficial. The pattern leading to conifer dominance varies somewhat among methods, however, and such differences are the basis for comparison of indirect effects (Newton and Norris 1976).

Kelpsas (1978) reported that herb cover and sprouts became dominant shortly after scarification. After a chemical only treatment, the herb cover remained sparse as it had been before treatment, for several months. The scarified area was rapidly colonized by grasses and forbs that were low in abundance and biomass on sprayed plots. The spray-only treatment supported an abundance of ferns and seedling shrubs and retained the greatest structural diversity.

The above study also demonstrated that physical changes in environment may be beneficial to certain animal species but not beneficial to management goals. In particular, the piling of brush with bulldozers resulted in colonizing the slash pile by burrowing animals that then feed on conifers in the vicinity. This focusing of animal activity is causing serious plantation losses on mechanically-cleared lands. This problem makes this alternative less viable because of indirect environmental effects.

Changes in vegetation attributable to reforestation operations eventually lead to development of a stabile forest cover. In the interim, instability created by plant succession may be of more or less significance to the long-term productivity of the site.

Miller (1974) observed that nutrient mobility in forests following removal of vegetation was determined by the degree of nutrient mineralization during the time of warm rains. They observed little increase in stream nutrient levels when nitrogen-rich watersheds were cleared by chemical, fire, or harvesting in an area of low summer rainfall. Likens et al. (1970) reported that long-term devegetation by cutting and application of a residual herbicide resulted in release of nutrients as the retention sinks decayed. In view of the rapid resurgence in vegetation after application of phenoxy herbicides, this group of chemicals must be regarded as having a strong tendency to maintain the nutrient retention system in comparison to other approaches to site preparation.

Consequences to Animals

The above influences of treatment on vegetation and associated habitat lead to both short and long term impacts on animals. Lawrence (1967) described the successional patterns of animals in response to developing vegetation. For each species, there are periods of optimum habitat, before and after which populations are predictably lower. Harshman (1972) lists plant communities in which deer are most prevalent, with the conclusion that greatest abundance is in cover dominated by young conifers and shrubs. These are precisely the kinds of communities promoted by the use of 2,4,5-T for conifer site preparation and release (Carter, et al. 1976, Newton 1975 and 1978). Savidge (1977), however, reported loss of preferred forage for mule deer in California chaparral types. The above shrub types are the plant communities in which residues of 2,4,5-T and TCDD have been investigated in deer and mountain beaver. Residues were not of biological significance (Newton and Norris 1968, Newton and Snyder 1978). These observations lend support to the wealth of literature on the use of phenoxy herbicides for constructive maintenance of wildlife habitat.

Changes in habitat affect small mammals in various ways. Hooven et al. (1978) documented increases and decreases in populations of small mammals as the result of changes in cover. Meadow mice, deermice, pocket gophers, mountain beavers, and shrews have all been shown to respond with changes in population after disturbance. Population structure changes were significant after elimination of herbaceous cover with phenoxy and triazine herbicides in southwestern Oregon. In northwestern Oregon, changes in mountain beaver population occurred after fire destroyed cover and food supplies. Both studies, suggest a new rodent-control strategy for reforestation; copulations of the most serious pest rodent in each area declined with certain specific cover changes. In no instance was a population eradicated, and selective vegetation control permitted manipulation of the pests without use of rodenticides.

All successful applications of vegetation management in forest-site preparation and release lead to the stabilization of habitat in a conifer-dominated forest type. This end result has profound consequences for animal habitat. The western conifers tend to have dense canopies and relatively low carrying capacities for various terrestrial mammals (Harshman 1972). The scatter pattern of harvested areas, however, creates a mosaic of diverse cover that provides considerable opportunity for species of the open, of the edge, of the brush, and of the conifer forest (Newton and Norris 1976). This opportunity is not available if the patch clearcutting system is made unworkable because of the unavailability of appropriate management tools. In the absence of successful vegetation control, the shrub communities will stabilize and prevent or delay development of conifers, and diversity will decrease as cutover types revert to semi-permanent brush fields.

Aquatic Environment

Vegetation control necessarily has some effect on watersheds. Water quality is essentially free of significant impacts from herbicide use, apart from effects of gross contamination on irrigated crops (Newton and Norgren 1977). Control of stream-site cover has other effects on stream environments, however.

Water temperature is modified by the heavy cover associated with riparian vegetation. Brown (1971) observed that total clearance of cover by logging and slash burning in the Oregon Coast Range was associated with major increases in water temperature. In contrast, Roberts (1975) reported that the effect of a brown, slash, and burn site preparation operation on a unit of comparable size and proximity did not cause a temperature increase of more than 1°C. The dead shade afforded by slashed hardwoods and riparian salmonberry apparently afforded adequate water protection. Ordinarily, spray operations are constrained from applying herbicides in the riparian zones either by law as in the western states, or by unsuitability of the type for conifer production, as in the South. The destruction of significant cover and attendant increase in water temperature have not been attributed to herbicides as far as can be determined.

Condition of riparian vegetation does have an influence on the nutrient content of the water. Miller (1974) observed that living red alder was associated with high levels of nitrate in water. Nitrate levels decrease somewhat after control of the alder, but nitrogen concentrations in all streams with histories of alder tend to be high. In addition to the nitrate effect, riparian cover also drops considerable organic material into streams, and the resulting degradation results in the formation of humic acids and slight acidification of the water. This is not known to be detrimental, but condition of the overstory would be expected to determine the degree of influence.

The choice of vegetation management tool in the riparian zone will determine whether riparian cover is affected. The more drastic the disturbance, the less effective will be the cover in attenuating effects of the physical environment on the stream. Where water quality is critical, it is generally silt and temperature considerations that determine which impacts are tolerable. For both the use of herbicide alternatives is desirable because of the lack of physical disturbance near the streambank.

PRESENT AND POTENTIAL USE OF 2,4,5-T

A survey of all USDA Forest Service Regions, the Bureau of Land Management in Oregon and various state and small private forestry groups was conducted by the Forest Service to determine use patterns and costs of various silvicultural treatments. A separate survey of forest industry lands in the South and Pacific Coast sections was conducted by the National Forest Products Association (NFPA). All Federal land managers responded, but responses from states and small private landowners were incomplete and estimates of acres treated are probably conservative.

Estimated present and potential use of 2,4,5-T, by section, treatment objective, and application method are shown in table 11. Because of present internal and external constraints, potential use on Federal lands is much greater than present use--an increase of 522 percent, if managers are free to use the method of first choice. Potential acres should be about the same as, or only slightly greater than, the estimated use on industrial forest lands where organization constraints are largely absent.

In the North section, estimates from table 11 suggest that only about 0.05 percent (96,750 acres) per year of all commercial forest lands is treated with 2,4,5-T applied alone or in combination with other herbicides, usually 2,4-D or picloram. This low apparent need results largely from the dominance of eastern hardwood forests where 2,4,5-T is not suitable. About 1 percent of the 2,4,5-T would be aerially applied. On those acres needing treatment, usually one, but occasionally two, applications are needed during the rotation.

Table 11--Estimated annual present and potential use of 2,4,5-T on commerical forest land by section, application purpose, and application method

Purpose and application method	North			South			Rocky Mountains			Pacific Coast		
	Present	Potential	Application rate	Present	Potential	Application rate	Present	Potential	Applicaiton rate	Present	Potential	Applicaiton rate
	------acres-------		-lb ae/acre[a/]	----acres-------		-lb ae/acre	-----acres-------		-lb ae/acre	-----acres-------		-lb ae/acre
Site preparation and rehabilitation												
Aerial application	1,500	40,600	2-3	200,000	585,700	2-4	20	4,400	2-3	29,142	57,184	2-4
Broadcast ground	1,200	5,400	3-4	131,050	336,500	2-4	0	800	2	1,369	3,670	3-4
Individual stem	30,000	89,400	1-3	19,300	65,100	4-6	0	0	2	489	3,746	2-3
Total	32,700	135,400	—	350,350	987,300	—	20	5,200		31,000	64,600	—
Release and TSI												
Aerial application	0	32,200	1-2	414,000	1,008,600	2	220	13,400	1-2	231,872	500,330	2
Broadcast ground	1,650	9,300	2	17,000	42,600	2-4	0	2,400	2	9,519	21,126	2
Individual stem	62,200	256,500	¼-2	8,250	31,900	2-6	0	0	1-2	4,609	15,844	1-3
Total	63,850	298,000	—	439,250	1,083,100	—	220	15,800		246,000	537,300	—
Fuel breaks												
Aerial application	0	0	—	0	0	—	0	0	—	0	6,000	2-4
Broadcast ground	200	700	2	0	0	—	0	0	—	800	3,700	2-4
Individual stem	0	10	2	0	0	—	0	0	—	70	400	4
Total	200	710	—	0	0	—	0	0	—	870	10,100	—
All purposes												
Aerial applicaiton	1,500	72,800	—	614,000	1,594,300	—	240	17,800	—	261,014	563,514	—
Broadcast ground	3,050	15,400	—	148,050	379,100	—	0	3,200	—	11,688	28,496	—
Individual stem	92,200	345,910	—	27,550	97,000	—	0	0	—	5,168	19,990	—
Total	96,750	434,110	—	789,600	2,070,400	—	240	21,000	—	277,870	612,000	—

a/ ae = acid equivalent

In the South, combined estimates from all ownerships suggest that only 0.4 percent (789,600 acres) of all commercial forest lands, mostly southern pine types, would be treated annually (table 11). Aerial sprays would be used on 78 percent, broadcast ground sprays on 19 percent, and individual stem treatments on 3 percent of the treated area.

The apparent need for 2,4,5-T is moderate in the Rocky Mountain section, about 0.03 percent (240 acres) of the total commercial forest would potentially be treated per year (table 11). Most of this would be used in the northern Rocky Mountains--Montana and northern Idaho. Because of the rugged terrain and remoteness and size of units, aerial spraying would be necessary for effective applications of 2,4,5-T, accounting for 85 percent of all treatments.

Like the South, the need for 2,4,5-T is great in the Pacific Coast section, because of the aggressive nature of the competing woody vegetation, the susceptibility of this vegetation to 2,4,5-T, and the relative resistance of the conifers, especially pines, to this herbicide. Estimates from table 11 indicate that about 0.4 percent (277,870 acres) per year of the forest land would be treated. Again, aerial spraying is important because of remoteness of units and mountainous terrain. Aerial application would be used on 94 percent of all treated areas.

Nationally, only 0.2 percent or 1.16 million acres of all commercial forest land (0.15 percent of the total 754 million acres classified as forest lands) is treated per year with 2,4,5-T applied alone or in combination with other herbicides. Most of this use is in the South and Pacific Coast sections. The most important use of 2,4,5-T on all ownerships is for release and TSI (749,300 acres per year), mostly of conifer plantations, followed by site preparation (414,100 acres per year).

The importance of individual application methods varies from section to section as a result of differences in treatment objectives, terrain, size of treated units, and access. Broadcast ground sprays with mistblowers and individual stem treatments with backpack sprayers and tree injectors are more useful on the gentle topography characteristic of much of the North and South. In contrast, aerial sprays are more common in the mountainous western United States where rugged terrain, large units, and remoteness of sites to be treated limit use of other application methods (fig. 25). Broadcast aerial and ground sprays are commonly used for site preparation, rehabilitation, and release, while individual stem treatments are preferred for precommercial thinning and TSI.

ALTERNATIVES TO 2,4,5-T--LIMITATIONS AND COSTS

The Forest Service survey of vegetation-management practices shows that a wide variety of techniques are commonly used. The relative importance of each technique varies by section and treatment purpose (table 12). A small, but significant, part of the total vegetation-management program on forest lands presently uses 2,4,5-T. Values in table 12 are derived from only a small sample and cannot be used to estimate acres treated by each method. They are provided merely to indicate that all available vegetation control methods are presently in use and that use of 2,4,5-T does not predominate.

The most intensive vegetation-management practices are used in the early stages of stand establishment (rehabilitation and site preparation) and development (release). During this critical time, small trees are vulnerable to damage, reduced growth, or mortality resulting from weed competition. These impacts may significantly reduce yields at harvest because they increase the length of time trees are exposed to damage from animals, reduce stand productivity, and reduce stocking levels below those needed for optimum stand management. Costs of treatment are also critical during these initial stages because they will be compounded for the longest period of time. The herbicide 2,4,5-T has its greatest impact during the first 10 years after harvest.

Costs of various stand establishment and young stand management practices on Federal and industrial lands are shown in table 13. Because local

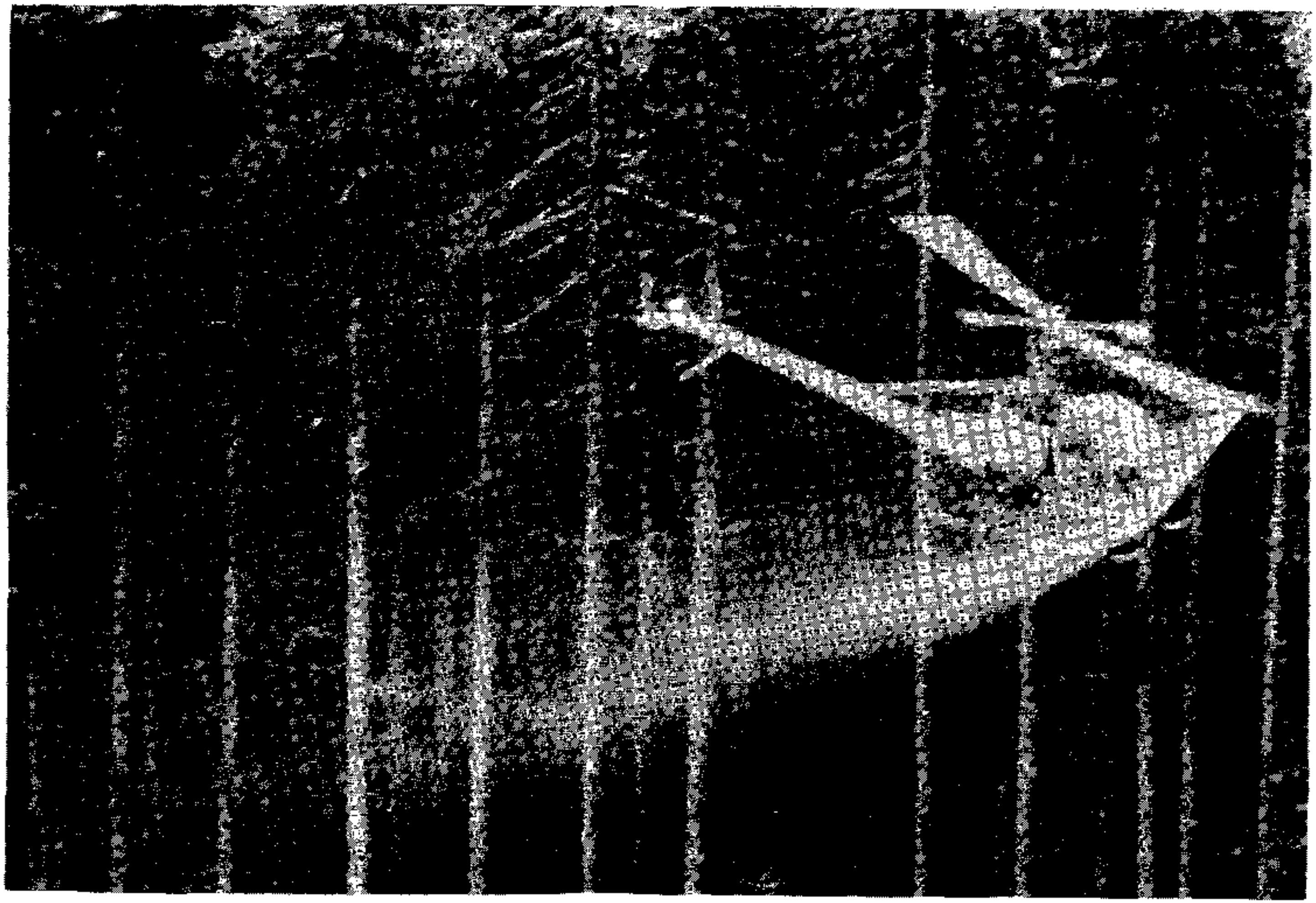


Figure 25. Aerial sprays are best for herbicide application in the mountainous terrain of the western United States.

Table 12--Estimated proportion of use of vegetation management methods on forest lands by section and purpose

Purpose and method	Proportion of use by section			
	North a/	South a/	Rocky Mountains a/	Pacific Coast b/
	percent			
Site preparation				
2,4,5-T	0.5	5	0	6
Other herbicides	2	5	0.2	4
Mechanical	26	28	45	24
Manual	65	1	20	4
Fire	6	9	35	32
Combination	-- c/	53	--	30
Rehabilitation				
2,4,5-T	--	41	--	10
Other herbicides	--	48	--	12
Mechanical	--	9	--	62
Manual	--	--	--	2
Fire	--	0.4	--	13
Combination	--	1	--	1
Release and TSI				
2,4,5-T	6	20	0.1	49
Other herbicides	33	14	0.5	14
Mechanical	0	0.4	0	trace
Manual	61	0.1	99	37
Fire	0	65	0	0
Combination	0	0	0	0

a/ Based on a sample of National Forest lands.

b/ Based on a sample of National Forest and industrial forest lands.

c/ Use not reported.

Table 13--Cost of various stand establishment and young stand management practices on Federal (USDA, Forest Service) and industrial forest lands by section

Purpose and method	North	South		Rocky Mountains	Pacific Coast	
	Federal	Federal	Industrial	Federal	Federal	Industrial
	$/acre					
Hazard reduction						
Broadcast burn	-	-	-	5-71	100-455	-
Machine pile and burn	-	-	-	35-80	160-150	-
Jackpot burn	-	-	-	25-45	35-50	-
Site preparation						
Broadcast burn	14	3	-	15-71	-	-
Disc	50	40	-	83	45-70	-
Shear and windrow	-	90	-	90-110	60-125	-
Broadcast spray aerial	32	20	25-	16	39-60	10-75
Broadcast spray ground		32	35	-	79-125	
Tree injection	62	50	-	-	42	-
Felling	162	150	-	48	200	100-1200
Mechanical and herbicide	-	-	50-100	-	120	50-150
Planting						
Manual	133	60	25-	118-190	70-158	50-
Machine	-	45	50	118	85	195

continued

Table 13--Cost of various stand establishment and young stand management practices on Federal (USDA, Forest Service) and industrial forest lands by section (continued)

Purpose and method	North	South		Rocky Mountains	Pacific Coast	
	Federal	Federal	Industrial	Federal	Federal	Industrial
	$/acre					
Release						
Broadcast spray aerial	32	20	10-	15-20	26-60	10-75
Broadcast spray ground		32	75	-	90-153	
Tree injection	62	50	-	-	42	-
Manual	162	150	-	4-18	135-618	100-1200
TSI						
Manual	-	11-60	-	60-122	60-122	100-1200
Injection	-	50	10-75	60	60-100	10-75
Animal damage control						
Caging	-	-	-	-	130-180	-
Fencing	-	40	-	10-15	-	-
Baiting	-	-	-	35	16	-

site conditions affect work productivity, costs for some practices are best expressed as ranges. Treatments using other herbicides generally cost the same to apply, but may involve more expensive chemicals or require additional treatments. Where other herbicides are equally effective, costs may be nearly the same with and without 2,4,5-T. Chemical costs of various broadcast sprays at average application rates based on 1976 prices are:

	Rate	Chemical cost	
	gallons/acre	$/gallon	$/acre
2,4,5-T	1/2	17.00	8.50
2,4-D	3/4	8.00	6.00
amitrole-T	1	13.00	13.00
dicamba + 2,4-D	1 1/2	13.00	19.50
fosamine ammonium	1	32.00	32.00
glyphosate	1/2	60.00	30.00
picloram + 2,4-D	2	17.50	35.00
silvex	3/4	18.00	13.50

The chemical cost difference varies from $2.50 per acre less for 2,4-D to $26.50 more per acre for picloram plus 2,4-D. In some situations, however, as much as a three-fold increase in total cost may be necessary to achieve equivalent effectiveness. Further it may not be possible to always obtain equivalent control because of differences in the spectrum of species controlled between 2,4,5-T and substitute herbicides.

Acceptable weed-control practices and probable substitutes for 2,4,5-T vary locally because of differences in forest types, topography, availability of alternatives, and other factors. Therefore, local practices and substitutes are discussed briefly below for the North, South, Rocky Mountain, and Pacific Coast sections.

NORTH

The herbicide 2,4,5-T is used in the North section primarily for release of pine, spruce, and fir from hickory, maple, oak, cherry, birch, aspen, and raspberry. In the Lake States, most of the present use is for control of maple, oak, and raspberry during conversion of jack pine, aspen, and low value hardwood stands to red pine. Conifer types presently occur on 34.2 million acres in the North (table 1). Phenoxy herbicides are also used to control residual overstory hardwoods following harvesting in the aspen-birch type. The present controversy in the Lake States concerning 2,4,5-T has severely restricted its current use, although the actual need is great.

Much of the North section, with the exception of the Appalachian Mountains, has relatively gentle topography that is suitable for equipment operation. Based on Forest Service use patterns, 91 percent of all site preparation is accomplished by mechanical or manual means (table 12). Mechanical site preparation is accomplished with root rakes or shearing blades that remove slash and unmerchantable trees and prepare seed beds for either seeding or planting. Logging slash and debris may either be left in place in windrows or piled and burned for disposal. Handfelling, girdling, and prescribed burning have also been used for site preparation in both hardwood and conifer stands. Some increase in both machine clearing and hand-felling as well as foliage spray of 2,4-D and glyphosate (if registered), would most likely replace the small present use of 2,4,5-T.

Phenoxy herbicides are most useful to release conifers from hardwoods; they are not commonly used for release of hardwoods. The spruce-fir and white-red-jack pine types in the Lake States and Northeast covered only about 28 percent of all commercial forest lands in 1970. This situation and existing restrictions on use of 2,4,5-T account for the low present use of herbicides for release in the North. Only 6 percent of all tree release and TSI was accomplished using 2,4,5-T; 33 percent was done with other herbicides, mostly 2,4-D (table 12). About 61 percent of all release and TSI was accomplished manually, including hardwood stands and other types where suitable herbicides were not available. In the absence of controversy, however, many of the stands treated manually would have been sprayed with 2,4,5-T.

A foliar spray containing 2,4-D is considered the best alternative to 2,4,5-T for release in the spruce-fir and white-red-jack pine types. Both 2,4-D and manual treatments are only about 25 to 35 percent as effective as 2,4,5-T for those situations where 2,4,5-T is used. Three or four treatments might be required to maintain yields at a total cost of $75 to $100 per acre for 2,4-D or $150 to $1000 per acre for manual cutting. Some increase use of silvex and injection treatments of Tordon 101 may also occur to control maples and certain other species.

The limited use of 2,4,5-T for timber-stand improvement, including precommercial thinning, could be readily replaced by other herbicides or manual cutting. Herbicides that might be used include 2,4-D, picloram plus 2,4-D (Tordon 101R), MSMA, or cacodylic acid; these would be applied as individual stem treatments using tree injectors or axes.

Hand cutting presently accounts for most TSI treatments, or about 88 percent based on Forest Service estimates. 2,4,5-T is used where resprouting species resistant to 2,4-D are a problem; therefore, only a slight increase in manual treatments would be expected.

The estimated proportion of replacement of various alternatives to 2,4,5-T is shown in table 14 for site preparation and in table 15 for release.

SOUTH

Much of the forest land in the South section is on gentle terrain suitable for mechanical treatments. In fact, 28 percent of all site preparation is accomplished using mechanical methods alone and 53 percent is accomplished using a combination of mechanical clearing and burning, based on Forest Service and forest industry data (table 12).

Table 14--Alternatives to 2,4,5-T for site preparation in the North section

Alternative	Application rate	No. of applications	Proportion of acres treated
	lb/ae/A		
2,4-D	3	1	0.10
silvex	b/	-	-
2,4-DP	-	-	-
glyphosate a/	1.5	1	0.30
fosamine ammonium	-	-	-
amitrole-T	-	-	-
silvex & 2,4-D	-	-	-
picloram & 2,4-D	1 gal	1	0.25
dicamba & 2,4-D	-	-	-
mechanical	-	1	0.05
prescribed fire	-	-	-
mechanical & fire	-	-	-
mechanical & herbicide	-	-	-
fire & herbicide	-	-	-
manual cutting	-	-	-
none	-	-	0.20

a/ Experimental use permit only.

b/ Not effective.

Table 15--Alternatives to 2,4,5-T for release in the North section

Alternative	Application rate	No. of applications	Proportion of acres treated
	lb/ae/A		
2,4-D	2	2	0.60
silvex	3	1	0.05
2,4-DP	b/	-	-
glyphosate a/	-	-	-
fosamine ammonium a/	-	-	-
amitrole-T	-	-	-
silvex & 2,4-D	-	-	-
picloram & 2,4-D	-	-	0.10
dicamba & 2,4-D	-	-	-
mechanical	-	-	-
prescribed fire	-	-	-
mechanical & fire	-	-	-
mechanical & herbicide	-	-	-
fire & herbicde	-	-	-
manual cutting	-	2	0.05
none	-	-	0.10

a/ Some question of selectivity.

b/ Not effective.

Rolling drum choppers, shearing blades, root rake blades, disking and Le Tourneau Tree Crushers are used to eliminate residual hardwoods on pine sites. Special measures to reduce erosion hazards, such as seeding grasses or leaving untreated strips along contours, may be used on slopes above 15 to 20 percent. Logging slash and brush are windrowed to permit machine planting. Bedding is used on sites with high water tables in the lower Gulf Coastal Plain; drum choppers or shearing and windrowing are also used on wet soils along the Atlantic Coastal Plain.

The herbicide 2,4,5-T is not used on bottom-land hardwood types. Its principal uses are as a foliar spray for site preparation and release in southern pine types and for conversion of oak-pine and oak-hickory types to pine (Peavey and Brady 1972). An estimated 5 percent of all site preparation in the South is accomplished with 2,4,5-T used alone (table 12). An additional 4 percent is accomplished using 2,4,5-T in combination with burning. Forest industry use of 2,4,5-T is considerably greater than use by federal agencies because of the higher intensity of management. Ten percent of all site preparation on industrial lands involves 2,4,5-T used alone or combined with fire. Tordon 101^{R} (picloram plus 2,4-D) can be used in place of 2,4,5-T with equivalent or better effect for site preparation but not for release.

About 20 percent of all release and TSI is conducted with 2,4,5-T (table 12) which accounts for 56 percent of all 2,4,5-T use in southern forests. Again, industrial forest lands show a greater use. Broadcast applications of either 2,4-D or silvex would damage the pine. Hence, manual cutting or injection with 2,4-D or Tordon 101^{R} are the only substitutes for release of pines.

Tordon 101^{R} at 1 gallon per acre ($32 per acre) or chopping ($40 per acre) or shearing ($55 per acre), often combined with windrowing ($35 per acre) and burning ($3 per acre) would likely be substituted for 2,4,5-T for site preparation in the loblolly, shortleaf, and longleaf-slash pine types. At least one manual release at $150 per acre would be needed to release the pines on most sites.

Tordon 101[R] at 1 gallon per acre ($32 per acre) or chopping and burning ($43 per acre) or shearing and windrowing ($90 per acre) might also be used to convert oak-pine and oak-hickory to southern pines. One manual release at $150 per acre would again be needed on most sites.

The estimated proportion of replacement of various alternatives for 2,4,5-T is shown in table 16 for site preparation and table 17 for release.

ROCKY MOUNTAIN

Historically, forest management intensity in the Rocky Mountains, outside of the northern Rocky Mountain region, has been less than elsewhere in the United States. Generally lower growth rates and timber values have not been conducive to investments in forest management. With recent increases in stumpage values, this situation is rapidly changing. Forest Service data suggest that very little 2,4,5-T is presently used, largely as a result of local moratoriums preventing use. As management intensity increases in young stands, however, the need will increase, especially in the northern Rocky Mountains where brush species are common on conifer sites. This will be most important in National Forests because the National Forest Management Act of 1976 requires satisfactory reforestation within 5 years after harvest. Failure to meet these requirements will require reduction in harvests.

Most sites in the Rocky Mountain section are prepared mechanically or by prescribed burning. As the more accessible areas on gentle terrain are logged, the use of fire likely will become more important. Control of grasses and forbs on drier sites using herbicides such as dalapon will also be necessary to insure prompt regeneration. Roller choppers, root rakes, shearing blades, discs, and various shredding and masticating devises are used on gentle slopes to crush or clear and windrow logging slash and vegetation (Gutzwiler 1976). Strip and spot clearing have also been used successfully.

Table 16--Alternatives to 2,4,5-T for site preparation in the South section

Alternative	Application rate	No. of applications	Proportion of acres treated
	lb/ae/A		
2,4-D	3	1	0.10
silvex	a/	-	-
2,4-DP	-	-	-
glyphosate	-	-	-
fosamine ammonium	-	-	-
amitrole-T	-	-	-
silvex & 2,4-D	-	-	-
picloram & 2,4-D	1 gal	1	0.40
dicamba & 2,4-D	-	-	-
mechanical	-	1	0.40
prescribed fire	-	-	-
mechanical & fire	-	-	-
mechanical & herbicide	-	-	-
fire & herbicide	-	-	-
manual cutting	-	-	-
none	-	-	0.10

a/ Not effective.

Table 17--Alternatives to 2,4,5-T for release in the South section

Alternative	Application rate	No. of applications	Proportion of acres treated
	lb/ae/A		
2,4-D	2	1	0.10
silvex	a/	-	-
2,4-DP	-	-	-
glyphosate	-	-	-
fosamine ammonium	-	-	-
amitrole-T	-	-	-
silvex & 2,4-D	-	-	-
picloram & 2,4-D	-	-	0.20
dicamba & 2,4-D	-	-	-
mechanical	-	-	-
prescribed fire	-	-	-
mechanical & fire	-	-	-
mechanical & herbicide	-	-	-
fire & herbicide	-	-	-
manual cutting	-	1	0.05
none	-	-	0.65

a/ Not effective.

Rehabilitation of old burns and reforestation failures may require considerable use of herbicides as a preparatory measure prior to mechanical clearing or burning. About 15.5 million acres are presently dominated by weeds (table 9). Where evergreen or mixed evergreen-deciduous brushfields occur, 2,4,5-T will be the herbicide chosen. Substitutes such as 2,4-D and silvex could be used with less effectiveness, thereby requiring higher application rates or more frequent treatment. New herbicides, such as fosamine and glyphosate, if registered, would be ineffective in these situations (Gratkowski et al. 1978).

The present level of management is reflected in the present acreage treated; only 240 acres were treated with 2,4,5-T in the entire Rocky Mountain section (table 11). Further, few herbicides have been specifically tested and developed here. The most important vegetation management programs are precommercial thinning and timber stand improvement in young well-stocked stands. Virtually all of this is accomplished manually (table 12).

PACIFIC COAST

As in the South, forest management is more intensive in the Pacific Coast section than in the North or Rocky Mountains. Based on Forest Service and forest industry use, all available vegetation-control practices are used where appropriate. Similar to other areas of the United States. The dominance of mechanical, fire, and combinations of mechanical and either herbicides or fire for site preparation and rehabilitation (table 12) reflects the need for more drastic disturbance to establish trees than for other purposes. Root rakes, dozer blades, shearing blades, and rolling choppers are commonly used to windrow or crush slash and brush on new cuttings and in existing brushfields. Clearing with root rakes has proven especially useful in rehabiliation of brushfields in southwestern Oregon (Gratkowski 1961c, Gratkowski and Anderson 1968), in the Coast Ranges and Cascade foothills of Oregon and Washington (Dimock et al. 1976), and in northern California. About 33 percent of all combination treatments on industrial forest lands use 2,4,5-T. Additional use of mechanical equipment, including its use in place of 2,4,5-T, is largely limited by lack of suitable terrain in the Pacific Coast section.

Because many of the more accessible areas on gentle topography have already been logged or rehabilitated, other methods will be needed to replace mechanical crushing and clearing for site preparation in the future. The most likely substitutes will be broadcast burning and herbicides. In established brushfields or on new cuttings dominated by residual vegetation, the area may be aerially-sprayed first to prepare the site for burning (Bentley et al. 1971b, Bentley and Graham 1976, Gratkowski and Philbrick 1965, Stewart 1978b). For desiccation alone, contact herbicides, such as dinoseb, are used. For longer term control of resprouting, 2,4,5-T or a combination of 2,4-D and 2,4,5-T are most effective. A combination of picloram plus either 2,4-D (Tordon 101) or 2,4,5-T (Tordon 155) has promise for control of deciduous coastal brush species. Unfortunately, strict state and Federal air-quality standards already limit the use of fire as a silvicultural tool. To meet future restrictions, reductions in acreage burned, modified burning practices, or increased use of herbicides may be needed.

In Oregon and Washington the most likely substitutes for 2,4,5-T for site preparation and rehabilitation in evergreen brush types in order of preference are: 2,4-D broadcast spray and Tordon 101 individual stem treatment, mechanical clearing with a root rake blade on gentle slopes, broadcast burning, and hand cutting. Estimated costs for equivalent effects are $100 to $130 per acre for repeated spraying, $150 per acre for mechanical clearing, $40 per acre for burning, and up to $1,600 per acre for four or five hand-clearing operations. In California, mechanical clearing ($120 per acre), broadcast burning ($100 per acre), broadcast spray with 2,4-D ($50 per acre), or hand cutting ($750 per acre) in that order, might be used to prepare sites for Douglas-fir. For the fir-spruce and ponderosa pine types, clearing followed by spraying with 2,4-D, burning, and hand clearing or grazing might be used to replace 2,4,5-T on Federal lands. Mechanical clearing, broadcast burning, broadcast spray with 2,4-D, or hand clearing would likely be used to replace 2,4,5-T for rehabilitation. Estimated cost for manual treatments would be much higher (up to $1,200 per acre) in mature brushfields.

For site preparation and rehabilitation in deciduous coastal brush species of Oregon and Washington, forest managers would probably select broadcast burning ($50 per acre); broadcast spraying with 2,4-D, picloram plus 2,4-D, amitrole-T, dicamba plus 2,4-D, glyphosate, or fosamine ammonium ($30 to $240 per acre); mechanical clearing with a root rake on slopes less than 35 percent or high-lead scarification (Stewart 1978 Ward and Russell 1975) on steeper slopes ($150 to $300 per acre); or hand clearing ($750 per acre).

As in other parts of the United States, the most extensive use of herbicides in the Pacific Coast section is for release. About 98 percent of all acres released (53 percent of acres treated for both release and TSI) was treated with herbicides, 78 percent with 2,4,5-T; the remainder was treated with other herbicides, usually 2,4-D or silvex (table 12). Available substitutes for releasing western conifers are limited in number. Acres reported treated on Federal lands in table 11 include 5,730 acres treated with silvex alone or in combination with 2,4-D for site preparation and 7,220 acres treated for release. In this case, it was used as a substitute for 2,4,5-T and resulted in less-effective brush control and greater damage to conifers. Two or more sprays of 2,4-D could be used to release Douglas-firs from evergreen brush species, and 2,4-D, glyphosate, or fosamine ammonium (in Oregon and Washington only) could be used to control deciduous brush. One or more applications of 2,4-D in a water carrier could also be used to release pines with less effectiveness on many brush species and a greater chance of injury to the pines (Gratkowski 1978). Mechanical brush cutters ($250 per acre) might be used on gentle terrain where crop trees may be seen by the operator. More commonly, three or more manual treatments ($800 to $1,600 per acre) would be used to release all species of conifers from evergreen or deciduous brush.

Only an estimated 4 percent of all precommercial thinning and TSI operations presently use 2,4,5-T. Because of its effectiveness, visual control of the end result, and selectivity, hand cutting is used on 91 percent. Other chemicals including cacodylic acid, MSMA, and picloram plus 2,4-D (Tordon 101) account for 5 percent of the pre-commercial thinning and TSI. Loss of 2,4,5-T will result in an increased use of manual treatments and a smaller increase in use of other herbicides, including the other chemicals mentioned above.

A total of 7,603 acres was treated to create or maintain fuel breaks between July 1, 1975 and September 30, 1976. Most were in the chaparral type near housing developments and other improvements in southern California. Herbicides are a valuable tool for rapidly establishing fuel breaks in mountainous terrain (Green 1977a and 1977b). Plants which produce fuels of low flammability are usually established in the treated strips to prevent or retard establishment of shrubs and trees which produce fuels of greater flammability (Nord and Green 1977). Spot or broadcast treatments with phenoxy herbicides may be used to remove undesirable species that successfully invade these areas. A combination of repeated 2,4-D or 2,4-DP applications, mechanical clearing, and hand cutting would most likely replace present use of 2,4,5-T.

The estimated substitution of various other methods for use of 2,4,5-T is shown in table 18 for site preparation and table 19 for release.

SUMMARY OF ALTERNATIVES

The major advantages and limitations of alternatives to 2,4,5-T are summarized in table 20. The major limitations to increased use of mechanical equipment in the North and South sections where terrain is more gentle are likelihood of soil disturbance and lack of selectivity. In the Rocky Mountains and Pacific Coast sections, mountainous terrain is an additional limitation. Prescribed burning is restricted in most areas of the United States by stringent air-quality standards and the narrow range of fuel moisture and weather conditions needed to obtain

Table 18--Alternatives to 2,4,5-T for site preparation in the Pacific Coast section

Alternative	Application rate	No. of applications	Proportion of acres treated
	lb/ae/A		
2,4-D	3	2	0.05
silvex	b/	-	-
2,4-DP	-	-	-
glyphosate	1.5	1	0.35
fosamine ammonium	6	1	0.05
amitrole-T	2	1	0.01
silvex & 2,4-D	2 & 2	1	0.05
picloram & 2,4-D	2 gal	1	0.25
dicamba & 2,4-D	-	-	-
mechanical	-	1	0.05
prescribed fire	-	-	-
mechanical & fire	-	-	-
mechanical & herbicide	-	-	-
fire & herbicide a/	5	1	1.10
manual cutting	-	1	0.01
none	-	-	0.10

a/ Using dinitro.

b/ Not effective.

Table 19--Alternatives to 2,4,5-T for release in the Pacific Coast section

Alternative	Application rate	No. of applications	Proportion of acres treated
	lb/ae/A		
2,4-D	2	2	0.25
silvex	3	1	0.05
2,4-DP	b/	-	-
glyphosate a/	1.1	1	0.35
fosamine ammonium a/	3	1	0.05
amitrole-T	1.5	1	0.02
silvex & 2,4-D	-	-	-
picloram & 2,4-D	-	-	-
dicamba & 2,4-D	-	-	-
mechanical	-	-	-
prescribed fire	-	-	-
mechanical & fire	-	-	-
mechanical & herbicide	-	-	-
fire & herbicide	-	-	-
manual cutting	-	2	0.01
none	-	-	0.27

a/ Some question of selectivity.

b/ Not effective.

Table 20--Costs, advantages, and disadvantages of alternatives to 2,4,5-T

Purpose of treatment	Methods of treatment		Cost per acre	Advantages	Disadvantages
Site preparation and rehabilitation	Mechanical treatment		$40-125	Exposes mineral soil; can be used on acres with herbicide-resistant species; can reduce fire hazard.	Increases erosion hazard; may cause soil compaction and rutting; limited on steeper slopes; stimulates resprouting.
	Prescribed fire		$ 5-455	Reduces fire hazard; exposes mineral soil; relatively low cost per acre under many conditions; not limited by terrain; reduces cost of planting by removing brush	Increases erosion hazard; stimulates resprouting and germination of some brush species; restricted by weather; causes air pollution.
	Herbicide: Silvex 2,4-D, Dicamba Picloram Fosamine ammonium Flyphosate Combinations	Aerial spray Ground spray Hand injection	$10-75 $32-153 $42-62	Aerial spray: cover large acreages with small crew; relatively low cost per acre; not limited by terrain, low disturbance to soils and watersheds.	Aerial spray: restricted by weather; some species are resistant; often not effective in multi-layered stands; increases fire hazards; high equipment costs limit minimum project size; application timing is critical; herbicide drift and vaporization can damage no-target areas. Hand injection: limited on steeper slopes; limited by available laborers; application timing is critical; temporarily increases fire hazard.
	Hand tools		$40-1200	Can be used on areas with herbicide-resistant species; low energy use; can reduce unemployment.	Stimulates resprouting; increases fire hazard; limited on steeper slopes high cost per acre; hazardous to workers; lack of available manpower.
	Combination of methods: herbicide and burn		$50-150	Same as listed under herbicides and prescribed fire	Same as listed under herbicides and prescribed fire
	Mechanical and burn		$80-200	Same as for mechanical equipment	Same as for mechanical equipment plus restricted by weather and causes air pollution.
Release	Prescribed fire		$ 3-71	Reduces fire hazard; relatively low cost per acre under many conditions; not limited by terrain.	Only partially selective; suitable for only a few conifer species, restricted by weather; causes air pollution; increases erosion hazard.
	Herbicides: Silvex 2,4-D Amitrole-T	Aerial spray Ground spray	$10-75 $32-153	Aerial spray: cover large acreages with small crew: relatively low cost per acre; not limited by	Aerial spray: restricted by weather; some species are resistant; high equipment costs limits minimum project size;

continued

Table 20—Costs, advantages, and disadvantages of alternatives to 2,4,5-T (continued)

Purpose of treatment	Methods of treatment	Cost per acre	Advantages	Disadvantages
Release (continued)	MSMA (injection) Picloram (injection) Dicamba (injection) Fosamine ammonium Glyphosate Combinations	Hand injection $42-62 Hand-pellets and stump treatment... $70-90	terrain. Hand injection: selective treatment; low energy use; can reduce unemployment.	application timing is critical; increases fire hazard; herbicide drift and vaporization can damage nontarget areas. Hand injection: limited on steeper slopes; temporarily increases fire hazard; limited by available laborers; application timing is critical.
	Hand tools	$40-1200	Can be used on areas with herbicide-resistant species; low energy use; can reduce unemployment; selective treatment.	Stimulates resprouting; increases fire hazard; limited on steeper slopes; hazardous to workers; limited by available laborers.
Precommercial thinning and TSI	Herbicides: MSMA, 2,4-D, silvex, picloram	Hand injection... $10-75	Selective treatment; low energy use; can reduce unemployment	Hazardous to workers; limited on steeper slopes; limited by available laborers; application timing is critical; temporarily increases fire hazard.
	Mechanical equipment	$15-175	Can be used on areas with herbicide-resistant species.	Limited on steeper slopes; can increase erosion hazards; can increase compaction and rutting; not as selective as hand treatment; increases fire hazard.
	Hand tools	$11-1260	Selective treatment; low energy use; can reduce unemployment.	Hazardous to workers; limited on steeper slopes; limited by available laborers; increases fire hazard.

acceptable results. Other herbicides are limited by lack of effectiveness, increased cost, or lack of registration. Cost and availability of labor are major deterrents to increased use of hand cutting of brush, especially for site preparation and release. For example, at an average productivity of 1/2 acre per day and 200 working days per year, it would have required 12,000 people to manually cut brush on the estimated 1.2 million acres treated with 2,4,5-T annually for site preparation, rehabilitation, and release. This is in addition to the manpower requirements to treat 340,000 acres manually for precommercial thinning and TSI.

In summary, it is obvious that a wide variety of practices are available and in use for controlling competing vegetation on forest lands. Each practice has its own unique set of advantages and disadvantages. Prescriptions in forest management are site specific and most practices are now being used where use experience has proven them to be cost-effective and environmentally acceptable.

The herbicide 2,4,5-T can be used to rehabilitate existing brushfields; prepare planting sites on current cuttings dominated by residual vegetation; release conifers, especially pines, from competing vegetation; and remove individual hardwood and conifer trees for precommercial thinning and timber-stand improvement. By far, the most important use is for conifer release, although a significant acreage is treated for site preparation. Substitution of other practices such as mechanical clearing, prescribed burning, other herbicides, manual cutting, or biological and cultural control, will result in increased costs, reduced effectiveness, or increased erosion and other environmental impacts. Use of 2,4,5-T is often the preferred treatment because of its selectivity, short persistence, and broad range of effectiveness on major competing species when applied alone or when combined with 2,4-D for release of conifers, or with picloram, dicamba, or 2,4-D for site preparation. This is especially important because most communities of competing plants are composed of several species. Use of less effective herbicides or herbicides with a more narrow spectrum of control will result in a rapid resurgence of resistant vegetation necessitating more frequent retreatments to maintain dominance of desirable trees.

Because of their low cost, ability to control sprouting, suitability for all topographic conditions, and minimal impact on sites, other herbicides are the most likely substitutes for 2,4,5-T where this herbicide is presently used. Picloram for site preparation and 2,4-D for release are the most probable alternates. If results of additional tests warrant, and registration is obtained, fosamine ammonium, glyphosate, and triclopyr may replace some uses of 2,4,5-T, but at increased cost. Intensive mechanical site preparation will also be used wherever soils and terrain permit.

CHAPTER 1: PART 2

ECONOMIC IMPACTS FROM LOSS OF 2,4,5-T IN TIMBER PRODUCTION

An analysis of individual forest-management situations that presently or potentially use 2,4,5-T was conducted to estimate the impact of cancellation on users (forest landowners) and consumers. These impacts can be increased timber production costs and/or reduced forest productivity resulting in higher stumpage prices[5/] that are passed on to the consumer in the form of higher wood product prices. The stumpage value represents about 75 percent of the wood-product price (USDA, Forest Service 1974).

PROCEDURES

Developing Alternative Silvicultural Methods

Timber type groups in each section of the United States using 2,4,5-T for management or type conversion were identified by regional panels of silvicultural experts. These panels were composed of silviculturists representing different ownerships within each type group.[6/]

5/ The stumpage price is the amount paid to the timber owner for standing timber. It is calculated by substracting road building, harvesting, and transporation costs plus a profit margin from the amount paid for logs at the processing plant.

6/ Panel chairmen were: Robert Frank (USDA, Forest Service Northeastern Forest Experiment Station, Orono, ME) and John Benzie (USDA, Forest Service North Central Forest Experiment Station, Grand Rapids, MN) for the North section; William F. Mann, Jr. (USDA, Forest Service Southern Forest Experiment Station, Alexandria, LA) and Thomas Russell (USDA, Forest Service Southern Forest Experiment Station, Sewanee, TN) for the South section; Raymond Boyd (USDA, Forest Service Intermountain Forest and Range Experiment Station, Moscow, ID) for the Rocky Mountains; and Phil Weatherspoon (USDA, Forest Service Pacific Southwest Forest and Range Experiment Station, Redding, CA) and Walter Knapp (USDA, Forest Service Pacific Northwest Region, Portland, OR) for the Pacific Coast section.

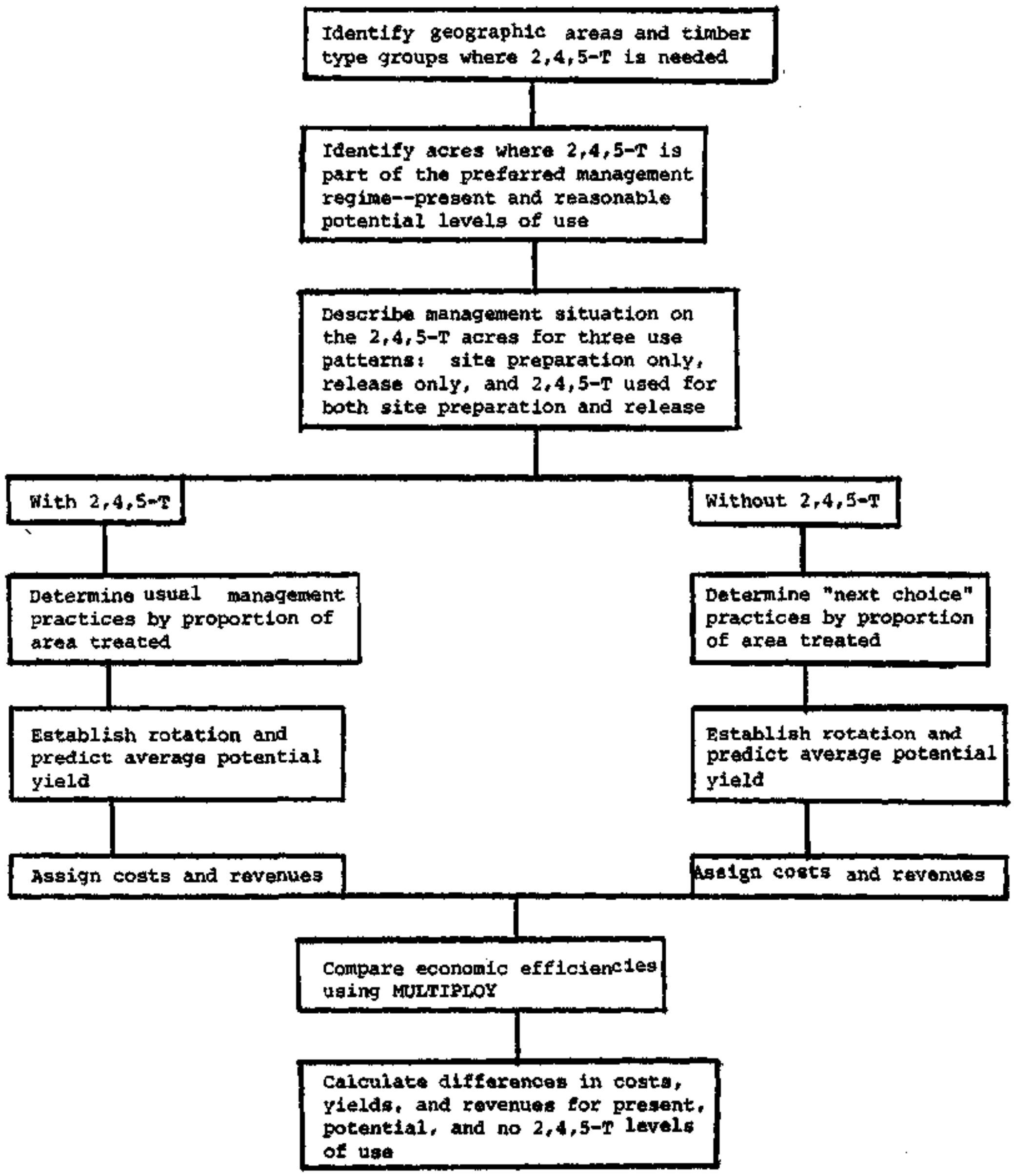


Figure 26. Diagram of procedures for developing management regimes, cost, and yield data for analysis of economic efficiency.

considered were those thought to be selected by most landowners consistent with landowner objectives, local availability, economic considerations, maintenance of site quality, and laws and regulations governing forestry activities. Again, the proportion of area treated by each silvicultural practice, including no treatment, was estimated for each step in the management sequence.

Regional average Forest Service and forest industry project costs from table 13 were assigned to individual practices. Costs of alternative herbicide treatments were determined by correcting the approporiate value in table 13 for the difference in chemical costs at the proper application rate. The proportions of use for each practice were then used to calculate weighted average costs for each step in the management sequence--site preparation, reforestation, etc.--as illustrated in table 21.

Finally, the panels developed harvest schedules and volumes for commercial thinnings and final harvest for each composite management regime. These were developed from several sources including yield tables for managed and unmanaged stands, stand growth simulation models, timber type management guides, and actual management experience. Yield impacts of alternative silvicultural prescriptions were estimated using results of studies comparing short-term effects of various practices on seedling survival and growth. Where such studies were not available, estimates were based on field experience, research in similar forest types, relative effectiveness of alternatives compared with 2,4,5-T, or a consensus opinion of the panel.

Determining Economic Efficiency

Economic efficiency of the alternative management regimes was analyzed by George Dutrow (USDA, Forest Service Southeastern Forest Experiment Station, Durham, NC) and Clark Row (USDA, Forest Service Forest Economics Research, Washington, D.C.) using MULTIPLOY (Row 1976), a computer-assisted economic analysis. Present net worth was calculated

Table 21—An example of a stylized silvicultural prescription used for the analysis of economic impacts

Practice	Cost (-) or income per unit	Number of units	Unit	Portion of area	Weighted averages	Year
	dollars				dollars	
Site preparation					-27	
Mechanical	-60	--	acre	0.3		1
Chemical	-30	--	acre	0.3		
Planting	-130	--	acre	1.0	-130	2
Animal control	-150	--	acre	0.6	-90	2
Release-chemical	-30	--	acre	0.8	-24	4
Precommercial thinning	-75	--	acre	0.7	-52	10
Commercial thinning	72	9.5	cunits	1.0	684	25
	92	17.9	cunits	1.0	1,647	35
	118	21.2	cunits	1.0	2,502	45
	151	20.6	cunits	1.0	3,111	55
	193	17.4	cunits	1.0	3,358	65
Harvest cut	247	105.6	cunits	1.0	26,083	75
Hazard reduction	-240	--	acre	1.0	-240	76

for the first rotation following cancellation of 2,4,5-T for a range of discount rates and assumptions concerning silvicultural costs, stumpage values, and timber yields. All discount rates and assumed increases in costs and revenues were related to real increases (in excess of inflation).

The primary analysis presented in this report was based on assumptions thought to best represent the situation during the first rotation following cancellation. Average project costs for each practice were assumed to increase only at the prevailing rate of inflation (a zero rate of real increase). Initial softwood stumpage prices were obtained from the draft timber assessment chapter of the USDA Forest Service 1980 Resource Planning Act (RPA) assessment.[7/] These values were determined by state panels of industry, government, and university foresters complemented by published state or regional timber price series. The prices were averaged for all softwood species and ownerships as shown in table 22.

The following product mixes or differential price assumptions were used to calculate stumpage values for thinnings and final harvests:

Northern conifer	<	40 year old, 100 percent pulpwood
	-	40-50 years old, 40 percent pulpwood and 60 percent sawtimber
	-	60 years old, 10 percent pulpwood and 90 percent sawtimber
Southern pines	<	30 years old, 100 percent pulpwood
	-	30 years old, 80 percent pulpwood and 20 percent sawtimber
	-	40 years old, 20 percent pulpwood, 60 percent sawtimber, and 20 percent veneer

7/ USDA Forest Service. Review draft of an assessment of the forest and range land situation in the United States. Chapter 6. Timber. USDA, Forest Service, Washington, D.C.

Table 22--Regional stumpage values for softwood pulpwood, sawtimber, and veneer in 1977 a/

Region	Pulp-wood	Saw-timber	Veneer
	-----------dollars per cubic foot-----------		
North	0.078	0.257	----
Northeast	0.060	0.233	----
Northcentral	0.096	0.281	----
South	0.128	0.610	0.765
Southeast	0.157	0.564	0.726
Southcentral	0.100	0.656	0.804
Rocky Mountains	0.047	0.417	----
Pacific Coast	----	0.932	----
Pacific Northwest	----	0.932	----
Pacific Southwest	----	0.932	----

a/ From USDA, Forest Service. Review draft of an assessment of the forest and range land situation in the United States. Chapter 6. Timber. USDA, Forest Service, Washington, D.C.

- 50 years old, 10 percent pulpwood, 60 percent sawtimber, and 30 percent veneer
- 60 years old, 5 percent pulpwood, 50 percent sawtimber, and 45 percent veneer

Rocky Mountain and Pacific Coast conifers - thinnings 75 percent of sawtimber stumpage

Douglas-fir stumpage prices rose 3 1/2 percent annually above inflation between 1910 and 1970 (USDA, Forest Service 1974). Similar trends have been predicted for all softwood timber prices during the next 50 years (Adams et al. 1979). Varying real price increases as predicted by the Adams model and shown in table 23 were used in the analysis.

The average yield for long-term investments has been about 10 percent over the last 10 years. The average rate of inflation was 5 to 6 percent for the same period. Therefore, a real discount rate of 4 percent was used for the primary analysis.

Additional analyses were conducted for the loblolly-shortleaf pine type in the South and the Douglas-fir type in northwestern Oregon and coastal Washington to compare different discount rates and cost, price, and yield levels. These analyses were used to test the sensitivity of differences in present net worth of management regimes with and without 2,4,5-T to the basic assumptions used in the primary analysis. Discount rates of 4, 6-7/8 (the present Water Resources Council recommended rate), and 10 percent; costs that were 70, 85, 115, and 130 percent of the values used in the primary analysis; and prices that were 60, 80, 120, and 140 percent of the values used in the primary analysis were evaluated.

Table 23--Relative softwood real price increases from 1977 to a future year a/

Region	1990	2000	2010	2020	2030
	percent per year				
Northeast	2.6	2.5	2.8	3.1	3.2
North Central	2.3	2.0	2.0	2.1	2.1
Southeast	5.0	4.2	3.7	3.4	3.1
Southcentral	5.2	4.1	3.7	3.3	3.1
Rocky Mountains	13.1	7.7	5.7	4.5	3.8
Pacific Northwest					
Westside	3.1	2.2	2.2	2.0	1.9
Eastside	4.8	3.3	2.9	2.3	2.0
Pacific Southwest	5.8	3.8	3.4	2.9	2.6

a/ Adams, Darius M. and Richard W. Haynes. A regionally disaggregated simulation model for estimating long-run timber demand-supply equilibrium. USDA, Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. (In press).

CALCULATING TOTAL IMPACTS

As indicated previously, canceling 2,4,5-T could result in increased timber growing costs and/or reduced forest growth. Most forests are managed to produce a continuous flow of timber and other benefits using an equal area or volume harvest to achieve a sustained yield of timber. Both the area and volume methods of forest regulation require balancing harvest and growth over the rotation. Therefore, changes in management practices that affect forest growth will result in concomitant changes in allowable harvests. Total differences in timber growing costs, annual productivity, and present net worth are useful measures of the importance of 2,4,5-T to forestry; present net worth is especially useful because it combines the effects of increased costs and reduced harvests. Methods for calculating these three indicators are described below.

Annual Impact on Timber Production Costs

An approximately equal number of acres would be harvested and would begin the silvicultural prescription schedule each year under the sustained yield-management concept assumed in this analysis. While no individual acre is treated with the entire schedule in any one year, every step is being applied somewhere throughout the management type each year. Therefore, the annual impact of losing 2,4,5-T, assuming fixed real costs, can be estimated from:

Annual impact on timber production costs (dollars/year)	=	(total silvicultural prescription cost with 2,4,5-T - total silvicultural prescription cost without 2,4,5-T) X (acres treated per year)

Impacts were calculated for each timber type group, 2,4,5-T use pattern (site preparation only, release only, and both site preparation and release), and use level (present and potential).

Annual Impact on Productivity

Productivity impacts on a given acre resulting from a change in silvicultural practice do not occur until that acre is scheduled for treatment and later harvested. Once the less effective practice is applied, the annual growth rate is reduced below that projected for the optimum practice. This reduced rate then continues throughout the remainder of the rotation. Assuming sustained yield management, an equal number of acres would be scheduled for this less effective treatment each year. Therefore, productivity impacts accumulate at equal annual increments throughout the first rotation following cancellation of 2,4,5-T, assuming sustained yield management. The impact the first year is estimated by:

Annual impact on on productivity (cubic feet/year) = (MAI with 2,4,5-T - MAI without 2,4,5-T) X (acres treated per year)

Where: MAI is the mean annual increment (total volume harvested/rotation age)

Since the impact accumulates, the total productivity loss "n" years after cancellation can be calculated from:

Total impact on productivity at year n (cubic feet/year) = (n) (annual impact)

The total loss would reach a maximum at the end of the first rotation (when n equals the rotation age) and stabilize at this level in succeeding rotations.

Productivity effects were calculated for each timber type group, 2,4,5-T use pattern, and use level included in the economic efficiency analysis. Assuming sustained yield management, reductions in productivity will result in equivalent changes in timber harvest. This adjustment could be made in equal annual accumulating amounts or the maximum reduction anticipated for the entire rotation could be applied immediately. The latter, called the allowable cut effect (ACE), is a matter of public policy and is followed on some industrial forest lands because of the long planning period required for most forest investment decisions. However, in this analysis, timber harvests were assumed to decline at a rate equivalent to the annual change in productivity.

Yield estimations for managed and unmanaged stands are the main source of error in this analysis. Few stands have been managed through an entire rotation and none have been managed for extensive periods employing alternative weed-control practices. Of necessity, estimates of harvest volumes were obtained from existing yield tables and growth models constructed from samples taken in stands of various ages subjected to treatments for varying periods of time. Impacts measured over relatively short intervals (5 to 20 years) in research studies or estimated from use experience were projected over the rotation using growth models or known relationships between stocking, growth of young stands, and mature stand development.

Initial Impact on Present Net Worth

Present net worth integrates the impacts of canceling 2,4,5-T on timber productivity and production costs, and discounts the costs and revenues to a common base. Although forest stands would be managed in perpetuity assuming a sustained yield policy, the economic analysis considered impacts only for the first rotation after cancellation. The initial change in present net worth is estimated from:

Initial change in present net worth (dollars/year)	=	(present net worth with 2,4,5-T - present net worth without 2,4,5-T) X (acres treated per year)

Thereafter, the present net worth changes due to the increases in stumpage values through time. Total accumulated effects on timber growing costs, productivity, lost stumpage income, and present net worth through the 1st, 5th, 10th and 50th year following cancellation were calculated for comparison. These time periods were arbitrarily selected as interim points of comparison in the 35 to 130 year rotation periods of the various timber types.

ECONOMIC IMPACTS BY SECTION AND TIMBER TYPE GROUP

North Section

Only 23 million acres (13 percent) of the 178 million acres of commercial forest lands in the North are in timber type groups where 2,4,5-T is not a preferred silvicultural practice for at least some conditions (table 24). 2,4,5-T is used on a portion of each timber type group occurring on the remaining 155 million acres. The estimated present and potential annual use pattern on these acres is:

	Annual area treated	
	Present	Potential
	acres	
Site preparation	16,900	57,000
Release	48,050	219,600
Site preparation and release	15,800	78,400

These figures represent the original number of acres subjected to the use patterns each year to prevent double-counting of areas receiving more than one treatment (the site preparation and release treatment). To convert the values in table 24 to the annual use shown in table 11, it is necessary to add two times the acres treated for both site preparation and release to the totals for the other two use patterns.

Management of the oak-gum-cypress and elm-ash-cottonwood type groups does not require use of 2,4,5-T. Use pattern and benefits of 2,4,5-T

Table 24--Estimated pattern of 2,4,5-T use in the North section by timber type group

Timber type group	Total commercial forest land	Management objective for 2,4,5-T acres	Annual area treated with 2,4,5-T by use pattern: Site preparation only, Present	Site preparation only, Potential	Release only, Present	Release only, Potential	Site preparation and release, Present	Site preparation and release, Potential
	million acres		acres					
White-red-jack pine	11.910	Conversion	1,000	3,000	3,500	24,400	1,500	10,000
Spruce-fir	18.899	Type management	2,000	13,000	6,500	107,000	500	30,000
Loblolly-shortleaf pine	3.422	Type management	8,500	23,900	13,600	25,600	10,200	25,600
Oak-pine	4.085	Conversion	3,300	13,200	4,000	19,800	2,000	9,900
Oak-hickory	55.536	Conversion	1,600	2,400	12,800	22,800	1,100	1,400
Oak-gum-cypress	1.361	None	—	—	—	—	—	—
Elm-ash-cottonwood	21.971	None	—	—	—	—	—	—
Maple-beech-birch	30.657	Type management	500	1,500	2,500	7,000	500	1,500
		Conversion	—	—	2,000	5,000	—	—
Aspen-birch	20.484	Conversion	—	—	3,000	7,000	—	—
Nonstock	9.571	Conversion	—	—	150	1,000	—	—

in management or type conversion of the oak-pine, maple-beech-birch, aspen-birch, and nonstocked type groups are described below. In addition, analyses of alternative-management regimes are discussed for the red-white-jack pine, spruce-fir, loblolly-shortleaf pine, and the oak-hickory type groups.

The oak-pine type is found on about 4.1 million acres in the North section mostly in the southern tier of states in this region. The herbicide 2,4,5-T is used to convert suitable sites from hardwood-dominated to southern pine-dominated stands. An estimated 3300 acres per year is treated with a foliar spray of 2,4,5-T for site preparation and 3900 acres for release. A potential of 13,200 acres for site preparation is projected because of the growing reliance on natural regeneration, forest industry acquisition of small private lands, and an increased interest in tree farming by the small private landowner. For the same reasons, the potential for release spraying with 2,4,5-T is expected to increase to 19,800 acres per year. Injection of hardwoods with 2,4-D or Tordon 101R and/or felling where conifer reproduction is present and perhaps use of a roller chopper where reproduction is absent would likely replace 2,4,5-T for site preparation, but fewer acres would be treated because of the greatly increased treatment costs. Tree injection and felling when hardwoods are at least 3 inches dbh (diameter at breast height) would also be used for release. The average productivity of oak-pine stands being converted is 40 cubic feet per acre per year compared with 80 cubic feet per acre per year for southern pines on the same sites. Thus, the 7200 acres per year converted to pines using 2,4,5-T increase the productive capacity of the North section by 288,000 cubic feet annually.

The herbicide 2,4,5-T is used for both type management and type conversion in the 30.9 million acre maple-beech-birch timber-type group. Broadcast ground foliar sprays of 2,4,5-T applied alone or with 2,4-D are used for site preparation to control maples and favor yellow birch, or to reduce the amount of beech and favor more desirable hardwoods. They are also used to discriminate against sprout growth and favor seedlings, except basswood. About 500 acres per year are presently treated for site preparation alone for natural seedling; potential use is about 1,500 acres. An additional 500 acres present and 1,500 acres potential are treated for both site preparation and release. Basal spraying to eliminate unwanted trees in young stands or unmerchantable trees in more mature stands is used on about 2,500 acres per year; potential use for release and TSI is about 7,000 acres.

About 3,000 acres per year of the maple-beech-birch type are being converted to conifer, usually white spruce or red pine, using 2,4,5-T to release the young plantations. The potential use for release is estimated to be about 5,000 acres per year. Ultimately, a total of 63,000 acres (0.2%) of the timber type group could be treated, mostly in the Lake States. Conversion to conifers is expected to increase mean annual increment from 50 to 114 cubic feet per acre. This represents an increase in production of 192,000 cubic feet each year of critically short softwood timber supplies at the present rate of conversion; about 4 million cubic feet per year will be added after conversion of the 63,000 acres using 2,4,5-T.

The aspen-birch type group occurs on 20.5 million acres of commercial softwood-forest lands in the North. About 3,000 acres per year are being converted to conifers, mostly red pine in the Lake States, using 2,4,5-T to release the plantations. Potential use for release of conifers is estimated to be about 7,000 acres per year. The herbicide 2,4,5-T would likely be recommended for conversion on a total of 142,000 acres (0.7%) of the aspen-birch type group. Conversion is expected to increase mean annual increment from 76 to 114 cubic feet per acre and add 114,000 cubic feet of softwood production annually at the present level of 2,4,5-T use. A total of 5.4 million cubic feet per year would be added by conversion of the 142,000 acres.

Nonstocked commercial forest land in the North section totals 9.6 million acres. It is estimated that only about 150 acres are treated with 2,4,5-T annually for release of conifers established on old fields or prepared sites. Estimated potential use for release is only about 1,000 acres per year. About 7,000 acres (0.1%) of the total nonstocked type group will be treated with 2,4,5-T for conversion. Establishment of conifers will likely increase mean annual increment from 0 to 114 cubic feet. Thus, 17,100 cubic feet are added each year to softwood timber production at the present level of 2,4,5-T use. Conversion of the 7,000 acres of nonstocked lands to conifers could add 789,000 cubic feet annually to the potential timber harvest.

Table 25 compares total silvicultural costs, productivity (MAI), and present net worth of management regimes with and without 2,4,5-T for the white-red-jack pine, spruce-fir, loblolly-shortleaf pine, and oak-hickory forest type groups. Potential use levels for all types, except the white-red-jack pine type, involved application of regimes that differed from those applied at the present level of use. Loss of 2,4,5-T, however, would likely result in substitution of the same practices for both use levels. Rotation ages considered in the analyses were: 90 years for the white-red-jack pine type, 70 years for the spruce-fir type, 35 years (industrial forest lands) and 60 years (public and small private lands) for the loblolly-shortleaf pine type, and 40 years (industrial forest lands) and 80 years (public and small private lands) for growing southern pines and northern conifers following conversion of the oak-hickory forest type group.

The initial impacts of canceling use of 2,4,5-T are summarized in table 26 by use level and use pattern for the four timber type groups analyzed. The values were obtained by multiplying the present or potential acres treated from table 24 by the appropriate difference in total silvicultural costs, productivity, and present net worth with and without 2,4,5-T from table 25. Totals for production cost, productivity, and present net worth were derived by algebraically summing quantities obtained for site preparation only, release only, and site preparation and release. Impacts vary by the measure used (costs, productivity, or present net worth) and use pattern as well as by timber-type group. For example, the loblolly-shortleaf pine type group

Table 25--Total silvicultural cost, productivity, and present net worth of stands managed with and without 2,4,5-T in the North section

Timber type group	Use pattern	Use level	Total silvicultural cost with 2,4,5-T	Total silvicultural cost without 2,4,5-T	Productivity with 2,4,5-T	Productivity without 2,4,5-T	Present net worth with 2,4,5-T	Present net worth without 2,4,5-T
			--dollars/acre--		--cubic feet/acre/year-		--dollars/acre--	
White-red-jack pine	Site preparation	Both	152	300	114	94	483	272
	Release	Both	194	300	114	94	414	272
	Site preparation and release	Both	168	300	114	94	471	272
Spruce-fir	Site preparation	Present	76	2	72	59	418	450
		Potential	117	2	86	59	442	450
	Release	Present	54	2	72	59	386	450
		Potential	102	2	86	59	561	499
	Site preparation and release	Present	109	2	72	59	580	450
		Potential	129	2	86	59	550	450
Loblolly-shortleaf pine (35 year rotation)	Site preparation	Present	70	106	75	80	779	805
		Potential	81	106	108	80	1,227	805
	Release	Present	74	76	80	60	864	696
		Potential	94	76	90	60	905	696
	Site preparation and release	Present	81	112	90	60	942	640
		Potential	64	112	100	60	1,107	640
(60 year rotation)	Site preparation	Present	70	106	75	80	1,138	1,374
		Potential	81	106	80	80	1,399	1,374
	Release	Present	74	76	80	60	1,415	1,088
		Potential	94	76	90	60	1,566	1,088
	Site preparation	Present	81	112	90	60	1,584	1,058
		Potential	64	112	100	60	1,794	1,058
Oak-hickory (40 year rotation)	Site preparation	Present	162	193	65	70	62	44
		Potential	161	193	65	70	23	44
	Release	Present	172	196	80	65	108	24
		Potential	172	196	80	65	108	24
	Site preparation and release	Present	137	196	75	68	133	34
		Potential	136	196	75	68	133	34
(80 year rotation)	Site preparation	Present	162	193	55	63	104	116
		Potential	161	193	55	63	73	116
	Release	Present	172	196	65	55	140	72
		Potential	172	196	65	55	140	72
	Site preparation and release	Present	137	196	60	60	151	92
		Potential	136	196	60	60	153	92

Table 26--Annual change in timber production cost, productivity, and present net worth following cancellation of 2,4,5-T in the North section

Timber type group	Use level	Site preparation only[a/] Production cost	Site preparation only[a/] Productivity	Site preparation only[a/] Present net worth	Release only[a/] Production cost	Release only[a/] Productivity	Release only[a/] Present net worth
		thousand dollars	thousand cu. ft.	thousand dollars	thousand dollars	thousand cu. ft.	thousand dollars
White red-jack pine	Present	148.0	-20.0	-211	371.0	-70.0	-497
	Potential	444.0	-60.0	-633	2,586.4	-488.0	-3,465
Spruce-fir	Present	-148.0	-26.0	64	-338.0	-84.5	416
	Potential	-1,495.0	-351.0	104	-10,700.0	-2,889.0	-11,877
Loblolly-short-leaf pine	Present	306.0	42.5	248	27.2	-272.0	-2,518
	Potential	597.5	-596.9	-9,061	-460.8	-768.0	-6,094
Oak-hickory	Present	49.6	8.5	-24	307.2	-185.1	-1,053
	Potential	76.8	12.8	56	547.2	-329.7	-1,876
All groups	Present	355.6	5.0	78	367.4	-611.6	-3,652
	Potential	-376.7	-995.1	-9,534	-8,027.2	-4,474.7	-23,312
		Site preparation and release[a/]			Total[a/]		
White red-jack pine	Present	198.0	-30.0	-298	717.0	-120.0	-1,006
	Potential	1,320.0	-200.0	-1,990	4,350.4	-748.0	-6,088
Spruce-fir	Present	-53.5	-6.5	-65	-539.5	-117.0	415
	Potential	-3,810.0	-810.0	-3,000	-16,005.0	-4,050.0	-14,773
Loblolly-short-leaf pine	Present	316.2	-306.0	-3,327	649.4	-535.5	-5,597
	Potential	1,228.8	-1,024.0	-12,699	-1,365.5	-2,388.9	-27,854
Oak hickory	Present	64.9	-6.9	-104	421.7	-183.5	-1,133
	Potential	84.0	-8.7	-133	708.0	-325.6	-1,952
All groups	Present	525.6	-349.4	-3,795	1,248.6	-956.0	-7,321
	Potential	-1,177.2	-2,042.7	-17,822	-9,581.1	-7,512.5	-50,667

a/ A positive number indicates an increase and a negative number a decrease in the value shown.

would have the highest increase in timber growing costs and the greatest reduction in productivity if 2,4,5-T were not available because of the high level of 2,4,5-T use at present in this type. Loss of 2,4,5-T would have major economic impacts for all use patterns at both the present and potential levels of use (table 26).

These four timber-type groups account for 79 percent of the present 2,4,5-T use in the section. Estimated impacts due to canceling the present uses of 2,4,5-T on management cost, timber growth, and present net worth are as follows:

End of year	Annual reduced timber growth	Cumulative		
		Increased management cost	Reduced timber harvest	Reduced present net worth
	million cu. ft.	million dollars	million cu. ft.	million dollars
1	1.1	1.2	1.1	7.3
5	4.8	6.0	13.7	37.4
10	9.6	12.0	50.2	72.2
50	38.9	60.0	1,125.7	238.7

Increased-management cost is estimated to be $1.2 million the first year without 2,4,5-T with a discounted cumulative increased-management cost of $60 million after 50 years. Annual management cost remains constant through the period of analysis because average project costs were assumed to increase only at the prevailing rate of inflation (a zero rate of real increase).

Reduced growth is estimated to be 1.1 million cubic feet per year the first year without 2,4,5-T and will continue to increase to an estimated 38.9 million cubic feet per year the 50th year. Cumulative reduced timber harvest resulting from the reduced timber growth is estimated to be 13.7 million cubic feet after five years and 1,126 million cubic feet after 50 years. Increased-management cost and reduced growth are components of total effect. These components may be combined by different methods. One method is calculation of present net worth of the growing timber. Thus, estimating present net worth in the North section results in an expected decrease of $7.3 million the first year without 2,4,5-T with a cumulative loss of $239 million after 50 years.

A second method is summing increased management costs and reduced stumpage income to estimate net income losses to timber growers. Reduced stumpage income is calculated from the product of the reduced harvest in a given year and the stumpage value in that year. Stumpage values were obtained from table 22 and inflated at the appropriate rate from table 23. Thus, assuming that reduced productivity would be reflected in reduced harvest under sustained yield management; adding cumulated reductions in stumpage incomes to cumulated increased management costs results in the following total impacts:

End of year	Cumulative increased management cost	Cumulative reduced stumpage income	Cumulative net income loss
	------------million dollars------------		
1	1.2	0.3	1.5
5	6.0	3.6	9.6
10	12.0	14.0	26.0

Land owners in the North section would have $1.2 million in increased-management costs and $0.3 million in reduced stumpage income for a net income loss of $1.5 million the first year after cancellation of 2,4,5-T uses at present levels. Cumulative net income losses are estimated to total $26 million at the end of 10 years. Impacts at potential use levels of 2,4,5-T would be much greater.

Of the 193 million acres of commercial forest lands in the South, 33 million acres (17 percent) are in timber-type groups not using 2,4,5-T for management (table 27). On the remaining 160 million acres, 2,4,5-T is used for type management or for conversion of selected low value hardwood stands to conifers. The estimated present and reasonable potential annual use pattern is:

	Annual area treated	
	Present	Potential
	--------acres--------	
Site preparation only	168,000	504,200
Release only	256,900	600,000
Site preparation and release	182,350	483,100

The management of the white-red-jack pine, spruce-fir, oak-gum-cypress, elm-ash-cottonwood, and maple-beech-birch forest-type groups either does not require applications of 2,4,5-T or such treatments are used only on limited acreage. Use patterns and benefits of use are described below for the longleaf-slash pine, oak-pine, and nonstocked type groups. Analyses of alternative management regimes with and without 2,4,5-T for the loblolly-shortleaf pine and oak-hickory types are also discussed.

Longleaf-slash pine stands occur on 18.3 million acres in a narrow belt along the Atlantic and Gulf Coastal Plains from North Carolina to East Texas and including all of Florida. Site preparation on the predominantly flat to gently rolling terrain is primarily by mechanical methods, fire, or a combination of the two. It is estimated that foliar applications of 2,4,5-T for site preparation are used on only 5,000 acres per year. Potential use, assuming higher stumpage prices or intensification of management on small private lands as a result of the federally funded Forestry Incentives Program (FIP) (Cooperative Forest Assistance Act of 1978), is estimated at 35,000 acres annually. Mechanical preparation or underplanting followed by tree injection for release are

Table 27--Estimated pattern of 2,4,5-T use in the South section by timber type group

Timber type group	Total commercial forest land	Management objective for 2,4,5-T acres	Annual area treated with 2,4,5-T by use pattern: Site preparation only		Release only		Site preparation and release	
			Present	Potential	Present	Potential	Present	Potential
	million acres		acres					
White-red-jack pine	0.257	None	—	—	—	—	—	—
Spruce-fir	0.013	None	—	—	—	—	—	—
Longleaf-slash pine	18.314	Type management	5,000	35,000	3,000	25,000	2,000	10,000
Loblolly-shortleaf pine	49,409	Type managmeent	123,000	345,800	197,600	370,600	148,200	370,600
Oak-pine	30,942	Conversion	25,000	100,000	30,000	150,000	15,000	75,000
Oak-hickory	56.324	Conversion	14,000	21,400	25,300	52,400	16,900	26,500
Oak-gum-cypress	29,268	None	—	—	—	—	—	—
Elm-ash-cottonwood	2.756	None	—	—	—	—	—	—
Maple-beech-birch	0.482	None	—	—	—	—	—	—
Nonstock	4.771	Conversion	500	2,000	1,000	2,000	250	1,000

likely substitutes for 2,4,5-T. Tree injection, using 2,4-D amine or Tordon 101[R], is the primary method of releasing pines. However, 2,4,5-T is presently the preferred method for release on 3,000 acres per year with a reasonable potential of 25,000 acres.

Oak-pine forests cover about 30.9 million acres in the South. An estimated 41 percent of the type has an adequate southern pine seed source, implying that most of those sites can be restored to high productivity by natural reseeding. An estimated 25,000 acres are treated annually by foliar spraying with 2,4,5-T for site preparation with a reasonable potential of 100,000 acres. As in the North, this increase of potential over present use is attributed to a growing reliance on natural reproduction, forest industry acquisition of small private lands, and an increased interest in tree farming by the small owner. Tree injection with 2,4-D amine or Tordon 101R, if hardwoods are large enough, or felling would likely replace 2,4,5-T where pine reproduction is present. A roller chopper might be used where reproduction is absent. Foliar spraying with 2,4,5-T for release is used on an estimated 30,000 acres per year with a potential of 150,000 acres. Felling or tree injection, if hardwoods are greater than 3 inches dbh, would likely replace 2,4,5-T for release. The average productivity of oak-pine stands converted to pine is 40 cubic feet per acre per year compared with 80 cubic feet per acre per year for managed pine stands. Thus, the 55,000 acres treated with 2,4,5-T annually for pine conversion add 2.2 million cubic feet per year to the productive capacity of the South.

There are 4.8 million acres of nonstocked and poorly stocked forest land in the South; almost 50 percent are heavily grazed lands with good timber-growing potential located in central Florida. Most of the nonstocked lands are believed to be upland pine sites because bottomland sites reproduce quickly. The major exceptions are bottomland sites abandoned after cultivation. Only about 1/4 million acres may be truly nonproductive, idle, and without a definite plan for reforestation.

Part is abandoned farm land and part is cutover pine land that has been taken over by brush. The herbicide 2,4,5-T is used on an estimated 500 acres per year for site preparation alone with a potential of about 2,000 acres. A total of 1,000 acres per year is treated for release of established southern pines with a potential use of 2,000 acres. For site preparation and release, present use of 2,4,5-T is estimated to be 250 acres per year with a reasonable potential of 1,000 acres. Broadcast burning, mechanical treatment, foliar spraying with Tordon 101, and combinations of these three would be the most common substitutes for 2,4,5-T used for site preparation. Injection with 2,4-D or Tordon 101 and hand felling would be used for release, but most situations requiring felling would remain untreated. Conversion of nonstocked and poorly stocked lands would increase mean annual increment from 25 to 55 cubic feet per acre per year. Thus, the use of 2,4,5-T on 1750 acres for converting nonstocked and poorly stocked lands in the South to southern pines results in 52,500 cubic feet more softwood production annually.

Table 28 compares total silvicultural cost, productivity, and present net worth of management regimes with and without 2,4,5-T for the loblolly-shortleaf pine and oak-hickory timber-type groups. Regimes developed for present and potential levels of use were different although the same practices would be used in both situations if 2,4,5-T were not available. Rotations of 35 years (industrial forest lands) and 60 years (public and small private lands) were analyzed for the loblolly-shortleaf pine type. Three situations were used to describe management of southern pines following conversion of the oak-hickory type: (1) a 35 year rotation with thinning (industrial forest lands where pulpwood markets are strong), (2) a 35 year rotation without thinning (industrial and other private lands where pulpwood markets are weak), and (3) a 60 year rotation (public and small private lands).

The impacts for the first year following cancellation of 2,4,5-T in the South are summarized in table 29 by use level and use pattern for both timber-type groups. The values were obtained from the estimated annual

Table 28—Total silvicultural cost, productivity, and present net worth of stands managed with and without 2,4,5-T in the South section

Timber type group	Use pattern	Use level	Total silvicultural cost: with 2,4,5-T	Total silvicultural cost: without 2,4,5-T	Productivity: with 2,4,5-T	Productivity: without 2,4,5-T	Present net worth: with 2,4,5-T	Present net worth: without 2,4,5-T
			—dollars/acre—		cubic —feet/acre/year—		—dollars/acre—	
Loblolly-shortleaf pine (35 year rotation)	Site preparation	Present	70	106	75	80	779	805
		Potential	81	106	108	80	1,227	805
	Release	Present	74	76	80	60	864	696
		Potential	94	76	90	60	905	696
	Site preparation and release	Present	81	112	90	60	942	640
		Potential	64	112	100	60	1,107	640
(60 year rotation)	Site preparation	Present	70	106	75	80	1,318	1,374
		Potential	81	106	80	80	1,399	1,374
	Release	Present	74	76	80	60	1,415	1,088
		Potential	94	76	90	60	1,566	1,088
	Site preparation and release	Present	81	112	90	60	1,584	1,058
		Potential	64	112	100	60	1,794	1,058
Oak-hickory								
(35 year with thinning)	Site preparation	Present	117	135	70	75	600	677
		Potential	116	135	70	75	661	677
	Release	Present	107	133	90	70	927	640
		Potential	111	133	90	70	921	640
	Site preparation and release	Present	96	138	85	80	870	744
		Potential	97	138	85	80	869	744
(35 year without thinning)	Site preparation	Present	117	135	70	75	844	888
		Potential	116	135	70	75	846	888
	Release	Present	107	133	90	70	1,138	824
		Potential	111	133	90	70	1,132	824
	Site preparation and release	Present	96	138	85	80	1,081	955
		Potential	97	138	85	80	1,080	955
Oak-hickory								
(60 year rotation)	Site preparation	Present	117	135	60	65	981	1,038
		Potential	116	135	60	65	982	1,038
	Release	Present	107	133	70	60	1,185	964
		Potential	111	133	70	60	1,181	964
	Site preparation and release	Present	96	138	68	60	1,162	947
		Potential	97	138	68	60	1,160	947

Table 29—Annual change in timber production cost, productivity, and present net worth following cancellation of 2,4,5-T in the South section

Timber type group	Use level	Site preparation only[a/] Production cost	Site preparation only[a/] Productivity	Site preparation only[a/] Present net worth	Release only[a/] Production cost	Release only[a/] Productivity	Release only[a/] Present net worth
		thousand dollars	thousand cu. ft.	thousand dollars	thousand dollars	thousand cu. ft.	thousand dollars
Loblolly-shortleaf pine	Present	4,446.0	617.5	3,545	395.2	-3,952.0	-36,030
	Potential	8,645.0	-8,812.2	-133,591	-6,670.8	-11,118.0	-86,416
Oak-hickory	Present	252.0	70.0	407	657.8	-480.7	-7,231
	Potential	406.6	107.0	539	1,152.8	-995.6	-14,530
All types	Present	4,698.0	687.5	3,952	1,053.0	-4,432.7	-43,260
	Potential	9,051.6	-8,705.2	-133,052	-5,518.0	-12,113.6	-100,947
		Site preparation and release[a/]			Total[a/]		
Loblolly-shortleaf pine	Present	4,594.2	-4,446.0	-47,751	9,435.4	-7,780.5	-80,236
	Potential	17,788.8	-14,824.0	-182,019	25,766.7	-34,754.2	-40,026
Oak-hickory	Present	709.8	-89.6	-2,280	1,619.6	-500.3	-9,103
	Potential	1,086.5	-140.4	-3,546	2,645.9	-1,029.0	-17,537
All types	Present	5,304.0	-4,535.6	-50,031	11,055.0	-8,280.8	-89,339
	Potential	18,875.3	-14,964.4	-185,564	22,408.9	-35,783.2	-419,563

a/ A positive number indicates an increase and a negative number a decrease in the value shown.

use levels shown in table 27 and the differences in total silvicultural costs, productivity, and present net worth calculated from data in table 28. At the present and potential levels of use, the greatest impacts occur in the loblolly-shortleaf pine type because of the high level of 2,4,5-T use and the intensity of present management on industrial lands. Increases in timber-production costs and losses in productivity are sizeable for all three patterns of 2,4,5-T use. These two type groups account for 87 percent of the present 2,4,5-T use in the section. Estimated impacts due to canceling the present uses of 2,4,5-T on management cost, timber growth, and present net worth are as follows:

End of year	Annual reduced timber growth	Cumulative: Increased management cost	Cumulative: Reduced timber harvest	Cumulative: Reduced present net worth
	million cu. ft.	million dollars	million cu. ft.	million dollars
1	8.2	11.0	8.2	89.3
5	41.4	55.5	124.2	430.6
10	82.8	111.0	455.7	821.2
50	300.8	555.0	9,813.6	2,679.5

Increased management cost is estimated to be $11 million the first year without 2,4,5-T with a discounted cumulative increased-management cost of $555 million after 50 years. Annual management cost remains constant through the period of analysis because average project costs were assumed to increase only at the prevailing rate of inflation (a zero rate of real increase).

Reduced growth is estimated to be 8.2 million cubic feet per year the first year without 2,4,5-T and will continue to increase to an estimated 301 million cubic feet per year the 50th year. Cumulative reduced timber harvest resulting from the reduced timber growth is estimated to be 124 million cubic feet after five years and 9,814 million cubic feet after 50 years. Increased-management cost and reduced growth are components of total effect. These components may be combined by different methods. One method is calculation of present net worth of the growing timber. Thus, estimating present net worth in the South section results in an expected decrease of $89.3 million the first year without 2,4,5-T with a cumulative loss of $2,680 million after 50 years.

A second method is summing increased-management cost and reduced stumpage income to estimate net income losses to timber growers. Assuming that reduced productivity would be reflected in reduced harvest under sustained yield management, adding cumulated reductions in stumpage incomes to cumulated increased management costs results in the following total impacts:

End of year	Cumulative increased management cost	Cumulative reduced stumpage income	Cumulative net income loss
	million dollars		
1	11.0	4.2	15.2
5	55.5	75.2	130.7
10	111.0	311.5	422.5

Land owners in the South section would spend $11 million more for stand management and received $4.2 million less stumpage income for a net income loss of $15.2 million the first year after cancellation of 2,4,5-T uses at present levels. Cumulative net income losses are estimated to total $422 million at the end of 10 years. Impacts at potential use levels of 2,4,5-T would be much greater.

Rocky Mountain Section

The present use of 2,4,5-T is very limited in the Rocky Mountains section due to past local moratoriums on use and application of less-intensive management techniques. However, rising stumpage values, past reforestation failure, and predicted timber shortages have resulted in recent changes in management practices. It is estimated that only the larch, lodgepole pine, and western hardwoods timber-type groups would not use 2,4,5-T as a preferred-management practice on at least a portion of the type (table 30). A small, but significant, amount of 2,4,5-T would be used for type management or conversion in the remaining timber type groups. The estimated present and potential annual use pattern in the Rocky Mountains is:

	Annual area treated	
	Present	Potential
	--------acres--------	
Site preparation	0	0
Release	180	10,600
Site preparation and release	20	5,200

Specific analyses of alternative management regimes with and without 2,4,5-T were not conducted for the Rocky Mountains section because of the low level of use and lack of use experience. Use patterns for each of the timber-type groups having a present or potential 2,4,5-T use are described below.

About 20 percent of the 11.9 million acre Douglas-fir type group is occupied by vegetation types where seral shrubs may cause regeneration problems and reduce growth of young trees. Productivity in this portion of the type is generally higher than for the type as a whole. The topography is too steep and soils are too fragile for widespread use of mechanical-site preparation. Experience with herbicides in the Rocky Mountain Douglas-fir type is limited, but studies in Oregon and Washington on similar species suggest that aerial sprays of 2,4,5-T

Table 30—Estimated pattern of 2,4,5-T use in the Rocky Mountains section by timber type group

Timber type group	Total commercial forest land	Management objective for 2,4,5-T acres	Annual area treated with 2,4,5-T by use pattern: Site preparation only		Release only		Site preparation and release	
			Present	Potential	Present	Potential	Present	Potential
	million acres		acres					
Douglas-fir	11.885	Type management	——	——	——	1,100	——	500
Ponderosa pine	14.454	Type management	——	——	——	600	——	300
Western white pine	0.631	Type management	——	——	90	1,000	10	500
Fir-spruce	9.800	Type management	——	——	——	500	——	300
Hemlock-spruce	0.896	Type management	——	——	90	1,000	10	500
Larch	2.032	None	——	——	——	——	——	——
Lodgepole pine	9.940	None	——	——	——	——	——	——
Western hardwoods	4.272	None	——	——	——	——	——	——
Nonstocked	2.671	Conversion	——	——	——	6,400	——	3,100

alone or combined with 2,4-D will be most effective for site preparation and conifer release. Assuming a 110 year rotation on the 1.8 million acres of public and industrial forest lands, and a potential need on 10 percent of the area harvested, the estimated potential use of 2,4,5-T is 1100 acres per year for release and 500 acres per year for both site preparation and release.

About 10 percent of the 14.4 million acre ponderosa pine type is subject to serious shrub competition during reforestation and early plantation development. Productivity of this portion is about 10 to 15 percent higher than for the remainder of the type. While shrub cover can, in some circumstances, provide favorable conditions for tree establishment, subsequent growth is often retarded by the competing vegetation and by tree-damaging rodents which thrive in brushy habitats. The herbicide 2,4,5-T is most effective on many of the competing brush species and is the only known and registered chemical suitable for release of ponderosa and associated pines. A potential use of 2,4,5-T on 600 acres annually for release and 300 acres for both site preparation and release is projected for this type.

The western white pine and hemlock-spruce type groups occur on 1.5 million acres and are among the most productive forest lands in the Rocky Mountains. Highly competitive seral shrub communities rapidly dominate much of these two types following wildfire or timber harvest. More than 30,000 acres of these and closely associated communities in the fir-spruce type in northern Idaho have been scheduled for release with 2,4,5-T by 1984. At present, the entire 2,4,5-T treatment is confined to these two type groups; 180 acres are treated for release only and 20 acres for both site preparation and release. A reasonable annual potential of 2,000 acres for release and 1,000 acres for both site preparation and release is estimated. Release treatments are expected to reduce the time required for young conifers to become free from competition by 10 to 20 years.

The fir-spruce type group occurs on 9.8 million acres of commercial forest lands in the Rocky Mountains section. About 10 percent of the type, found on north-facing slopes and at lower elevations, is dominated by seral shrub communities following disturbance. Included in this area are 305,800 acres of highly productive true fir type. For this portion, 2,4,5-T is preferred for both site preparation and release. In contrast, other herbicides seem best for site preparation in the Englemann spruce-subalpine fir portion of the fir-spruce type group. However, 2,4,5-T is best for conifer release. Steep slopes and fragile, easily compacted soils make use of herbicides attractive for site preparation in most of the fir-spruce type group. Based on a 110 year rotation and a probable seral shrub problem on 10 percent of the type, it is estimated that 500 acres would require site preparation and 300 acres would require both site preparation and release on an annual basis.

A total of 2.7 million acres of commercial forest land is classified as nonstocked or poorly stocked due to past reforestation failure and wildfires. Many of the most productive sites are dominated by seral shrub species. The majority of these are susceptible to 2,4,5-T alone or combined with 2,4-D or Tordon 101. All National Forest lands in the nonstocked category are to be reforested by 1984; much of the nonproductive lands owned by forest industry will also be reforested, but over a longer period of time. An estimated potential use of 2,4,5-T on 6,400 acres per year for release and 3,100 acres per year for both site preparation and release are likely until these areas are converted to the appropriate conifer types. An increase in productivity from 0 to 50 cubic feet or more per acre per year should result from this conversion. Therefore, 475,000 cubic feet of softwood timber will be added to the productive capacity of the Rocky Mountains for every 9,500 acres converted using 2,4,5-T.

Pacific Coast Section

The herbicide 2,4,5-T is not used for management of 12.2 million acres (18 percent) of the 67.6 million acres of commercial forest land in the

Pacific Coast section. It is used on a portion of the remaining 55.4 million acres for type management and conversion of selected western hardwood stands and nonstocked areas to conifers (Table 31). The estimated present and reasonable potential use pattern on these areas is:

	Annual area treated	
	Present	Potential
	---acres---	
Site preparation only	1,100	1,900
Release only	216,100	474,600
Site preparation and release	29,900	62,700

The western white pine, fir-spruce (in Oregon and Washington), hemlock-Sitka spruce, larch, and lodgepole pine type groups do not use a significant amount of 2,4,5-T. A description of the use pattern and benefits of use in the redwood, western hardwood, and nonstocked categories as well as for fuelbreak management are included below. Results of analyses of alternative management regimes for the Douglas-fir, ponderosa pine, and fir-spruce (in California) type groups are also presented.

The redwood timber-type group is a small but economically important type covering only 803,000 acres in a narrow belt along the Pacific Coast from central California to southwestern Oregon. The potential area where redwood could grow is about 1.5 million acres. About 35,000 acres of this type are harvested each year, usually by clearcutting, but partial cutting is becoming more prevalent. About 378,000 acres are either nonstocked or poorly stocked and require site preparation and planting. An additional 75,000 acres of seedling and sapling stands presently need release from competing shrubs and weed trees, largely evergreen species. Except for older understocked areas, 2,4,5-T is not usually needed for site preparation in this type. For release, a 7,500 acre present and 20,000 acre potential use of 2,4,5-T applied alone or in combination with 2,4-D is estimated. Because most of the weed

Table 31--Estimated pattern of 2,4,5-T use in the Pacific Coast section by timber type group

Timber type group	Total commercial forest land	Management objective for 2,4,5-T acres	Annual area treated with 2,4,5-T by use pattern: Site preparation only		Release only		Site preparation and release	
			Present	Potential	Present	Potential	Present	Potential
	million acres		acres					
Douglas-fir	18.902	Type management	—	—	160,000	333,700	20,100	44,200
Ponderosa pine	13.509	Type management	—	—	36,800	83,000	—	—
Western white pine	0.198	None	—	—	—	—	—	—
Fir-spruce	8.029	Type management	—	—	700	11,300	—	—
Hemlock-Sitka spruce	9.922	Type management	—	—	—	—	—	—
Larch	0.711	None	—	—	—	—	—	—
Lodgepole pine	3.294	None	—	—	—	—	—	—
Redwood	0.803	Type management	—	—	7,500	20,000	—	—
Western hardwoods	8.545	Conversion	600	900	4,400	13,100	5,300	9,500
Nonstocked	3.707	Conversion	500	1,000	6,700	13,500	4,500	9,000

species are evergreen and resprout readily, substitute herbicides are not readily available and handcutting may be too expensive for general acceptance. Further, greater use of partial cutting may lead to additional brush problems in the future.

There are 8.5 million acres in the western hardwood type group in the Pacific Coast section. Much of this type group occurs on land previously dominated by conifer type groups. About 533,000 acres of tanoak, red alder, madrone, and other hardwoods occur on medium to high sites in the coastal Douglas-fir and redwood forest-type groups in northern California. About 50 percent (266,000 acres) would likely be converted to Douglas-fir and redwood during the next 30 years. About 75 percent or 199,000 acres would be treated with 2,4,5-T applied alone or combined with 2,4-D for site preparation and release; a present use of 700 acres and potential use of 6,650 acres is estimated. Repeated sprays of 2,4-D or mechanical clearing, both combined with broadcast burning for site preparation when necessary, would probably replace most use of 2,4,5-T in tanoak and madrone stands. Mean annual increment is expected to increase from 45 to 100 cubic feet per acre following conversion. Productivity at the present rate of 2,4,5-T use would increase 38,500 cubic feet per year or a total of 9.0 million cubic feet per year following conversion of the 199,500 acres needing treatment with 2,4,5-T.

About 50 percent of the 865,000 acres of red alder and associated hardwoods included in the western hardwood group and growing on medium to highly productive conifer sites in western Oregon and Washington may be converted to Douglas-fir and western hemlock. The present conversion rate of 10,000 acres per year requires use of 2,4,5-T combined with 2,4-D, picloram, or broadcast burning for site preparation on 580 acres per year, for release on 3,700 acres per year, and site preparation and release on 5,260 acres per year. At a potential conversion rate of 20,000 acres per year, the reasonable potential use of 2,4,5-T is estimated to be 900 acres for site preparation, 6,500 acres for release, and 9,500 acres for site preparation and release. Fosamine ammonium and glyphosate would replace many uses of 2,4,5-T for site preparation, except as preburn desiccation sprays; Tordon 101 would be used for release. On equivalent sites, mean annual increment is 101 cubic feet per acre for red alder (40 year rotation), 138 cubic feet per acre for Douglas-fir (70 year rotation), and 230 cubic feet per acre for western hemlock. The average annual increase in productivity over an equivalent time period (70 years) for conversion to Douglas-fir is 37 cubic feet per acre. At the present rate of 2,4,5-T use, conversion adds about 353,000 cubic feet annually to softwood production capacity in the Pacific Northwest. A total of 15.2 million cubic feet per year would be added by converting the 411,000 acres needing 2,4,5-T.

The total nonstocked and poorly stocked area in the Pacific Coast is 3.7 million acres, including about 1.8 million acres of recent cuttings. The remaining 1.8 million acres are dominated by shrubs and herbaceous vegetation. About 500,000 acres in northern California and western Oregon and Washington, and 250,000 acres in eastern Oregon and Washington are likely to be converted to conifers. Where terrain permits, site preparation is accomplished using mechanical clearing; spraying and burning are used on steeper slopes. The present program is estimated to result in conversion within 60 years and will require an annual 2,4,5-T application on 500 acres for site preparation, 6,700 acres for release, and 4,500 acres for site preparation and release. A reasonable potential program will result in conversion within 30 years and a doubling of the present estimated use. The productivity of nonstocked and poorly stocked land is less than 10 cubic feet per acre per year. Average production after conversion would be about 90 cubic feet per acre per year. Thus, conversion of this 11,700 acres of nonstocked and poorly stocked lands in one year adds 936,000 cubic feet of softwood production. This increment is achieved for each 11,700 acres converted and the increase in yield will continue in perpetuity.

The herbicide 2,4,5-T is used for establishing and maintaining fuelbreaks in the highly flammable chaparral type of southern California. This herbicide is somewhat more effective on scrub oak, poison oak, Eastwood manzanita, and other hard-to-kill species than are other phenoxy herbicides. However, one spray never gives adequate control of such species--at least three are required. During the course of three annual sprays, differences between the standard mixture of 2,4,5-T with 2,4-D and 2,4-D alone become less and less. Chamise, the most abundant shrub, as well as coastal brush species, most shrub seedlings, Ceanothus species, some of the manzanitas, big sagebrush, and rabbitbrush are about equally susceptible to 2,4,5-T and 2,4-D. Therefore, 2,4,5-T is only used in mixture with 2,4-D and then only to control mixed chaparral dominated by hard-to-kill species. Repeated sprays of 2,4-D or a combination of 2,4-D and dichloprop (2,4-DP) would readily substitute for the present low level of 2,4,5-T use in chaparral fuelbreaks.

Tables 32 A and B compare total silvicultural costs, productivity, and present net worth of alternative management regimes for five management or vegetation types in the Douglas-fir type group, three management types in the ponderosa pine type group, and two types in the fir-spruce type group of the Pacific Coast section. Potential use levels involved more extensive application of present management practices, so identical substitute practices would be adopted for both the present and potential use levels if 2,4,5-T were canceled. Rotation ages used in the analysis varied by management type and ownership with shorter rotations used on more productive sites and on industrial forest lands than on less productive sites and on public lands (table 33).

Impacts at the end of the first year following cancellation of 2,4,5-T are shown in table 34 for the three timber-type groups analyzed. These values were obtained by multiplying the estimated present and potential use from table 31 by the difference in silvicultural cost, productivity, and present net worth for mangement with and without 2,4,5-T from table 32. The herbicide 2,4,5-T is not generally used for site preparation alone and this use pattern was not analyzed. Impacts on both timber production costs and productivity are greatest where 2,4,5-T is used for release only because of the high estimated present and potential use level. On the average, production costs may actually decrease in the Douglas-fir timber type group where 2,4,5-T is used for both site

Table 32A--Total silvicultural cost, productivity, and present net worth of Douglas-fir stands managed with and without 2,4,5-T in the Pacific Coast section

Timber type group[a/]	Use pattern	Annual 2,4,5-T use		Total silvicultural cost		Productivity		Present net worth	
		Present	Potential	with 2,4,5-T	without 2,4,5-T	with 2,4,5-T	without 2,4,5-T	with 2,4,5-T	without 2,4,5-T
		----acres/year----		----dollars/acre----		--cubic feet/ acre/year----		---dollars/acre--	
Douglas-fir	Site preparation	—	—	—	—	—	—	—	—
-DF, CA	Release	0	1,200	163	141	65	48	570	338
70 year	Both	0	2,500	130	141	58	48	852	338
-DF, CA	Site preparation	—	—	—	—	—	—	—	—
115 years	Release	13,000	14,000	524	614	83	69	108	-135
	Both	—	—	—	—	—	—	—	—
-DF, SWOR	Site preparation	—	—	—	—	—	—	—	—
	Release	29,568	85,008	338	349	134	103	590	246
	Both	3,696	10,626	398	427	134	103	528	166
-DF, NWOR	Site preparation	—	—	—	—	—	—	—	—
and WWA	Release	47,768	91,420	324	290	197	158	1,272	951
	Both	10,236	19,590	384	336	197	158	1,207	902
-DF, Cascades	Site preparation	—	—	—	—	—	—	—	—
	Release	69,513	130,160	356	341	152	129	842	677
	Both	6,134	11,485	416	350	152	129	782	667
-SNMC	Site preparation	—	—	—	—	—	—	—	—
85 years	Release	0	800	452	313	112	96	707	391
	Both	—	—	—	—	—	—	—	—
-SNMC	Site preparation	—	—	—	—	—	—	—	—
130 years	Release	200	300	526	675	90	86	25	135
	Both	—	—	—	—	—	—	—	—

a/ DF - Douglas-fir, CA - California, SWOR - Southwest Oregon, NWOR - Northwest Oregon, WWA - Western Washington, SNMC - Sierra Nevada Mixed Conifer.

Table 32B—Total silvicultural cost, productivity, and present net worth of ponderosa pine and fir-spruce stands managed with and without 2,4,5-T in the Pacific Coast section .

Timber type group[b/]	Use pattern	Annual 2,4,5-T use		Total silvicultural cost		Productivity		Present net worth	
		Present	Potential	with 2,4,5-T	without 2,4,5-T	with 2,4,5-T	without 2,4,5-T	with 2,4,5-T	without 2,4,5-T
		---acres/year---		---dollars/acre---		---cubic feet/ acre/year---		---dollars/acre---	
Ponderosa pine	Site preparation	—	—	—	—	—	—	—	—
-Pp CA	Release	7,500	8,800	443	506	115	97	896	421
	Both	—	—	—	—	—	—	—	—
-Pp OR	Site preparation	—	—	—	—	—	—	—	—
and WA	Release	27,620	63,010	330	414	50	38	315	75
	Both	—	—	—	—	—	—	—	—
-SNMC	Site preparation	—	—	—	—	—	—	—	—
85 years	Release	0	7,400	452	313	112	96	770	391
	Both	—	—	—	—	—	—	—	—
-SNMC	Site preparation	—	—	—	—	—	—	—	—
130 years	Release	1,800	2,700	539	675	90	86	24	-137
	Both	—	—	—	—	—	—	—	—
Fir-spruce	Site preparation	—	—	—	—	—	—	—	—
Red fir/white	Release	0	3,300	147	31	116	81	1,279	691
fir 70 years	Both	—	—	—	—	—	—	—	—
Red fir/white	Site preparation	—	—	—	—	—	—	—	—
fir 125 years	Release	0	4,100	487	538	121	105	298	162
	Both	—	—	—	—	—	—	—	—
Fir-spruce	Site preparation	—	—	—	—	—	—	—	—
SNMC 85 years	Release	0	2,900	452	313	112	96	707	391
	Both	—	—	—	—	—	—	—	—
SNMC	Site preparation	—	—	—	—	—	—	—	—
130 years	Release	700	1,000	539	675	90	86	17	-102
	Both	—	—	—	—	—	—	—	—

b/ P_p = Ponderosa pine, WA = Washington.

Table 33--Rotation ages used for analysis of alternative management regimes of Pacific Coast timber type groups.

Timber type group	Management type	Rotation
		years
Douglas-fir	California Douglas-fir	70, 115
	Southwest Oregon Douglas-fir	85
	Northwest Oregon and Southwest Washington Douglas-fir	65
	Cascades Douglas-fir	75
	Sierra Nevada mixed conifers	85, 130
Ponderosa pine	California ponderosa pine	80
	Oregon and Washington ponderosa pine	120
	Sierra Nevada mixed conifers	85, 130
Fir-spruce	red fir - white fir	70, 125
	Sierra Nevada mixed conifers	85, 130

Table 34--Annual change in timber production cost, productivity, and present net worth following cancellation of 2,4,5-T in the Pacific Coast section.

Timber type group	Use level	Site preparation only[a/] Production cost	Site preparation only[a/] Productivity	Site preparation only[a/] Present net worth	Release only[a/] Production cost	Release only[a/] Productivity	Release only[a/] Present net worth
		thousand dollars	thousand cu. ft.	thousand dollars	thousand dollars	thousand cu. ft.	thousand dollars
Douglas-fir	Present	---	---	---	-1,141.8	-4,561.2	-40,444
	Potential	---	---	---	-2,958.5	-9,424.7	-84,567
Ponderosa pine	Present	---	---	---	3,037.4	-473.6	-10,481
	Potential	---	---	---	5,185.8	-1,043.7	-22,542
Fir-spruce	Present	---	---	---	95.2	-2.8	-83
	Potential	---	---	---	-58.0	-116.0	3,533
All groups	Present	---	---	---	1,990.8	-5,037.6	-51,008
	Potential	---	---	---	2,169.3	-10,584.4	-110,642
		Site preparation and release[a/]			Total[a/]		
Douglas-fir	Present	-788.9	-654.9	-5,165	-1,930.7	-5,216.1	-45,609
	Potential	-1,362.6	-1,382.6	-12,427	-4,321.1	-10,807.3	-96,994
Ponderosa pine	Present	---	---	---	3,037.4	-473.6	10,481
	Potential	---	---	---	5,158.8	-1,043.7	-22,542
Fir-spruce	Present	---	---	---	95.2	-2.8	-83
	Potential	---	---	---	-58.0	-116.0	-3,533
All groups	Present	-788.9	-654.9	-5,165	1,202.0	-5,692.5	-56,173
	Potential	-1,362.6	-1,382.6	-12,427	806.7	-11,967.0	-123,069

a/ A positive number indicates an increase and a negative number a decrease in the value shown preparation and release. In this case, managers often would substitute less expensive, but also less effective, practices.

The three timber-type groups analyzed in the Pacific Coast account for 86 percent of the present area treated with 2,4,5-T in the section. Estimated impacts due to canceling the present uses of 2,4,5-T on management cost, timber growth, and present net worth are as follows:

End of year	Annual reduced timber growth	Cumulative		
		Increased management cost	Reduced timber harvest	Reduced present net worth
	million cu. ft.	million dollars	million cu. ft.	million dollars
1	5.7	1.2	5.7	56.2
5	28.5	6.0	85.9	266.0
10	56.9	12.0	315.6	496.7
50	284.6	60.0	7,310.2	1,503.2

Increased-management cost is estimated to be $1.2 million the first year without 2,4,5-T with a discounted cumulative increased-management cost of $60 million after 50 years. Annual management cost remains constant through the period of analysis because average project costs were assumed to increase only at the prevailing rate of inflation (a zero rate of real increase).

Reduced growth is estimated to be 5.7 million cubic feet per year the first year without 2,4,5-T and will continue to increase to an estimated 285 million cubic feet per year the 50th year. Cumulative reduced timber harvest resulting from the reduced timber growth is estimated to be 86 million cubic feet after five years and 7,310 million cubic feet after 50 years. Increased-management costs and reduced growth are components of total effect. These components may be combined by different methods. One method is calculation of present net worth of the growing timber. Thus, estimating present net worth in the Pacific Coast section results in an expected decrease of $56 million the first year without 2,4,5-T with a cumulative loss of $1,503 million after 50 years.

A second method is summing increased-management cost and reduced stumpage income to estimate net income losses to timber growers. Thus, this method results in the following total impacts:

End of year	Cumulative increased management cost	Cumulative reduced stumpage income	Cumulative net income loss
	---------million dollars---------		
1	1.2	5.1	6.3
5	6.0	85.0	91.0
10	12.0	340.8	352.8

Land owners in the Pacific Coast section would have $1.2 million in increased-management costs and $5.1 million in reduced stumpage income for a net income loss of $6.3 million the first year after cancellation of 2,4,5-T uses at present levels. Cumulative net income losses are estimated to total $353 million at the end of 10 years. Impacts at potential use levels of 2,4,5-T would be much greater. Present and potential impacts were estimated for Oregon by the Oregon Department of Forestry and USDA, Forest Service, Pacific Northwest Region, in the Oregon 2,4,5-T Assessment Report. This report presents both biologic and economic analysis of the use of 2,4,5-T in Oregon. It reflects at the state level, the results of the USDA-States-EPA 2,4,5-T Assessment Team's analysis which was done at the regional and national level. The Oregon report is Appendix 1 of this report.

United States

The impact of canceling 2,4,5-T use for timber production in the United States is summarized in tables 35 and 36. The timber types included in

Table 35—Change in timber productivity 1, 5, 10 and 50 years after canceling 2,4,5-T in the North, South, and Pacific Coast sections and the United States

Section and use pattern	Annual change in timber productivity in year: 1	5	10	50
	------thousand cu. ft./year---------			
North				
Site preparation	+5	+25	+50	-390
Release	-612	-3,058	-6,116	-25,228
Site preparation and release	-349	-1,747	-3,494	-13,308
Total	-956	-4,780	-9,560	-38,926
South				
Site preparation	+688	+3,438	+6,876	+25,005
Release	-4,433	-22,166	-44,332	-160,877
Site preparation and release	-4,536	-22,681	-45,362	-164,972
Total	-8,282	-41,409	-82,818	-300,844
Pacific Coast				
Site preparation	—	—	—	—
Release	-5,038	-25,188	-50,376	-251,880
Site preparation and release	-655	-3,274	-6,549	-32,745
Total	-5,692	-28,462	-56,925	-284,625
United States				
Site preparation	+693	+3,463	+6,926	+24,615
Release	-10,083	-50,412	-100,824	-437,985
Site preparation and release	-5,540	-27,702	-55,405	-211,025
Total	-14,930	-74,651	-149,303	-624,395

Table 36—Accumulated increased timber growing costs, reduced softwood harvest and present net worth 1, 5, 10 and 50 years after canceling 2,4,5-T in the North, South, and Pacific Coast sections, and the United States

Section and use pattern	Accumulated increased timber growing costs through year				Accumulated reduced softwood timber harvest through year				Accumulated reduced present net worth through year			
	1	5	10	50	1	5	10	50	1	5	10	50
	---million dollars---				---million cu. ft.---				---million dollars---			
North												
Site preparation	0.3	1.5	3.0	15.0	(0.0)[c/]	(0.3)	(0.8)	(15.5)	(0.1)[a/]	(0.3)	(0.5)	(2.5)
Release	0.4	2.0	4.0	20.0	0.7	8.8	31.9	713.5	4.0	19.9	38.8	131.2
Site preparation and release	0.5	2.5	5.0	25.0	0.4	5.2	19.1	427.7	3.7	17.8	33.9	110.0
Total	1.2	6.0	12.0	60.0	1.1	13.7	50.2	1,125.7	7.6	37.4	72.2	238.7
South												
Site preparation	4.7	23.5	47.0	235.0	(0.7)[c/]	(10.2)	(37.7)	(835.4)	3.9[a/]	(20.2)	(40.9)	(158.7)
Release	1.0	5.0	10.0	50.0	4.4	66.4	243.8	5,382.0	43.3	210.0	402.9	1,342.8
Site preparation and release	5.3	26.5	53.0	265.0	4.5	68.0	249.6	5,267.0	49.9	240.8	459.2	1,495.4
Total	11.0	55.0	110.0	550.0	8.2	124.2	455.7	9,813.6	89.3	430.6	821.2	2,679.5
Pacific Coast												
Site preparation	—	—	—	—	—	—	—	—	—	—	—	—
Release	2.0	10.0	20.0	100.0	5.1	76.1	279.4	6,469.1	51.1	241.4	450.5	1,360.3
Site preparation and release	(0.8)[b/]	(4.0)[b/]	(8.0)[b/]	(40.0)[b/]	0.6	9.8	36.2	841.1	5.2	24.6	46.2	142.9
Total	1.2	6.0	12.0	60.0	5.7	85.9	315.6	7,310.2	56.2	266.0	496.7	1,503.2
United States												
Site preparation	5.0	25.0	50.0	250.0	(0.7)[c/]	(10.5)	(38.5)	(850.9)	4.0[a/]	(20.5)	(41.4)	(161.2)
Release	3.4	17.0	34.0	170.0	10.2	157.3	555.1	12,564.6	98.4	471.3	892.2	2,834.3
Site preparation and release	5.0	25.0	50.0	250.0	5.5	83.0	304.9	6,535.8	58.8	283.2	539.3	1,748.3
Total	13.4	67.0	134.0	670.0	15.0	223.8	821.5	18,249.5	153.2	734.0	1,390.1	4,421.4

a/ Indicates an increase in present net worth

b/ Indicates a decrease in timber production costs

c/ Indicates an increase in softwood timber harvest this analysis account for 86 percent of the estimated use of 2,4,5-T on all forest lands in the United States. Estimated impacts due to canceling the present uses of 2,4,5-T on management cost, timber growth, and present net worth are as follows:

End of year	Annual reduced timber growth	Cumulative		
		Increased management cost	Reduced timber harvest	Reduced present net worth
	million cu. ft.	million dollars	million cu. ft.	million dollars
1	15.0	13.5	15.0	153.2
5	74.6	67.5	223.8	734.0
10	149.3	135.0	821.5	1,390.1
50	624.4	675.0	18,249.5	4,421.4

Increased-management cost on all forest lands in the United States is estimated to be $13.5 million the first year without 2,4,5-T with a discounted cumulative increased-management cost of $675 million after 50 years.

Reduced growth on all forest lands in the United States is estimated to be 15 million cubic feet per year the first year without 2,4,5-T and will continue to increase to 624 million cubic feet per year the 50th year. Cumulative reduced timber harvest resulting from the reduced timber growth is estimated to be 224 million cubic feet after five years and 18,250 million cubic feet after 50 years (table 36). Increased-management costs and reduced growth are combined by two methods - present net worth and annual net income. Present net worth of all forest lands in the United States is expected to decrease $153 million the first year without 2,4,5-T with a cumulative loss of $4,421 million after 50 years.

Assuming that reduced productivity would be reflected in reduced harvest under sustained yield management and adding cumulated reductions in stumpage incomes from all forest lands in the United States to cumulated increased management costs show the following total impacts:

End of year	Cumulative increased management cost	Cumulative reduced stumpage income	Cumulative net income loss
	------------million dollars------------		
1	13.5	9.6	23.1
5	67.5	163.8	231.3
10	135.0	666.3	801.3

Forest land owners in the United States would spend $13.5 million more for stand management and received $9.6 million less in stumpage income for a net income loss of $23.1 million the first year after cancellation of 2,4,5-T uses at present levels. Cumulative net income losses are expected to total $801 million at the end of 10 years.

The present use of 2,4,5-T in the Rocky Mountains is limited to 180 acres treated for conifer release and 20 acres for site preparation and release, mostly on an experimental basis. Because of the lack of use experience, an economic analysis of impacts was not attempted. However, rising stumpage values, past reforestation failures, and predicted timber shortages all suggest an increased intensity of forest management and use of 2,4,5-T. A reasonable potential of 10,600 acres annually for release alone and 5,200 acres for both site preparation and release is projected for the Douglas-fir, ponderosa pine, western white pine, hemlock-spruce, fir-spruce and nonstocked forest-type groups in the Rocky Mountains.

CHAPTER 2: THE BIOLOGIC AND ECONOMIC ASSESSMENT OF 2,4,5-T USE IN FORAGE PRODUCTION ON RANGE AND PASTURE LANDS IN THE UNITED STATES

SUMMARY

The grazing resources in the United States consist of approximately 1 billion acres. At least one-third of the grazing area is estimated to be infested with undesirable woody plants and herbaceous weeds. Annual losses from weeds and brush on rangeland and pasture and cost of control are conservatively estimated at nearly $2 billion annually. Weeds on grazing lands induce losses by decreasing forage production, watershed yield, wildlife habitat, and recreational use. Cost of handling livestock, death in injury losses of livestock, and human allergies are greatly increased by stands of poisonous, thorny or pollen-producing species. Proper vegetation management is paramount since about 75 percent of all domestic animals and most wildlife depends upon grazing lands for survival.

In the southwest, mesquite is a particularly troublesome range-brush species. It occurs on about 93 million acres and successfully competes with desirable range-forage species for light, space, nutrients, and water. By conservative estimate, mesquite may reduce overall forage yield by as much as 30 percent. Mesquite and many other brush species are susceptible to low rates of 2,4,5-T. Historically 2,4,5-T has been applied in the southwest to a relatively small acreage annually (1 million acres) and is used on sites with greatest potential and return. Mesquite control may last from 5 to 20 years from a single application of 0.5 pound per acre of 2,4,5-T before retreatment with 2,4,5-T or an alternative method is needed. Most alternative methods cause greater environmental damage (chemical, mechanical, fire, or biological) or are not economically feasible. Thus, the use of 2,4,5-T is the most feasible and practical treatment when compared to alternatives.

The primary oaks causing problems in livestock production are post oak, blackjack oak, and sand-shinnery oak. Post and blackjack oak are many times associated with several other problem woody plants such as winged elm and yaupon. The post oak Savannah occupies more than 11 million acres of grazing land in east central Texas while nearly 9 million acres of shrub or shin oaks infest western portions of Texas. Oaks are not unique to Texas, but several different species cause management problems in several states. The primary problems on grazing lands infested with oaks are depressed forage production and utilization, labor efficiency, soil moisture loss, and poor environmental quality. Post-blackjack oaks can be controlled by applying 2,4,5-T in frills on the trunk, to cut stumps, or as basal sprays to individual plants. However, a majority of the acreage is treated by aircraft. Alternative methods of control such as hand removal or mechanical practices are expensive, slow, and sometimes hazardous to humans from physical injuries. 2,4,5-T is also used on other woody species on western rangelands (yucca, cactus, etc.) in preference to other chemicals or methods due to cost, effectiveness, and safety.

It has been estimated that at least 18 eastern states use 2,4,5-T for woody plant control on about 1 million acres. Many weed species are common to both western pastures and eastern grazing lands, but there are many woody and herbaceous weeds that are more troublesome in eastern U.S. pastures. The same control methods applicable to western rangelands can be applied in the east; however, hand and ground application are more common than aerial application.

Increased forage and livestock production as a result of 2,4,5-T sprays on rangeland are well documented. Detrimental effects on livestock or wildlife have not been observed.

Partial economic analyses were done for 93 million acres of mesquite-infested rangeland, 35 million acres of oak rangelands, and 14.3 million acres of sand-shinnery oak rangelands. Insufficient data prevented more than a brief description of the uses of 2,4,5-T on the following species and problems in pastures, rangelands and farms and other farm and ranchlands:

Species or problem	Area	Acres infested	Economic Importance of 2,4,5-T
		Thousand	
Cactus	U.S.	78,600	Significant
Hardwoods	U.S.	Unknown	Significant
Yucca	U.S.	50,000	Significant
Poisonous plants	U.S.	Unknown	Significant
Desert shrub	West	124,600	Significant
Fence rows	U.S.	Unknown	Significant
Pastures	U.S.	101,061	Significant
Misc. woody plants	U.S.	1,000,000	Significant

Economic losses associated with these uses if 2,4,5-T becomes unavailable are unknown. However, these uses are considered very important to affected land users. With 2,4,5-T, beef producers are able to control invading plants and keep an area from becoming heavily infested. If these plants were allowed to go uncontrolled, affected beef producers would reduce animal stocking rates and experience a corresponding reduction in beef production and income.

Approximately 1.6 million acres of rangeland infested with mesquite, post-blackjack oak and sand-shinnery oak are treated annually with 2,4,5-T or mixtures of 2,4,5-T plus picloram, or 2,4,5-T plus dicamba or silvex. Approximately 15 million acres of rangelands are treated once every 5 to 16 years depending on the length of rotation period. Treatment rates vary from 0.5 to 2 pounds per acre for a total use of about 1.9 million pounds of 2,4,5-T annually. At present, only minor quantities of silvex and dicamba are used.

Silvex could be substituted for 2,4,5-T on about 1.5 million acres and would produce about equal control on many major woody plant species.

The increased cost per acre varies from $0.25 to $1. This represents an increased cost of $375,000 to $1.5 million annually. Silvex annually is less effective than 2,4,5-T for the control of some poisonous plants, desert shrubs, and many other woody plants.

If 2,4,5-T and silvex become unavailable, dicamba may be substituted on 433,000 acres in the area west of the 100th meridian. Application rates are 0.5 pound per acre and cost at least $2.50 per acre more than 2,4,5-T. Landowners may not be willing to pay the additional cost except to reduce brush density and reduce labor required for working livestock. In the brush areas east of the 100th meridian, results from dicamba are erratic and adequate control is rare.

Mechanical-control methods such as two-way chaining, root plowing plus seeding, tree grubbing, and fire have limited use on rangelands. Two-way chaining is limited to areas having trees with stem diameters of over 4 inches. There are very few mesquite areas that meet these specifications. Also, chaining must be done when soil is moist for trees to be uprooted. In some areas it requires up to 20 years for trees to attain a stem diameter of 4 inches before another chaining operation would be successful. Application of 2,4,5-T is the most successful for control of regrowth following chaining. Chaining is used best 2 to 3 years following 2,4,5-T application to extend the life span of the herbicide treatment and to remove the dead tree tops for faster decay.

If 2,4,5-T becomes unavailable and silvex remains available, beef production from the mesquite-infested rangelands, post-blackjack oak rangelands, and sand-shinnery oak rangelands is estimated to decrease 2.1 million pounds the first year without 2,4,5-T. Beef production losses would be maximized the fifth year without 2,4,5-T at 10.5 million pounds. Cumulative losses over the 16-year evaluation period are estimated to be 147.6 million pounds of beef without 2,4,5-T.

If both 2,4,5-T and silvex become unavailable, beef production is estimated to decrease 21.5 million pounds the first year. Cumulative losses over the 16-year evaluation period are estimated to be 1.8 billion pounds of beef. If 2,4,5-T and silvex become unavailable and dicamba is not used, beef production is estimated to decrease 27.7 million pounds the first year. Cumulative losses over the 16-year evaluation period are estimated to be 2.5 billion pounds. Expected changes in beef production from the rangeland areas due to a lack of 2,4,5-T and/or effective alternatives for weed and brush control are small compared to U.S. beef production, and range from .015 to .470 percent of U.S. beef production. The expected quantity change is certainly more significant to the affected producers.

Expected income losses from the mesquite-infested rangelands, post-blackjack oak rangelands, and sand-shinnery oak rangelands are $785,500 the first year without 2,4,5-T, if silvex and dicamba are available. Cumulative losses over the 16-year evaluation period are estimated to be $26.6 million. If silvex becomes unavailable along with 2,4,5-T, reductions in producer income are estimated at $5.6 million the first year with a 16-year cumulative loss of $262.5 million. Further, if 2,4,5-T and silvex become unavailable and dicamba is not used, reductions in producer income are estimated to increase to $6.9 million the first year with a 16-year cumulative loss of $347.5 million. These impacts were derived assuming <u>ceteris paribus</u> conditions with respect to price and production levels. Additional economic losses to the producer are increased labor cost of working livestock and deterioration of range conditions; i.e. increased top soil loss due to reduced herbaceous cover, increased undesirable plants, and reduced wildlife populations.

CHAPTER 2: PART 1

BIOLOGIC IMPLICATIONS OF 2,4,5-T USE ON PASTURE AND RANGELANDS

INTRODUCTION

Grazing lands represent an important resource in the United States, not only for forage production but also for watersheds, conservation of soil and water, wood, lumber, medicinal and industrial compounds, mining, and recreational purposes. Williams et al. (1968) indicated that 75 percent of all domestic animals and most wildlife depend upon grazing lands for survival. Such land is usually only suitable for grazing because it is too steep, shallow, sandy, arid, wet, cold, or saline for crops.

Development and maintenance of the proper density and composition of vegetation is the most important problem in managing range and pasture resources. 2,4,5-T is an important tool in solving this problem. Other chemicals and various cultural practices are also used. This chapter covers the biologic and economic role of 2,4,5-T (and alternatives) in the management of range and pasture lands. Important range and pasture management goals, weed problems and control practices, and cost and yield data are included in substantial detail for mesquite and oak-dominated lands in Texas and Oklahoma. Data are less complete for pasturelands and for rangeland-management problems involving several other problem species.

THE RANGE AND PASTURE RESOURCE IN THE UNITED STATES

Estimates vary on the total grazing land available in the USA. Blakely and Williams (1974) indicate there are 698 million acres of privately owned grazing land and 262.7 million acres of federally owned grazing land, for a total of 960.7 million acres. Thomas and Ronningen (1965) consider the grazing resource as 1 billion acres, whereas the Forest Service, USDA, considers about 1.2 billion acres (48 contiguous states) forest-rangeland with about 835 million acres (69%) grazed by livestock in 1970 (Anonymous 1977a). Alaska has 351 million acres of forest-range, or 97 percent of its total land area. Hawaii has only 3 million acres, but this is 70 percent of its land area (Anonymous 1977a).

Of the billion acres of range and pastureland in the USA, about one-third are estimated to be infested with undesirable woody plants (Williams et al. 1968). Klingman (1962) indicated woody plant infestations of rangeland included 76 million acres of juniper species, 70 million acres of mesquite, and 96 million acres of sagebrush. Platt (1959) reported acreages from a survey of 36 range authorities in the western U.S. and Canada. A total of nearly 600 million acres of land covered with woody plants were reported with an additional 264 million acres of herbaceous weeds (many poisonous to livestock), for a grand total of over 863 million acres infested. Platt (1959) indicated some acreages were counted more than once because of interspersed stands of two or more undesirable species. However, Platt further stated that it was not net acreage but the acreage requiring treatment that was important. Main woody plants included chamise, manzanita, sagebrush, rabbitbrush, southern blackbrush, broomweed, juniper, creosotebush, cactus, yellow pine, aspen, mesquite, acacia, scrub oak, wild rose, willow, snowberry, and yucca.

A conservative estimate of reduced forage production from weeds and brush in 1975 was 13 percent on western ranges and 20 percent on eastern pastures and ranges (Anonymous 1965). Annual losses from weeds and brush on rangeland and cost of control are conservatively estimated at $1.7 billion. Weeds and brush induce losses by decreasing forage production, water yield from watersheds, wildlife habitat, and recreational use. Cost of handling livestock, death and injury losses of livestock, and human allergies are greatly increased by dense stands of poisonous, thorny, or pollen-producing plants. Although poisonous range weeds often infest only a small percentage of a grazing area, they kill livestock and also restrict proper utilization of desirable forage species in the area. Weeds also restrict establishment of new forage seedings.

Vegetation on rangelands may be characterized by highly diverse mixtures of forage and weed species. The forage component may consist of one to many desirable forage grasses intermixed with forbs and browse.

Undesirable woody and herbaceous weeds are vigorous competitors and may dominate rangelands, sometimes as a result of overuse or mismanagement, greatly lowering their productivity. Selective weed control is required for range improvement, especially where these undesirable weeds constitute long-lasting disclimax communities. Maintenance of desirable vegetation discourages reinvasion of weeds and prolongs the period before retreatment is needed.

Heady (1975) defines range management as a land-management discipline that skillfully applies an organized body of knowledge known as range science to renewable natural-resource system for two purposes: (1) protection, improvement, and continued welfare of the basic range resource, which may include soils, vegetation, and animals; and (2) optimum production of goods and services in combinations needed by mankind. Proper vegetation management is many times the largest single management problem to livestock production, wildlife habitat, and recreational use.

Pastures and rangelands, whether grazed or protected, require some type of management to maintain the desired vegetation. On grazed lands, livestock tend to select the more palatable species leaving less palatable weeds and brush to spread and multiply. If grazing is too intense, the process is greatly accelerated. After a few years, especially in warm climates, drastic control measures must be employed or the weed problem intensifies. Some areas can be treated by mechanical means with satisfactory results; however, on areas too steep, wet, rocky, or subject to wind and water erosion, aerial application or individual plant treatment with herbicides (2,4,5-T) may be the only economical and practical control measure available.

TEXAS MESQUITE

Mesquite is the most troublesome range bush species in Texas and is probably the singlemost important woody plant problem in the Southwest. It successfully competes with desirable range forage species for light, space, and nutrients and is an extravagant user of water. Its presence degrades range watersheds, the present excessive cover is not necessary for quality wildlife habitat, and heavy infestations reduce recreational potential of rangeland. By conservative estimate, mesquite may be reducing overall direct yield of range products by as much as 30 percent. This estimate does not include indirect losses resulting from reduced effectiveness of livestock care, increased labor costs, etc. Brush management is applied to mesquite-infested rangeland to expedite secondary succession in an effort to optimize the yield of range products. Several tools, including the herbicide 2,4,5-T are utilized for this purpose. Each method has unique strengths and characteristic weaknesses and each method has utility for specific situations relative to brush growth type, terrain, soils, and other factors. Thus, potential for universal substitution of present mechanical, burning, or biological methods for use of 2,4,5-T is constrained by a complex of biological and economical factors. Most of the alternative methods cause greater environmental detriment than aerial spraying with 2,4,5-T when label instructions are followed with proper application technique. Although 2,4,5-T is applied to a relatively small acreage annually, it is used on those sites with greatest production potential. Consequently, the net effects of its unavailability would most likely seriously impact overall range livestock production. Research is presently underway to quantify acute impacts and to estimate the chronic effects.

ESTABLISHED MANAGEMENT GOALS

The primary management goals of mesquite control on Texas rangeland are to: (a) reduce or eliminate the competitive effect of mesquite and associated woody plants on growth, development, and yield of herbaceous forage species critical for effective livestock production; (b) improve efficiency of labor for the handling and care of livestock; (c) conserve moisture presently utilized by excessive cover of woody plants on range watersheds for use by range forages, wildlife, man, and livestock; and (d) enhance wildlife habitat management capabilities.

The relative importance of these management goals varies somewhat among geographic areas depending on associated vegetation, characteristics of the livestock enterprise, and management preference. However, regardless of relative importance within a given situation, they are invariably integral parts of the management logic where brush management is a consideration for range improvement.

The Problem

Occurrence of 93 million acres of mesquite (Platt 1959) on extensive areas of grazing lands has long been a primary management problem for ranchers of the entire Southwest. Of the 107 million acres of rangeland in Texas, about 87 percent is infested to some extent with brush. The present mesquite problem in Texas arose largely from increases in the density and stature of plants following three long droughs of 1917-20, 1930-35, and 1951-57. Mesquite previously was restricted to waterways or as scattered mottes across the prairie but has gradually thickened to form moderate to heavy stands on the more productive rangelands (Scifres 1973). These infestations seriously interfere with livestock management and often reduce the production of desirable range forage plants. Surveys by the Soil Conservation Service published in 1964 and revised in 1973 indicated that mesquite occurred on 56 million acres of rangeland in Texas. Approximately 16 million acres of Texas rangeland are heavily infested with mesquite, 18 million acres have a moderate infestation, and 22 million acres have a light infestation. During the 9-year interval separating the surveys, the number of acres increased for the light infestation and decreased for the dense infestations. Without effective brush-management efforts, the light and moderate infestations will gradually thicken increasing the proportion of the heavy infestation. Mesquite also rapidly invades abandoned croplands, pastures seeded to perennial grasses, rights-of-way, fence rows and areas around stock ponds, drainage ditches, irrigation canals, dams, and spillways.

Honey mesquite occurs primarily east and northeast of the Rio Grande River in New Mexico, throughout south and west Texas and extends to northern Oklahoma and to Louisiana on the east. Velvet mesquite predominates in Arizona, extreme western New Mexico, lower California, and Mexico. Western mesquite occurs in California, southern Nevada, Utah, western Arizona, southern New Mexico, and parts of Texas. Honey mesquite is the primary problem species on rangeland in Texas.

Biology/Ecology of Plant Communities Associated with Mesquite

Mesquite may occur in almost pure stands or as a component of woody plant communities composed of numerous other species. The most cosmopolitan brush problem on rangeland, it is a primary range management consideration in all vegetation resource areas of Texas. Varieties of mesquite that grow upright vary in growth form from single-stemmed trees 10 feet or taller, to small, few- to many-stemmed shrubs. The many-stemmed growth form is often the result of sprouting following injury or top removal of the tree-type form.

Mesquite occurs at elevations up to 4,500 feet where the average annual minimum temperature exceeds -5°F with 200 or more frost-free days. Mesquite occurs along drainageways in areas of low rainfall (6 inches or less), is adapted to moist soils in 15- to 20-inch rainfall belts, and occurs on calcareous soils where rainfall exceeds 30 inches.

Mesquite typically has a taproot with an extensive lateral root system and thrives best on moderate to deep, fine-textured soils. Seedlings rapidly establish root systems, and roots of well-established plants may penetrate vertically to depths of 15 to 40 feet. The roots often extend laterally as much as 50 feet from the base of the plant. When soil moisture is adequate, mesquite is an inefficient user of water (McGinnies and Arnold 1939, Tiedemann and Klemmedson 1978, Cable 1977). However, under extremely low moisture availability in the upper profile, it is able to survive due to reduction of leaf area, increase in thickness of the leaf cuticle, almost complete cessation of growth

(Wendt et al. 1968), and use of moisture deep within the soil profile by its taproot.

In the xeric Trans-Pecos, mesquite is the greatest problem along waterways and valleys where it is associated with mixed scrub brush species (Scifres 1978). On the High Plains, it is the primary brush problem associated with species of cactus such as cholla and with yucca. On the Rolling Plains, mesquite occurs as the most abundant woody species in association with woody plants such as lotebush, catclaw, sand-shinnery oak, sand sagebrush, and algerita. On the Cross Timbers and Prairies, the Post Oak Savannah, and on the Blackland Prairies, mesquite may occur in solid stands primarily interspersed among the oak communities. On the Coastal Prairie, South Texas Plains, and Edward Plateau, it occurs as a dominant of mixed brush or "chaparral" associated with species of *Acacia*, *Aloysia*, *Lycium*, *Zanthoxylum*, *Celtis*, and *Quercus* or as solid stands. An ever-present component of the range vegetation, no other woody species exerts such an influence on natural resource management. No other woody plant is more widely adapted to range conditions in Texas.

Mesquite is a prolific seed producer in years of good moisture conditions and the seed, upon scarification, is capable of germinating immediately upon leaving the parent plant (Scifres and Brock 1972). Mesquite seedlings are capable of vegetative growth within 7 days after seed germination unless the topgrowth is removed to beneath the cotyledonary scars (Scifres et al. 1970).

Thus, without the application of control procedures, that mesquite can be expected to spread into new areas and present stands can be expected to thicken is a gross understatement of its potential.

Impact on Commodity Yield

Unfortunately, little quantitative data are available regarding the impact of mesquite on the yield of range animal products, water, and upon land-management practices. Yield from rangeland supporting light canopy covers of honey mesquite is probably not being reduced at present. However, mesquite control should be practiced as a preventative measure to keep the light infestations from thickening into moderate and, ultimately, heavy stands. Light infestations, based on 1964 estimates by SCS, encompass about 39 percent of the infested acreage. On the average (across all sites and years), range product yield is probably cut by at least 25 percent on areas supporting moderate mesquite infestations, about 18 million acres or 32 percent of the infested acreage. On these acreages supporting heavy mesquite infestations, about 16 million acres or 29 percent of the infested area, yield of livestock products is probably being reduced by at least 60 percent. These estimates are felt to be conservative, and if true, mesquite alone may be reducing the overall yield of range products in Texas by as much as 30 percent. This estimate does include costs of indirect losses resulting from reduced livestock care, reduced labor costs in gathering and handling livestock, control of associated herbaceous weeds, poisonous plants and other indirect benefits. Brush spraying was felt to be a major economic advantage during outbreaks of the screwworm fly because of accessibility of infected animals. These estimates are supported by experimental results discussed in subsequent sections.

MANAGEMENT STRATEGIES

The art and science of range management, including brush management, is premised on ecological principles. A natural resource, the ecological integrity of rangeland must be respected for optimium sustained yield of its products to be achieved. The vegetation component of the range ecosystem is the basic producer used by a myriad of consumers. Man can be the primary beneficiary of production from rangeland by applying careful and judicious management.

Under pristine conditions, rangelands of the southwestern United States were highly productive, dynamic, open grasslands or savannahs. Woody plants were restricted primarily to the drainageways and scattered individuals dotting the landscape (Scifres 1978). However, continued overuse by domestic livestock and restriction of naturally occurring fires augmented by periodic drought, allowed adapted woody plants to encroach upon the grassland and convert most of it in Texas to brushland. Domestic grazing animals, not allowed to range over broad areas as did their predecessors, preferentially used the herbaceous vegetation selectively releasing the less-preferred woody plants. Responding to a deep, innate fear of fire, man suppressed the role of range burning. Thus, woody plants were given the advantage. The situation is typified by present conditions of vegetation in Texas and New Mexico where impact of brush encroachment has been documented (York and Dick-Peddie 1969).

During the last 50 years, great amounts of financial and human resources have been directed toward development of technology to cope with the excessive woody plant cover on rangeland. Since the woody plant invasion is not a natural ecological phenomenon in the absence of disturbance, the effort has been one of "range restoration" -- an effort to "repair" the ecological system and restore it to its maximum level of productivity. These lofty objectives may not be universally articulated by the lay person nor understood by the uninformed, but the axiom -- "kill brush to grow grass" depends on implementation of certain management practices the use of which hinge on well-defined, ecological principles. Brush management as an integral part of range management is indeed "ecology applied."

An array of range-improvement tools is available for application to rangelands, singly or in various combinations, including chemical, mechanical, biological, and burning techniques. Each method possesses unique strengths relative to accomplishing range-improvement objectives, and each is characterized by certain weaknesses. Thus, only rarely can one method be directly substituted for another with the same economic and ecological result. <u>These tools must be applied judiciously to expedite secondary ecological succession</u> . . . to restore grasses and forbs characteristic of grasslands while reducing the cover of highly competitive woody plants. Judicious application is dictated by requirements to reach management goals and by economic necessity. Much of our native rangeland in the best range condition will sustain an animal unit yearlong on about 10 acres depending on rainfall. Thirty to forty acres may be required for the same animal unit on the same rangeland with a heavy brush cover. Compared to herbicide use in row crop agriculture as an annual requirement, range-improvement practices are applied at rather widely spaced intervals (5, 10 or more years between treatments). Range resource management must be understood to truly assess herbicide use for range improvement. Range restoration requires methodical manipulation of vegetation primarily by grazing and browsing animals augmented by occasional synthetic techniques such as herbicidal plant management. Yet, these synthetic inputs, including occasional use of herbicides, are critical to the range resource attaining its potential for livestock and wildlife production in a reasonable length of time and/or for sustaining that potential.

Mechanical and chemical methods are the primary approaches to brush management and are now employed on approximately 1.5 to 2 million acres each year in Texas. Herbicides such as 2,4,5-T were fully developed in the early 50's and widespread acceptance occurred in the late 50's. During that time period, the use of mechanical methods declined with replacement by use of effective herbicides because of (a) the cost of equipment and energy, (b) ineffectiveness of some mechanical methods, and (c) the excessive disturbance, an ecological detriment (especially in drier areas), of some mechanical methods. Most of the range-improvement efforts with herbicidal brush control involved 2,4,5-T and herbicide mixtures containing 2,4,5-T. Combinations of 2,4,5-T with picloram or dicamba introduced in the 1960's have broadened the spectrum of species controlled and improved control of others over use of 2,4,5-T alone. Use of 2,4,5-T in combination (as half of the mixture) can actually result in increased control of some species with a reduction in the amount of 2,4,5-T applied than when the chemical is used alone. Yet, cancellation of registered uses of 2,4,5-T on rangeland would also result in loss of these effective herbicide combinations.

Application of 2,4,5-T for honey-mesquite control includes individual-plant and broadcast applications. Individual-plant treatments account for a relatively small percentage of the acreage treated each year. Broadcast methods are most widely used on about one million acres for brush control with air broadcast as the most popular.

Cut-Stump Method

The cut-stump method involves treating exposed, freshly cut stump surfaces with herbicide. Hoffman (1975a) suggests using 8 pounds of 2,4,5-T in 100 gallons of diesel oil or kerosene for treatment of mesquite stumps. Effective control results from applying the herbicide solution to cut surfaces and basal plant parts until runoff occurs. The herbicide may be applied as a pour or with various types of hand or power sprayers. One gallon of herbicide solution will treat about 40, 4-inch stumps (Hoffman 1975a). Although the cut-stump method can be effective at any season, results are usually best from treatments in the winter and summer months. The stump should be treated immediately after cutting. The method is used for low density infestation, 125 stems or fewer per acre, and on relatively small areas usually by the landowner or under his supervision.

Basal-Spray Method

Although the cut-stump method is effective, considerable labor may be involved in cutting the trees. Therefore, many workers prefer the basal-spray method. Single-stemmed trees or plants with few stems having trunks of 5 inches or less in diameter on sandy, rocky or porous soil are most easily controlled with basal sprays (Hoffman 1975b, Fisher et al. 1946). Plants with trunk diameters greater than 5 inches should be frilled and herbicide applied in the cuts. Frills, or cuts through the bark may be made with a hand axe or similar tool. Herbicide solutions described for use as cut-stump treatments are used, and 1 gallon of herbicide solution will treat about 20, 4-inch trees. Although some contractors are available for basal spray applications, most basal spray work is usually done by the landowner or under his supervision.

Foliage Treatment of Individual Trees

When relatively large areas are infested with dense stands of mesquite, more than 125 stems per acre, broadcast sprays are more feasible than individual-tree treatments. Ground equipment may be used, especially on regrowth, but aerial application is the most rapid and economical treatment method available.

Less than 0.33 pounds per acre of 2,4,5-T is not effective under "drought conditions". It is not conducive to rapid growth of mesquite, or when foliage is damaged by hail or insects (Fisher et al. 1956). One-half pound per acre of 2,4,5-T is usually as effective as higher rates (0.75 to 1 pound per acre) and gives more consistent results than lower rates. Therefore aerial-applications of 2,4,5-T at 0.25 pounds per acre with an equal rate of picloram or dicamba are the most widely used treatments for mesquite control. Under good growing conditions in late spring, 0.25 pounds per acre of 2,4,5-T has resulted in effective control. High rates, 1 or 2 pounds per acre, usually do not improve mesquite control but may control herbaceous weeds and associated brush. Soil applied, substituted urea herbicides such as monuron are effective but are not registered for use, and dicamba granules and picloram pellets have proved ineffective.

Mesquite is most susceptible to foliar sprays at 50 to 90 days after first leaves emerge in the spring. Any environmental factor which limits growth and development, limits effectiveness of the sprays. The leaves must be fully developed and turning dark green but not too heavily cutinized to allow entry of the herbicides from the leaves through the stems to the crown and roots. These conditions generally occur from mid-May to July 1. The time of movement of greatest amounts of food materials from leaves coincides closely with maximum movement of herbicides in mesquite. Maximum canopy development and leaf surface area are undoubtedly prime requisites for optimum activity of foliar-applied herbicides. Therefore, aerial broadcast applications of 2,4,5-T and related hormone herbicides are made only in the spring and under optimum growing conditions. The timing restriction regulates the acreage of mesquite sprayed annually. Spray effectiveness usually lasts from 5 to 7 years, often for 10 years and, occasionally, as long as 15 or 20 years.

Although the addition of picloram to 2,4,5-T may increase the number of mesquite plants killed because the combination is usually synergistic, effectiveness of the combination is regulated by the same factors that influence the activity of 2,4,5-T alone so that frequency and timing of application of the combination is essentially the same as for 2,4,5-T applications. The addition of picloram to 2,4,5-T also has usually increased the range of associated undesirable species controlled. Although the combination of dicamba with 2,4,5-T has not proven to be synergistic, several associated broadleaf weed species are apparently more susceptible to the mixture than to 2,4,5-T alone.

Many carriers and additives have been tested for the aerial application of herbicides to mesquite. None have proved consistently superior to a 1:3 or 1:4 diesel oil:water emulsion. For years, the herbicides were applied in 3 to 5 gallons per acre of carrier. However, based on recent research, carrier volume has been reduced to 1 gallon per acre for some areas of the State, reducing application costs and use of diesel oil. Low-volatile esters and amine salts are probably the most widely used 2,4,5-T formulations. Low-volatile esters are apparently the most popular when 2,4,5-T is used alone but the registered combinations containing dicamba and picloram contain amine salts.

Nearly 30 million acres of mesquite have been treated with 2,4,5-T in the past 30 years. However, economics, previous experience, and drought influence acreage treated in any given year. From 1961-1971, an average of about 900 thousand acres was sprayed annually in Texas varying from fewer than 600 thousand to over 1.1 million acres/year. However, on the average, only about 1 percent of the acreage needing treatment is sprayed per year. The total brush acreage in Texas probably could not be treated by all available methods in the average man's lifetime at the present rate of application even if all treatments were totally effective and retreatment was never necessary. Factors that limit mesquite spraying are:

1. Proximity of crops susceptible to growth-regulator herbicides.

2. Short time period in which mesquite is susceptible to sprays and the variation in herbicide effectiveness due to soils and growth form.

3. Fluctuations in weather and effect of drought on plant growth which reduce effectiveness of sprays.

4. Necessity for retreatment to maintain effective control.

5. Economics and the potential productivity of some rangelands.

Estimated Levels of 2,4,5-T Use

The average rate of 2,4,5-T used alone is 0.5 lb/acre and 0.25 lb/acre when applied in combination with picloram or dicamba. Based on brush-control patterns in the State for the last 20 years, a total of about 1.5 million acres of brush (about 3.8% of the acreage needing treatment and about 1.7% of the total acreage) are treated annually by chemical and mechanical means. An average of 900,000 acres are treated with herbicides, mostly 2,4,5-T or herbicides containing 2,4,5-T. Most of this acreage, probably two-thirds, are treated with 2,4,5-T at an average rate of 0.5 lb/acre. The remainder may be treated with 2,4,5-T in combination with other herbicides. Thus, it could be expected that about 375 thousand pounds annually would be used in the State for range improvement.

Cost for Use

Average costs for aerial application of 0.5 lb/acre of 2,4,5-T were about $5.50/acre (1977 prices). Cost of applying 2,4,5-T + picloram at 0.5 lb/acre total herbicide was about $10.50/acre and was $14.50/acre for 1 lb/acre of the herbicide mixture. Cost for 2,4,5,-T + dicamba at 0.5 lb/acre was about $8.50/acre. All costs varied somewhat among jobs, with the 2,4,5-T + picloram treatment being most constant. These costs per acre include herbicide, application, diesel oil, and flaggers.

Effect of Use on Commodity Yield

Influence of brush control on commodity yield is generally measured as changes in range forage production and/or changes in production of livestock products. Both of these aspects will be entertained in this section. However, it must be understood that broad generalizations are difficult since the magnitude of positive response of herbaceous range vegetation concomitant with decreased woody plant influence following herbicide application varies with:

1. Potential productivity of the range site. Vegetation on sites having deep fertile soils respond more quickly and to a greater magnitude following brush suppression than that on shallow soils (Scifres et al. 1974).

2. Rainfall conditions. Regardless of treatment effectiveness and edaphic potential of the range site for vegetation production, drought regulates the absolute extent of the response within any given year.

3. Effectiveness of the herbicide against the target species. Woody species associated with honey mesquite must also be considered since relative susceptibility varies widely among species.

4. Phytoxicity of the herbicide to herbaceous species. Herbicides containing 2,4,5-T usually reduce the broadleaved population immediately after broadcast spraying. Many broadleaf species are considered undesirable.

The influence of site potential, which also influences brush cover, on herbaceous vegetation response was demonstrated by Dahl et al. (1978). Three years after aerial treatment with 0.5 lb/acre of 2,4,5-T, Shallow Redland sites with a light original honey mesquite infestation (canopy cover = 5%) yielded only 120 lb/acre (oven-dry) more grass than adjacent untreated sites. However, a Valley site with a moderate to heavy mesquite infestation (canopy cover = 28%) yielded 330 lb/acre more grass and a Deep Hardland with a heavy mesquite infestation (canopy cover = 35%) supported 445 lb/acre additional forage compared to the same sites left under brush cover. The study was conducted in an area that normally receives about 22 inches of precipitation annually, but the workers failed to mention rainfall conditions the year of evaluation. Scifres and Polk (1974) found that herbaceous vegetation yield in the area after spraying a light infestation of honey mesquite increased in years of above average rainfall over that of unsprayed rangeland. Areas compared from June 1966 to November 1967 in a 36-inch rainfall area showed that 2,4,5-T sprayed pasture produced 16,570 pounds of dry forage/acre while the unsprayed pasture produced only 6,810 lb/acre. The extra 9,760 lb/acre of usable forage means 375 more animal unit days of grazing (Hoffman 1971).

An example of the interaction of rainfall and brush control with herbicides was reported by Scifres et al. (1977). The workers studied vegetation responses after spraying mixed-brush (Prosopis-Acacia) infestations along the Coast in Southeast Texas. The soil was a Sarita fine sandy loam, normally considered of good production potential and responsive to brush-management treatments. However, many of the species were not susceptible to 2,4,5-T alone so mixtures containing picloram or dicamba were also studied. The first year of study, about 28 inches of rainfall were received, most of which occurred during the growing season. The year of treatment, untreated brushy areas produced 4,800 lb/acre of grass. Yield of rangeland treated with 2,4,5-T was increased by 1,200 lb/acre. Rangeland treated with the herbicide combinations, at the same rate of total herbicide, was increased by 2,800 to 3,000 lb/acre.

If half of the extra forage were utilized by grazing animals and 26 lb/day of forage were required to sustain an animal unit (1,000 lb cow with calf or equivalent), the treatment would result in 54 extra days grazing per acre. Then, for every 6.8 acres treated, an extra acre of grazing would be generated with management practices which assures conserving integrity of the grassland ecosystem.

By the third year of the study of Scifres et al. (1977), the influences of resistant woody species and dry weather were exhibited with only 100 lb/acre increase from 2,4,5-T alone and a 600 lb/acre increase from 2,4,5-T + dicamba but a 2,400 lb/acre increase from 2,4,5-T + picloram over untreated areas. Only 2 extra days grazing per acre were generated by the least-effective treatment, but 46 days extra grazing were present on the best treatment, compared to untreated brushland, even during this stress period. During this dry period, the herbaceous cover of untreated areas was damaged because of the low amounts of forage available to sustain the range animal population. No significant damage occurred on the sprayed areas which, during the preceding years of adequate rainfall, had built a protective herbaceous cover. Thus, proper herbicide use is not only important from the standpoint of livestock production but also from the view of resource conservation.

Fisher et al. (1972) reported grass and forb yields from four locations in 1971 where the 2,4,5-T + picloram combination was applied for brush control 2 years earlier. Average forage grass yield on brushy pastures was 1,052 lb/acre compared to 1,710 lb/acre on sprayed rangeland. Average forb yield was 180 lb/acre on sprayed and 4.8 lb/acre on brush rangeland. These findings are consistent with the report of Cable (1976) concerning aerial spraying of mesquite in Arizona with 2,4,5-T. Cable concluded that "Perennial grass herbage production can increase dramatically following control of velvet mesquite (with 2,4,5-T), particularly if precipitation is above the long-time mean," and that "spraying velvet mesquite with 2,4,5-T in 2 successive years can provide long-lasting benefits. After 20 years, the sprayed area in this study is still producing significantly more grass than the unsprayed area."

Cross et al. (1976) evaluated aerial applications of 2,4,5-T on calf and lamb production at several locations from 1969 to 1974. Pastures of approximately the same size with similar infestations of honey mesquite, soils, and range conditions were selected for each study in the Rolling Plains, the Trans Pecos, and the Edwards Plateau resource areas.

One pasture at each location was aerially sprayed with low-volatile ester in June at 0.5 lb/acre in a total volume of 4 gpa of a diesel oil:water emulsion (1:3). A comparable pasture was left untreated. Grazing was deferred until fall after spraying on both treated and untreated pastures at each location. The pastures were then stocked with brood cows selected by the ranch operator. Calf weights were adjusted for sex at an average age of 9 months.

The average weaning weight of calves raised on the sprayed pastures was 541 pounds (318 calves), while the average weight of calves weaned from the untreated pastures was 518 pounds (311 calves) (Cross et al. 1976). The weight of lambs was essentially the same for both pastures for the period. Higher average gain for the lambs on the aerially sprayed pasture is thought to be due to the somewhat higher rate of stocking. Detailed economic analysis of 2,4,5-T use statewide is badly needed to accurately assess the importance of the production changes. Such an analysis is presently being undertaken by Texas Agricultural Experiment Station Scientists.

Too often, range-improvement practices are viewed solely from the standpoint of increasing agricultural production. The value of wise conservation practices, especially for future generations, is difficult to quantify. Woody plants, as will be described in the subsequent section, are of some value if present in proper quantities and at the appropriate place. However, excessive brush cover is of little value to man, his animals, or wildlife. Safe, effective herbicides are essential tools for approaching the objectives of sustained yield of range products while maintaining environmental quality.

Herbicide Use and Wildlife Habitat

Emphasis on quality wildlife habitat in development of range-improvement schemes by natural resource managers is no longer solely couched in an attitude of good conservation or simply for aesthetic motives -- game management has become an important economic consideration (Berger 1973). In some cases, Texas landowners are realizing net profits per unit area from hunting leases that approach or exceed those from livestock production (depending on livestock prices). Herbicide use may reduce, maintain, or improve habitat quality depending on range site, wildife species, maturity of the brush stand, and pattern of herbicide use. The basic dependency of game animals upon range vegetation for cover and food can be met, and livestock productivity simultaneously improved through the appropriate use of brush-management techniques including application of herbicides such as 2,4,5-T.

Grass release by reducing brush cover with sprays is a valid approach to habitat improvement for certain species of wildlife. Grass seeds are important dietary components of game birds such as mourning dove (Zenaidura macoura), bobwhite quail (Colinus virginianus), and wild turkeys (Meleagris gallopavo). By preserving key sites for nesting, roosting, and loafing cover, and, in the case of wild turkeys, fruits of woody plants as a food source, herbicides can be used to develop the range resource for bird hunting concomitant with increasing livestock production. For instance, bobwhite quail prefer lotebush for nesting and loafing cover in the Rolling Plains of Texas. Some mesquite is used during the summer months, but lotebush is preferred. Renwald et al. (1978) suggest that four large honey mesquite plants and two lotebushes are required per acre for bobwhite quail habitat. Since 2,4,5-T does not control lotebush and usually kills about 20 to 25 percent of the mesquite plants, use of the herbicide is not inconsistent with the habitat need of bobwhite quail.

The mourning dove is another important bird of many Texas range ecosystems including the Rolling Plains. Soutiere and Bolen (1976) studied nesting habits of mourning doves on tobosagrass-mesquite rangeland which had been sprayed, burned, or sprayed followed by burning. They concluded that spraying had no major effect on dove population since the temporary loss of some nesting sites in the trees was compensated by ground nesting and that ground nests were more successful than tree nests. As the surviving mesquite plants resprouted, the doves began to reestablish nests in the junctions of large branches. Ground nests did not suffer from excessive predation as compared to tree nests.

In the past, broad-scale overuse of herbicides on rangeland has most likely reduced quality of habitat for ungulates such as white-tailed deer. Complete treatment of large acreages reduces availability of browse and forbs for at least the season of treatment. However, recent research in Texas has shown that as much as 80 percent of mature mixed-brush stands may be aerially sprayed with herbicides such as 2,4,5-T + picloram without detriment to white-tailed deer habitat. By applying the herbicide in alternating strips, ample browse and cover for deer may be maintained (Beasom and Scifres 1977, Tanner et al. 1978). A critical concern is the interrelationship between forb production and diversity since white-tailed deer show pronounced seasonal requirements for certain key forb species which may be produced only on certain range sites (Beasom and Scifres 1977, McMahan and Inglis 1974, Tanner et al. 1978). Many of those forbs are highly susceptible to herbicides such as 2,4,5-T + picloram (Beasom and Scifres 1977). Strip spraying, properly planned, can be designed to preserve important forb species for white-tailed deer, improve livestock production and optimize the economic status of the management unit compared to no herbicide use (Whitson et al. 1977). Darr and Klebenow (1975) concluded that aerial spraying of brush with 2,4,5-T in north Texas had little detrimental effect on white-tailed deer and that, in some instances, spraying may have been beneficial. The standing dead tops provided screen for the deer and new sprouts from sprayed trees provided food and cover. This research is consistent with the finding of Beasom and Scifres (1977) since 2,4,5-T is not as detrimental to forbs as 2,4,5-T + picloram, and also since Darr and Klebenow (1975) evaluated the sprayed areas several years after treatment when the forbs had reestablished.

MECHANICAL, HAND LABOR AND FIRE METHODS

Mechanical Methods

Most mechanical brush-management techniques have evolved from two basic approaches, removing the aerial portion of the plant only or removing the entire plant, originally accomplished by hand labor or with animals.

Since energy and equipment-production costs have steadily and drastically risen, use of heavy equipment now must be carefully planned in the overall range-management effort. The more costly methods are feasible for use only on sites with high production potential (Scifres 1978). In many cases, mechanical brush-management techniques have been eliminated as potential range-improvement methods because of cost and low potential productivity of the specific range site.

Selection of a mechanical brush-management method depends upon objectives of the range manager, terrain, growth habit and density of the mesquite, associated potential problem species, and botanical composition of the desirable plant community. Each method has certain strengths and applicability to given situations, but also possesses characteristic weaknesses which restrict broadscale use. These factors must be considered when considering substitution of one method for another.

Shredding

In general, woody plants are not easily controlled by simple top removal methods such as shredding. Top removal by shredding may reduce canopy cover the season of application, but new sprouts readily develop from crowns and remaining stem segments of mesquite. For instance, removal of honey mesquite top growth was more effective in north Texas in May than in other months, but even at the best time (as related to plant control) for top removal, about 25 percent of the above-ground growth had been replaced by the end of the first growing season (Wright and Stinson 1970). The rate of top growth replacement depends heavily on growing conditions following shredding, especially rainfall. However even during dry periods after shredding, many species of woody plants replace their top growth more readily than shallow-rooted herbaceous species. On the short term, shredding is beneficial by improving visibility over the rangeland and releasing range forage. However, for maximum effectiveness on species such as honey mesquite, shredding may have to be repeated at relatively close intervals, probably at least every third growing season even in the more arid parts of Texas.

Repeated top removal of some woody species induces a change in growth habit but rarely reduces density. For instance, repeated shredding of honey mesquite causes the number of branches to increase, and the plant tends to spread along the ground rather than to grow upright. This growth habit tends to complicate management efforts in the long term since few alternatives, except herbicides, are applicable.

Heavy, durable shredders are required to withstand the rough rangeland terrain. Even with heavy equipment, shredding on hilly, rocky, rough terrain is not suggested. For such areas, equipment must move slowly, breakdowns are frequent, and labor is costly. Also, there is a definite size limitation on woody plants that can be shredded effectively with most equipment. Most efficient shredding is usually accomplished with plants of 2.5 inches stem diameter or smaller. Therefore, shredding is often used as a maintenance method since it is not effective on infestations containing larger trees.

Shredding is probably applicable to no more than 2 percent of the brush-infested areas of Texas except as used for maintenance of the effectiveness of other methods. Although the cost is relatively low (probably $4-$7/acre and to $10/acre for initial shredding), it usually costs more than 2,4,5-T and cannot be considered a viable alternative to herbicide use unless shredders of adequate size and durability are developed for use on areas which are normally sprayed (Hoffman 1978a). Some prototype shredders have been developed which fit the above criteria but cost of production of such heavy equipment most likely will greatly reduce or eliminate economic feasibility except on areas with no other viable alternative. Present availability of such equipment is seriously restricted. Costs for producing such shredders may be $60,000/unit or higher. No data are available on potential future availability of contract work with such equipment.

Following shredding in South Texas, the woody plant cover may be essentially replaced within 5 years. Thus, the beneficial effects on forage and livestock yield are temporary (approximately 2 years) at best. In the middle Gulf Coast, a mixed brush species area had to be shredded every 2 years for it to be considered an effective control method with no plants being killed during a 6-year study conducted by Hoffman (1978a).

Potential direct effects of shredding on humans are generally restricted to the operator. However, use of flail-type (rotary) shredders in brush presents a hazard from flying woody segments, rocks and other objects.

Environmental effects of shredding are not generally considered detrimental. Since desirable vegetation response is short-term, the effects on range animals are only temporary. Soil erosion is minimal and compaction is a problem only on relatively heavy-textured wet soils subjected to shredding equipment. Shredding has no known effects on water quality, sedimentation, or other components of quality aquatic habitat.

Roller Chopping

Roller choppers are constructed from heavy drums or cylinders with several blades running lengthwise with the roller. The weight and durability of the roller chopper adapts it to rough topography and to the dense woody plant stands normally encountered under rangeland conditions. Also, considerably larger plants can be roller chopped than can be shredded athough very large trees cannot be chopped effectively. The obvious disadvantage as compared to shredders is the power source required to pull and effectively operate the roller chopper. Roller chopping may leave a higher woody plant stubble than does shredding but not such that shredding cannot be used as a secondary or followup method. Considerable time may be required for the debris left by roller chopping to decay.

Efficacy of roller chopping, both short and long term, is very similar to that described for shredding (Mutz et al. 1978). Estimated cost of roller chopping using moderately heavy equipment is about $6.10/acre on Texas brushland. Roller choppers are available in a variety of sizes, and contract sources are generally available. Other environmental impacts are similar to those described for shredding. Roller chopping has been used most on areas supporting mixed brush stands, generally where spraying is not a viable alternative. Therefore, potential for increased use of roller chopping as an alternative to herbicide use is anticipated to be extremely low. Rolling choppers are best adapted to modify the seedbed prior to seeding adapted grass species following root plowing operations. It is expected that roller chopping will not strongly influence brush-management programs as a future management option and will likely not change range livestock production compared to its present influence. This method of brush control was abandoned by many land owners in the early 1950's because of the increased and rapid sprouting of woody plants.

Power Grubbing

Power grubbing is best adapted for control of thin, open stands of woody plants on sites with a good grass cover (figs. 1 and 2). Generally, 150-200 plants/acre is the upper limit for effective use of power grubbing. "Crown sprouters" such as mesquite must be uprooted well below the lowest dormant bud to prevent regrowth (Scifres 1973).

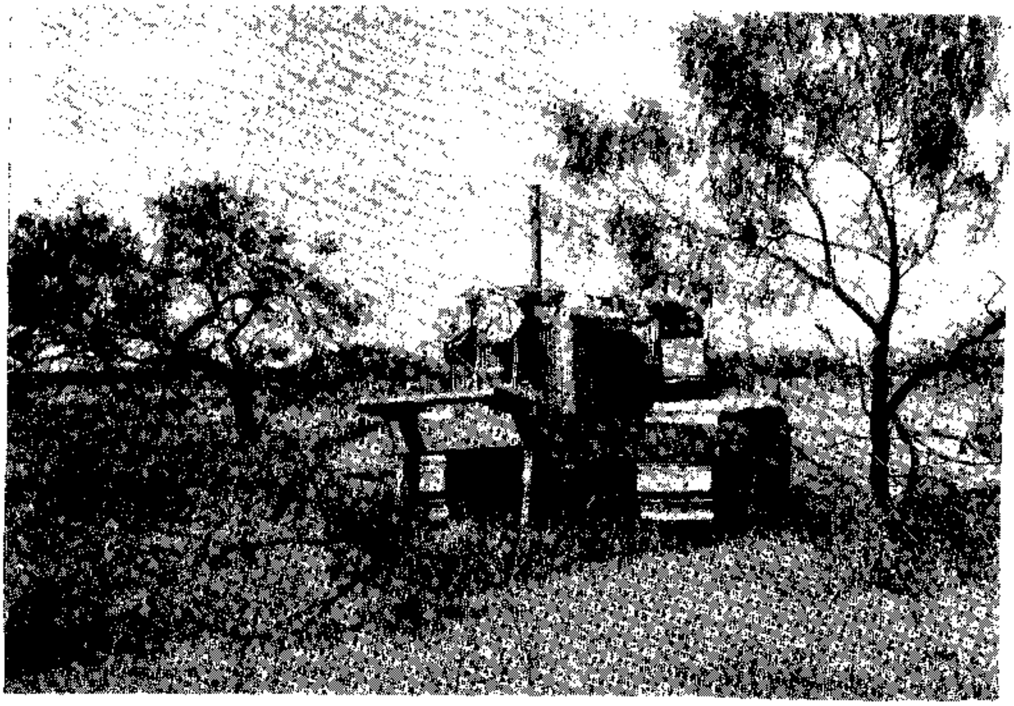


Figure 1. High energy tree grubber. Effective for remaining woody plants when density is less than 125 stems per acre.

Figure 2. Low energy tree grubber rear mounted on farm tractor. Crawler-type low energy grubbers are mounted on the front similar to the high energy grubber.

Generally, the most effective and economical situation for grubbing woody plants is when the soil is moist enough to allow a high percentage of the plants to be grubbed deep enough to prevent regrowth. On heavy clay soils that are dry and hard, more time is required for plant removal and many of the plants are cut off (leaving bud tissue intact) rather than being uprooted. Grubbing has not been successful on deep sands where heavy accumulations of soil occur around the base of the woody plants increasing the effective depth requirement for grubbing or where shallow rocky soils prevail.

Most effective control is usually obtained by grubbing sites where the woody plants are widely spaced and large enough to be easily seen by the equipment operator. Small plants are often missed, especially when the grubbing is done while the woody plants are dormant. Attempts to control dense brush stands by grubbing greatly reduces the grass cover. The surface is left extremely rough, and the operation can become very costly if high density stands are treated. Also, retreatment is usually necessary at regular intervals (every 2 or 3 years) to remove small plants that are missed, new seedlings that have emerged, and plants that were not completely destroyed by the initial grubbing operation.

The greatest restriction to the use of grubbing, by hand or with heavy equipment, is the lack of feasibility to dense brush stands. With densities of over 250 plants/acre, especially large plants, the power-grubbing operation essentially becomes one of plowing the land. Therefore, grubbing is restricted to light stands of brush composed mostly of small plants -- a maintenance operation. Yield of range forage and animal products is usually not significantly increased by grubbing but rather range improvement via some primary method is prolonged or reinvasion is avoided.

Cost of grubbing varies greatly depending on plant density and is difficult to estimate since the work is usually contracted on an hourly basis. Low-energy grubbers have been developed which decrease the operational costs compared to conventional equipment but are limited by plant density restrictions as is larger, more costly equipment. Wiedemann et al. (1977) compared high-energy (120 hp) grubber efficiency to that of the low grubber (65 hp) on mesquite in North Texas. Low-energy grubbing of infestations supporting about 10 trees/acre costs only about $1/acre at a contract cost of $25/hr for machinery operation. High-energy grubbing in approximately the same density costs about $1.84/acre at a contract cost of $40/hr; however, low-energy grubbing of a mesquite density of about 100 trees/acre costs about $7.50/acre. Consequently, when moderate-to-high densities of mesquite are considered, aerial spraying with 2,4,5-T is more than competitive with power grubbing, even low-energy grubbing, and does not cause the soil disturbance. Low-energy grubbing does have potential for control of moderately-dense stands of huisache (*Acacia farnesiana*) and similar species that are not susceptible to 2,4,5-T (Bontrager et al. 1978).

Power grubbing is of limited availability from contract sources. There is no estimate of the number of land owners which may have the capability of developing grubbing equipment, but cost of equipment and its conversion would most likely be prohibitive for many land managers.

Potential effects of power grubbing on humans are generally restricted to the operator. Unless equipped with a protective canopy, the operator runs the risk of being injured by falling remains of woody plants and debris during operations.

Direct environmental effects are generally related to damage of the grass cover by grubbing action of the blade. Pits left by the grubber collect and hold water and may be revegetated within a year in subhumid environments (Bontrager et al. 1978). However, under semiarid conditions, the pits may not be revegetated for 2 or more growing seasons. Artificial seeding of pits at the time of grubbing is recommended strongly to aid in re-establishment of a cover to reduce soil erosion and soil moisture evaporation to prevent a reduction of livestock-carrying capacity.

Since applicability of power grubbing is severely restricted by brush density, it is anticipated to have no significant future impact on range livestock production over its present influence, even in the absence of herbicides for brush control.

Chaining

The greatest value of chaining is the low inital cost of quickly knocking down, uprooting, and thinning out moderate to dense stands of medium to large trees (fig. 3). It is not effective for control of small, many-stemmed plants that are too limber to be uprooted. Many such plants will not be affected, or the tops are broken off at the ground surface causing a more dense infestation because of excess crown sprouting. "Double or two-way chaining," covering the area twice in opposite directions, will usually break off nearly all the above ground growth of woody plants and uproot from 10 to 80 percent of large trees when the soil moisture content is adequate. The need for two-way chaining varies with subsequent operations that are anticipated and ultimate use of the land. However, for maximum range improvement of areas supporting dense, heavy brush stands, two-way chaining is preferred over one-way chaining. Chaining is recommended where trees have at least 4 inch diameter stems and the population density does not exceed 1,000 plants/acre. Conducted properly, however, chaining has been accomplished in all sizes of vegetation; the upper limit in size and density of trees varying with tractor size and width of swath chained.

Chaining alone offers only temporary benefits (Scifres et al. 1976). However, when used in combination with other methods such as raking or aerial spraying, it usually reduces the overall cost of controlling troublesome species. In dense south Texas brush, chaining of areas sprayed 2 years previously was completed in about half the time required to chain unsprayed areas. Chaining 2 to 3 years following an aerial application of herbicides has been used extensively in northwest Texas for control of honey mesquite. The combination of aerial spraying,

Figure 3. Two-way chaining effective on trees with stem diameters over 4 inches. Raking is needed to remove debris of chained down woody plants for followup treatment of sprouts.

Figure 4. Root plowing generally is used to convert native rangeland vegetation to introduced forage plant. Root plowing should be followed by raking and burning woody plant debris, modification of seedbed, and seeding plus deferment from grazing until forage plants are established.

which is most effective on small plants, and chaining, which improves the kill by uprooting the hard-to-kill large plants, will give good control of species such as honey mesquite from 10 to 20 years before retreatment is necessary (Scifres 1973). The chaining operation causes soil disturbance when trees are uprooted. The bare soil is covered readily by annual weeds which reduce forage establishment, supply no food for game birds, and is a range fire hazard. Poisonous range plants also invade the disturbed area causing livestock death losses. Chained areas should be sprayed with 2,4-D to control broadleaf weeds and the spraying can be done only by aerial application (Hoffman 1975b). On range sites supporting mostly old trees, low in vigor with many dead branches, chaining followed by aerial application of herbicides to control regrowth offers a means of reducing the overall cost of control. The same general practices are occasionally used in stands of oaks. Also, as more effective herbicides are developed, the practice may have increased promise for management of south Texas mixed brush.

Chaining must be carefully applied to brush stands supporting pricklypear (Martin et al. 1974). High soil moisture content, conducive to effectiveness of chaining on most brush, may serve to seriously increase the pricklypear stand resulting in replacement of the original problem with an even more formidable species.

One-way chaining, based on 1977 prices, costs about $6.50/acre. Two-way chaining would cost about $9.50/acre and two-way chaining followed by raking, stacking, and burning the brush piles would cost about $22.50/acre.

Based on one study in a mature south Texas mesquite-dominated brushland, one-way chaining only slightly increased forage yield (Scifres et al. 1976). However, this forage increase was not greater than forage release which occurred after aerially spraying the same year with 2,4,5-T + picloram (Scifres et al. 1977). Moreover, the aerial spraying, based on 1977 prices, would cost about $14.50/acre contrasted to $22.50/acre for the mechanical practice.

Chaining is widely available, usually on a contract basis. However, with the rapidly increasing cost of energy and equipment, cost for chaining can be expected to increase significantly. Chaining, like most mechanical methods, does not generally have direct effects on humans except for tractor operators.

The acute environmental effects of chaining, especially broadscale use, are manifested by almost immediate and total destruction of wildlife habitat. When properly applied, however, chronic detrimental effects of chaining are generally considered negligible. Range vegetation is generally improved following proper application of chaining, but followup measures such as herbicide application are usually required to control plants which are broken off rather than being uprooted and for those with limber stems which were not pulled out by the chain. Large mesquite trees are slow to decay and should be raked to allow followup maintenance control with ground equipment. If large trees are not raked, which costs $10/acre or more, the only maintenance method left is to apply an effective herbicide such as 2,4,5-T by aerial broadcast. Chaining generally has no negative effects on water quality, sedimentation, or downstream water users.

Dozing

The bulldozer blade is not efficient for clearing rangeland. Large trees may have to be dug out of the ground for removal and small, limber stems simply break off under the weight of the blade. Bulldozers are most popular for removal of large trees especially with dense stands, and their use is usually based on economics rather than effectiveness. The conventional dozer blade or large V-blades are most commonly used. The plants are simply uprooted leaving large pits which may be of some benefit in trapping and holding moisture on the rangeland. However, dozing dense stands of trees drastically disturbs the soil leaving it open to erosion unless the surface is quickly stablized wth plant cover. Unless the operator is extremely cautious, valuable topsoil is removed and placed in mounds or windrow piles (Scifres 1978).

Efficacy of dozing as related to the target species is extremely high. However, when return of native vegetation is considered, effectiveness must be considered to be low since the soil is bared and the vegetation must be replaced via the long process of secondary succession. Most resource managers consider dozing only in preparation for reseeding the land. Dozing may cost from $50 to $150/acre depending on brush size and density. Dozing can result in loss of top soil left open to wind and water erosion until stabilized with vegetation which, if done artificially, adds substantial cost to the operation. Although brush dozers are generally available, anticipated future use is relatively low because of costs and environmental damage.

Dozing is highly destructive to wildlife habitat on rangeland in terms of both acute and chronic response. Dozing of moderately steep to steep slopes may accelerate water erosion and potentially increase sedimentation. Bulldozing as a control method is limited to about one-half percent of the infested mesquite acreage and is not an effective alternative.

Root Plowing

The root plow or root cutter severs the brush plants below the root zone preventing regrowth of nearly all brush species except those with shallow root systems, such as whitebrush and pricklypear (fig. 4). It is a highly effective method which kills all sizes of woody plants (Dodd 1968). However, root plowing usually destroys a high percentage of perennial grasses so revegetation is often planned as a followup measure. Total cost/acre ranges from $25 to $90/acre of plowing, seedbed modification and seeding (Hoffman 1976). Ultimate success of the operation depends on rainfall following root plowing. Generally, the highest survival of native and seeded grasses has resulted from root plowing and seeding during the late winter and early spring (Scifres 1978). When forage grass establishment is unsuccessful, another seeding operation is necessary which costs from $18 to $26/acre (Hoffman 1976). Although practiced in low rainfall areas, its best use is restricted to sites with best moisture relationships. Like chaining, root plowing may seriously worsen pricklypear problems by increasing the stand density (Dodd 1968). Although moisture infiltration rates are often increased by root plowing compared to untreated rangeland, moisture losses by evapotranspiration are accelerated which more than compensates for increased infiltration (Hughes 1966). Vegetation is usually of lesser grazing value following root plowing than on untreated rangeland for as long as 10 years (Mutz et al. 1978, Hughes 1966) because invaders are favored when the perennial sod is damaged. In Sterling County a root plowing-seeding demonstration conducted on heavily infested mesquite rangeland was seeded 6 consecutive years for an additional cost of $72.05/acre at 1967 prices. Woody plants which had invaded were treated three times during the 11 year study. In 1977, the area still did not have a satisfactory forage grass cover. Therefore, root plowing cannot be considered a feasible substitute, economically, ecologically, or managerial-wise for herbicides such as 2,4,5-T. It has applicability for about 3 million acres of specific rangeland sites which would not be treated with 2,4,5-T, initially.

Hand Labor

Grubbing is one of the oldest methods of physically removing individual plants (fig. 5). Early work was accomplished with shovels, axes, and the "grubbing hoe." Obviously, the work was painstaking, tedious, and slow. However, once the plant is grubbed beneath the lowermost dormant bud, its regenerative capacity is eliminated. Although there is an upper limit to plant size that can be hand grubbed, the primary requirement for its effective application is the availability of manpower. With present high labor costs and the need to cover relatively large areas, hand grubbing is no longer a feasible practice for large areas. It would be most difficult for hand grubbing to compete with power grubbing. For instance, if an area supports 10 trees per acre and an individual could remove a plant every 20 minutes steadily all day at a minimum wage of $2.65/hour with no indirect employer costs, hand grubbing would cost about $8.84/acre (an extremely conservative estimate). The same area could be power grubbed with

Figure 5. Hand grubbing of seedling woody plants. Labor generally not available for this kind of control.

low-energy methods for about $1.00/acre. Under the same conditions, a stand of 100 trees would cost $88.40/acre to hand grub (another conservative estimate since human efficiency would probably be reduced in the heavier stand) contrasted with $7.50/acre for low-energy grubbing or even $22.50/acre for two-way chaining, raking, stacking, and burning the debris. This can also be contrasted with a 1977 cost of only $5.50 for aerial application of 2,4,5-T. These contrasts must be considered optimistic since securing a labor force willing to grub mesquite for minimum wage would be a recruiting feat. If the average density grubbed was only 50 trees/acre and 20 minutes were required to remove a tree, two man days would be required to clear one acre. This may be contrasted to aerial application of herbicides during which four men (pilot + mixer + two flagmen) may easily spray 500 acres in a day (125 acres/man day). Since no data are available for direct use, such comparisons are difficult to make meaningful. However, the replacement of aerial spraying with hand labor on rangeland not only seems to lack feasibility, the consideration appears slightly ridiculous.

Use of hand labor, whether by grubbing with chain saws, shovels, or axes, greatly increases the potential of direct human injury during brush-management operations. Indirect damage from snakes, insects, thorns, and other natural causes would probably be substantial. Hand grubbing is not an alternative control except on areas around corrals, water areas, and fence lines where 2,4,5-T cannot be used.

Prescribed Burning

Prescribed fire is applied for brush management for either reclamation or maintenance purposes. Reclamation burns are installed under extreme conditions (high air temperature, relatively high wind speeds, low relative humidity) to facilitate maximum damage to the crowns of larger trees. On the average, about three such burns applied at 2-year intervals (6-year program) are required to equal the effectiveness of a single herbicide application relative to range improvement (brush suppression and forage release). Maintenance burns are used as followup measures to practices such as aerial spraying to augment range improvement and to extend the life of the initial practice (Scifres 1975, Dodd and Holtz 1972). Efficacy of burning is dependent upon a complex of interacting variables related to characteristics of the specific fire applied, climate, weather, the plant community, and growth habit of the target species including phenological stage at the time of the burn. Fire presently appears to have most application in areas with an average annual rainfall exceeding 22 inches. Fire generating maximum temperatures of 780°F around the plant will control mesquite plants 1.5 years old or younger (Wright and Bunting 1975). The same fire usually controls less than 10 percent of mesquite plants averaging 3.5 years old and did not kill plants 10 years or older. Mesquite plants with basal diameters of 0.5 inch or less may be killed by fire whereas those with diameters of 2 to 6 inches usually survive. Fire resistance increases with age of woody plants as lignification, trunk diameter, and bark thickness increase. Insect damage and other biotic pressures which alter state of tree health increase susceptibility to fire, but the influence of these variables may be relatively minor when overall range improvement is considered.

Neuenschwander et al. (1976) reported prescribed fire to burn down 3 to 80 percent and to kill 25 percent of the mesquite on a northwest Texas site. Following the fire, number of basal resprouts increased from 145 to 241 percent, but 60 percent of the new sprouts died by the end of the first growing season. Resprouts continued to develop thereafter until number of resprouts on plants in burned areas was similar to that of plants in the unburned area. These burns were applied under optimum fuel and weather conditions.

Costs of burn vary with objective of application of the fire and other factors, but can be categorized as those associated with: (1) Procedures necessary for fuel development of preparation. Examples are deferment costs for development of fine fuel or crushing or mashing to improve continuity of the coarse (woody) fuel prior to burning. (2) Installation of fire guards including equipment and personnel requirements. (3) Installation of the burn primarily as related to personnel and fire safety equipment. Include time for patrolling of fired area after burn out. (4) Deferment of grazing after burning to allow adequate development (regrowth) of range forage plants.

Forage response following burning is highly dependent upon rainfall. In an area of 24 to 28 inches average annual precipitation, herbage yields following burning in the spring were increased 41 percent whereas forage increase was only 13 percent in a year when only 6.5 inches of rainfall were received (Wright 1974). During the wetter year, burning increased yields of little bluestem but did not affect yields of sideoats grama or tall grama. During the dry year, production of all three species was lower on the burned area. Thus, a prime consideration in use of fire compared to aerial spraying is the increased risk and uncertainty regarding extent of range improvement. Benefits of fire not shared by other methods include improved palatability of rough forage plants, potential reductions in parasite loads on range animals, and improvement in livestock distribution over the range. Efficacy of range burning for long-term improvement of mesquite brushlands would apparently depend on repeated use over a relatively long period of time.

The availability of fire for use in range improvement is limited by (1) attitudes concerning use of burning and (2) level of present technology related to fire and brush management. Although it may be considered of general availability, potential of broadscale, proper application of burning is still relatively limited. With our present levels of technology, fire might be applied to 10 percent of the brushland of Texas successfully. Proximity of urban areas is always a prime consideration in the application of fire.

Potential direct detrimental effects of fire on humans, considering the entirety of the population, are extremely low from range burning. Fires are usually applied considerable distances from urban areas and smoke and particulate matter are only short lived in the atmosphere and usually confined to the area surrounding the burn. The greatest potential direct effect is upon the individuals installing the burn or upon the property and person of the individual owning the land being fired. Although no data are available, damage to persons and property by prescribed burns is considered extremely minor and not to be confused with damage incurred by periodic wildfires. Yet, when compared to aerial spraying, the potential for direct injury to humans must be considered significantly greater than herbicide use.

The environmental impact of prescribed burning depends on intensity of the fire, plant community burned, soil characteristics, and physical characteristics. One of the most important variables is slope of area burned in relation to soils and rainfall as they influence soil loss. Wright et al. (1976) reported that accumulative soil losses within 18 months after burning steep slopes in northwest Texas reached 5 to 7 tons/acre. Such losses have not been observed on level to gently undulating lands in southeast Texas, on heavy clay soils, and where the long growing season allows relatively rapid replacement of the vegetative cover following fire.

The short-term effects of fire on the vegetation depend on weather following the burns, intensity of the burn, and composition of the vegetation. Improperly applied, range fires can exert serious detrimental effects on vegetation requiring years for recovery. Applied under proper conditions, the effects of fire are usually highly favorable. Shrubs are suppressed and herbaceous species including native legumes are augmented both in presence and total yield. The resultant effects of fire on the vegetation are generally directly reflected in welfare of the animals on burned rangeland. Properly applied, range animal populations (both domestic and wild) are benefited. Improperly applied or followed by drought conditions, the effects of fire on range animals, especially livestock, may be extremely detrimental. If applied under stress conditions followed by drought, or on excessively steep slopes, burning has the potential of accelerating soil erosion, increasing sedimentation, and reducing water quality on downstream users. However, under the present use pattern, it is doubtful that such occurrences would be significant.

Although fire has potential of becoming a more important brush-management tool, it is not viewed as an alternative replacement for herbicide use in Texas. Rather, it is considered a tool for use in conjunction with herbicides because: (1) Reclamation burning is a slow, tedious process which does not fit well with most range-management enterprises. One herbicide application can probably be viewed, relative to the effects on vegetation, as roughly equivalent to 2 or 3 reclamation burns. (2) Present status of fire technology is far behind that concerning herbicide use. Effective fire plans are yet to be developed for many of the situations which exist on Texas rangeland. (3) The need for repeated burns required for significant suppression of crown sprouters such as mesquite, increases the risk and uncertainty to management. (4) Prevailing attitudes concerning fire seriously restrict its application. Even if appropriate technology were available, a massive educational effort would be required to facilitate understanding of fire behavior and the practical application of burning.

Average cost of fire is estimated at $1.00/acre for the inital burn and $0.50/acre for subsequent burns under good management and depending on size of management unit burned.

POTENTIAL IMPACT OF NO CONTROL EFFORTS

The impact of "doing nothing" relative to mesquite control will vary significantly among vegetation regions of the State and among ranches within vegetation regions. Therefore, the most logical view is probably one which considers the potential overall impact. Osborn and Witkowski (1974) evaluated potential impact of unrestricted brush encroachment on a 130-county area in the western half of Texas. They estimated mesquite encroachment for reducing range herbage by an equivalent of 924,000 to 1.8 million cow-producing units in that 130-county area alone. They also felt that total output of range livestock could be increased from 12 to 23 percent if mesquite did not exist. In addition, total economic activity in the State is decreased by over $400 million because of the loss of herbage production resulting from the mesquite infestation based on economic activity in 1967. The investigators felt that the reduced economic activity is delaying or discontinuing private investment in that industry, resulting in a regressive attitude in the private sectors. As a consequence, decision makers in the public sector have a decreasing base on which to establish repayment schedules for capital improvements. These economic impacts do not consider potential losses of water, reductions in water quality, or reduced wildlife habitat quality.

OAKS, OAKLAHOMA AND TEXAS

The primary oak problems influencing range livestock production are the post oak/blackjack oak complex (*Quercus stellata/Q. marilandica*) and sand-shinnery oak (*Q. havardii*). Oak infestations reach from central and west Texas to western and northern Oklahoma.

Although post and blackjack oaks are common to Texas and Oklahoma, they will be entertained separately since associated woody species vary. Winged elm (*Ulmus alata*) and eastern redcedar (*Juniperus virginanus*) probably are the most common components in both the northern and southern extremes but, for example, yaupon (*Ilex vomitoria*) does not occur to any significant extent in Oklahoma. Yet, it is common in southeastern and southcentral Texas and influences range recovery after control methods are applied to the Post Oak Savannah.

ESTABLISHED MANAGEMENT GOALS

The primary management goals for oak-infested grasslands are identical to those cited for Texas mesquite on rangeland. These goals generally relate to increased range-forage production and utilization, improved labor efficiency, moisture conservation, enhanced environmental quality, and improved wildlife habitat.

THE PROBLEM

The Post Oak Savannah physiographic province occupies more than 11.3 million acres of gently rolling to hilly lands in eastcentral Texas

(Gould 1969). The concept of savannah used here is outlined by Dyksterhuis (1957). Savannah is recognized as a grassland with isolated trees which are of considerable value in furnishing livestock shade. According to Dyksterhuis "On a nonarable site where the climax cover is savannah, the proper use is most likely to be natural pasture (range)." At one time, a vast savannah reached from south central Texas to northern Oklahoma. However, the cessation of natural fires and heavy grazing have "hastened the dominance of woody species" with concomitant reductions in range forage. Increasing cover of woody plants closes the savannah, converting them to almost impenetrable thickets. Millions of acres in the Post Oak Savannah physiographic province of Texas now support dense thickets which almost eliminate forage production. Whereas annual forage production on much of the Post Oak Savannah should reach 6,000 to 8,000 lb/acre, much of the area is producing less than 500 lb/acre. Stocking rates of unsprayed pastures were 30 to 40 acres/animal unit while stocking rate following spraying was 14 to 16 acres per animal unit (Hoffman 1978a).

The post oak/blackjack oak association is also common in much of the Cross Timbers and Central Basin physiographic provinces (Darrow and McCully 1959). It is estimated that 11.3 million acres of East Texas, most of which has high forage-production potential, are occupied by these oaks and associated woody species rather than producing range forage.

Blackjack and post oaks are major problems on an estimated 6 million acres in the central Cross Timbers, in the northeast Ozark highlands, and in the southwest Quachita highlands of Oklahoma (Elwell et al. 1970). Sand-shinnery oak is a major problem on an estimated 1 million acres in the western Rolling Red Plains area in Oklahoma (Elwell et al. 1974).

Low-growing, shrubbing oaks, or "shin oaks" also infest about 8.7 million acres of Texas rangeland (Rechenthin and Smith 1967). About 3 million acres of the High and Rolling Plains of Texas alone are infested with sand-shinnery oak. It has been suggested that controlling 70 percent or more of the sand-shinnery oak in dense infestations would conserve the equivalent of 2 inches of rainfall annually and leave ample brush for wildlife cover (Rechenthin and Smith 1967).

Biology/Ecology of Plant Communties Associated with Oaks

Blackjack oak is associated with post oak, forming the overstory in the Post Oak Savannah of Texas (Scifres and Haas 1974). Where the range deteriorates primarily from grazing abuse, the oaks increase in density and a secondary woody layer of difficult-to-control species such as yaupon and winged elm develops. Low-growing shrubs and vines common to these woodlands include saw greenbriar (Smilax bona-nox), skunkbush (Rhus sp.), southern dewberry (Rubus trivalis), gum bumelia (Bumelia languinosa), coralberry (Symporicarpos orbiculatus), Mexican plum (Prunus mexicana), and American beautyberry (Callicarpa americana). On certain sites, species such as downy hawthorne (Crataegus mollis), sugar hackberry (Celtis palida), and common honeylocust (Gleditsia triacanthos) may be present in limited quantities. Although not normally considered a component of the Post Oak Savannah, willow baccharis (Baccharis salicina) is becoming an invader of abandoned cultivated fields and disturbed areas. This complex is composed of stem, root, and crown sprouters which complicate the management problems.

Upland soils in the Post Oak Savannah of Texas are sandy, and the lowlands range from sandy loams to clays (Scifres and Haas 1974). Excellent forage grasses such as little bluestem (Schizacyrium scoparium), Indiangrass (Sorghastrum nutans), and switchgrass (Panicum virgatum) usually occur under good grazing management in open areas and especially where brush control has been used as a range-improvement technique. Potential herbaceous vegetation also includes purple top (Tridens flavus), silver bluestem (Bothriochloa saccharoides), and Texas wintergrass (Stipa leucotricha). Deterioration of the grasslands is indicated by invaders such as annual threeawns (Aristida sp.), red lovegrass (Eragrostis oxylepis), broomsedge bluestem (Andropogon virginicus), splitbeard bluestem (Andropogon ternarius), and common broomweed (Xanthocephalum dracunculoides).

Landowners in Texas liked the advantages of oak brush management with 2,4,5-T over mechanical methods because: (1) it did not disturb the soil; (2) better range forage plants re-established faster; (3) less sprouting from stumps; and (4) it is not such a complete and sudden "shock" to soils and plants (Hoffman et al. 1950-77).

The oaks are a part of the climax communities on many of the soils of Oklahoma (Gary and Galloway 1969). However, they have largely become thicketized, presenting management problems similar to those described for the Texas Post Oak Savannah. Highly productive bunchgrasses have been replaced by much lesser productive shade-tolerant grasses, especially annuals.

Sand-shinnery oak infests deep sands or sandy soils with shallow clay layers near the surface (Robison and Fisher 1968). Most sand-shinnery oak plants are 2 to 4 feet tall but circular mottes of plants 6 to 12 feet tall occur in most stands. The mottes afford excellent wildlife cover. Sand-shinnery oak reproduces from acorns and well-developed, lateral rhizomes. Rhizomes occur in the surface 6 inches of soils and have small but viable buds along their entire length (McIlvain 1956). The underground portion of sand-shinnery oak may comprise 90 percent or more of the total biomass (Pettit and Deering 1970) and, upon release from apical dominance by top removal, resprout profusely.

Sand-shinnery oak is normally associated with species such as small soapweed (Yucca glauca) and sand sagebrush (Artemisia filifolia). Climax communities are dominated by species such as little bluestem and other productive bunchgrasses. Climax communities can be reinstated by application of selected range-improvement techniques followed by good grazing management.

IMPACT ON COMMODITY YIELD AND MANAGEMENT STRATEGIES WITH HERBICIDES

In Texas, blackjack and post oaks can be controlled by applying 2,4,5-T in frills on the trunk, to cut stumps as basal sprays on individual plants (Darrow and McCully 1959). About 16 lb (acid equivalent) of herbicide per 100 gal of diesel oil are recommended for such treatments. Foliage sprays of 2 to 4 lb/acre in at least 20 gal/acre of total solution are effective with ground broadcast application equipment. However, where the woody plant cover is dense and large trees are a part of the stand, aerial spraying is the only feasible method of applying broadcast treatments. Aerial herbicide sprays are most effective when used in a 2 or 3-year program. The first application requires 2 lb/acre of 2,4,5-T in 4 or 5 gal/acre of a diesel oil:water (1:3 or 1:4) emulsion followed the next year or the year after by application of 1.5 to 2 lb/acre of 2,4,5-T. Results from a 6-year study conducted in Erath County comparing low volume (1 gal/acre of diesel oil) to standard (4 gal/acre of oil:water emulsion volume) produced equal oak control and resulted in a savings of $0.75/acre advantage of application for the low volume technique. A 2 lb/acre rate of 2,4,5-T was applied each year for two consecutive years (Hoffman and Gary 1968).

For conversion of oak brushland to grassland, 2,4,5-T has been the standard herbicide treatment for more than 25 years. Meyer et al. (1970) reported that picloram (4-amino-3,5,6-trichloropicolinic acid) was more effective for control of mixed hardwood brush in east Texas than 2,4,5-T, dicamba (3,6-dichloro-*o*-anisic acid), or isocil (5-bromo-3-isopropyl-6-methyluracil). However, picloram failed to control white ash (*Fraximus americana*), saw greenbriar or redbay (*Persea barbonia*). Mixtures of 2,4,5-T and picloram resulted in better overall levels of brush control than either herbicide alone at the same application rate. Therefore, the herbicide mixture is gaining in popularity for oak control, especially for maintenance control. At 39 months after application to 4-year-old oak regrowth, plots near College Station sprayed with 2,4,5-T + picloram supported 1,267 lb/acre of grass standing crop. Where the regrowth was untreated, 806 lb/acre of grasses were harvested and brush regrowth cover was increasing. The standing crop difference represented 5 to 7 animal grazing days per acre (Scifres and Haas 1974). Landowners in Texas stated that stocking rates increased from 30 acres/animal unit to 11 acres/animal unit and range improved from poor to good condition in 2 years following control with 2,4,5-T. Also, calves marketed from treated areas averaged 100 pounds per animal more than calves grazing on untreated pastures. A 6-year study in Erath County showed that a pasture sprayed with 2,4,5-T had a stocking rate of 8 acres/animal unit of stocker cattle as compared to an unsprayed area with a stocking rate of 15 acres/animal unit (Hoffman and Gary 1968). Darrow and McCully (1959) reported that forage yields decreased over a 4-year period from 453 lb/acre to 223 lb/acre where Post Oak Savannah was allowed to progressively thicken. Where the woody plants were removed, forage yields increased from 545 lb/acre to 1290 lb/acre over the same period. Elwell et al. (1974) reported that grass yields from blackjack and post oak-infested areas of Oklahoma produced from 100 to 900 lb/acre depending on moisture conditions, management practices, and location in the state. If 50 percent of this forage is used by livestock and 26 lb/day are required to sustain an animal unit, the brushy areas would afford 2 to 17 animal unit day's grazing (i.e. from 21 to 182 acres would be required for each animal unit yearlong). Following spraying with 2,4,5-T, herbage yields ranged from 2350 to 4000 lb/acre. Thus following treatment, only 5 to 8 acres would be required per animal per year even with leaving half the standing forage for range improvement.

Yield increases of 10 fold have resulted in some instances following application of 2,4,5-T for oak control in Oklahoma and 2 to 4 fold increases are quite common (Elwell et al. 1974, Stritzke et al. 1975). Oak infestations also cause management problems in addition to reducing range forage yield. Numerous cattle deaths are reported each year due to oak poisoning (especially from shinnery oak) where good range grazing management is not practiced. Problems of handling and care of livestock in areas supporting oak infestations are similar to those discussed for mesquite.

The rate of 2,4,5-T used for oak control usually varies from 1 to 2 lb/acre. Low-volatile ester formulations are generally preferred. Most 2,4,5-T is applied by aircraft. The number of acres treated each year in Oklahoma varies from 100,000 to 400,000 depending on the economic outlook especially relative to the livestock market and suitability (adequate moisture etc.) during the spray season. The two consecutive treatments of 2 lb/acre are usually applied to stands supporting large trees over a dense understory. The first application removes the overstory to allow maximum penetration of the understory application by the second spray application. Young sprouts may be sprayed with 1 lb/acre every third year as a maintenance treatment. The level of use is now considered minimal and can be expected to increase as additional food production is needed. Cost of "turn-key" spray jobs varies from $9 to $15 depending on size of job and herbicide rate. Because 2,4,5-T is effective for controlling oaks and livestock, carrying capacity has usually doubled following treatment. Consumer savings from the added beef produced in Oklahoma were estimated at $15,880,000 in 1971 (Richardson 1973).

Dense sand-shinnery oak infestations severely reduced grass production in northwest Texas and western Oklahoma. Management of infested range is complicated by sand-shinnery oak's toxicity to livestock and livestock poisoning is routinely reported (Dollahite et al. 1966, Boughton and Hardy 1936). The species is most poisonous during flowering and before formation of new leaves in the early spring when forages are of low availability (Robison and Fisher 1968).

About 0.5 lb/acre of 2,4,5-T is used for sand-shinnery oak control (Robison and Fisher 1968). Applications from May 1 to June 1, when shinnery oak is in full leaf and actively growing, are most effective. Spraying plus grazing deferment increased forage production 3 to 5 times as compared to unsprayed and deferred sand-shinnery oak ranges in the Rolling Plains of Texas. These forage-production responses under proper management may double or triple livestock-carrying capacities by the year after spraying. However, two or three successive applications of 2,4,5-T are usually required to maximize grass production on sites infested with sand-shinnery oak.

MECHANICAL, FIRE AND HAND LABOR METHODS

Hand removal of standing oak brush in Oklahoma varies from 2 to 128 hours at a cost of $5.30 to $339.20/acre, depending on brush infestation (Elwell et al. 1974). Some firewood may be salvaged from these areas to offset the cost of clearing. For example, it took 74.5 hours (at a cost of $197.43) to clear an acre and 15.5 cords of firewood were obtained in one study (Elwell et al 1974). A net profit of $10/cord of firewood, could pay for about half of the labor cost associated with clearing. Since cutting does not kill the oaks, resprouting from the base of the cut stumps results in 3 to 4 times the number of stems as in the original stands. These resprouts usually overgrow the grass in 3 to 5 years and control at this time by cutting would be more difficult. Also, no income from firewood could be expected. Mowing of such resprouts does little to decrease the number of sprouts, and oak brush is still a major problem on areas mowed repeatedly for as long as 20 years (Elwell et al. 1974). Such areas must be mowed every 2 years to control sprout growth. Forage production from mowed areas is usually only slightly better than where the brush sprouts are not controlled and some forage is sacrificed during the mowing operation.

Burning in Oklahoma has not been effective for oak control and the number of new sprouts increased 59 percent with 2 annual burns (Elwell et al. 1974). In general, burning is no more effective than mowing and some forage must be reserved as a source of fine fuel rather than utilized by grazing animals.

Hand removal of thicketized oak brush is not practiced to any significant extent in Texas because of the shortage of labor willing to become involved in the task, and density of the woody plant cover. Much of the understory vegetation is composed of multistemmed species and vines which have no value as firewood or as posts. Cutting is only a temporary method of control since resprouts quickly develop following top removal of these species. Scifres and Haas (1974) reported that post oak and blackjack oak developed regrowth within a month after cutting. At 1 year after top removal, 90 percent of the oak stumps supported sprouts exceeding 3 feet tall which averaged over 1.5 inches in diameter at the base. The researchers estimated that 50 percent of the original canopy was replaced within a year after top removal although plant height was reduced. Understory species such as winged elm demonstrated even greater regrowth potential. Thus, top removal whether by hand cutting or with heavy equipment offers only temporary release from competitive pressure of woody plants in the Post Oak Savannah. A single application of sprays containing 2,4,5-T + picloram (1:1) at 1 to 2 pounds per acre total herbicide resulted in a 66 percent reduction in canopy cover of the oaks after 39 months in the same area (Scifres and Haas 1974).

Followup treatment is required the year after top removal and unless the original brush removal was done so that no stumps remained, shredding the year after treatment would not be feasible. Generally, herbicides such as 2,4,5-T or 2,4,5-T + picloram are the most effective treatments for maintenance of oak control.

Burning is not widely practiced in the Post Oak Savannah of Texas. The overstory woody cover should be removed to release fine fuel for the fire to carry effectively. In general, 2,500 to 3,000 pounds per acre of fine fuel as continuously distributed as possible are required for effective range burns. Only scattered herbaceous plants occur in thicketized Post Oak Savannah.

Chaining effectively reduces the woody plant cover in the Texas Post Oak Savannah, but because of the size and density of the woody plants, relatively large equipment is required. Costs may exceed $50 per acre for this practice (compared to $20 for mesquite) since the debris must be stacked and burned to allow use of the rangeland following treatment. Dozing is generally practiced only on those lands contemplated for conversion to tame pasture [Coastal bermudagrass (*Cynodon dactylon*) or bahaigrass (*Paspalum notatum*)]. This practice now costs from $50 to $180 per acre depending on brush density and intensity of land preparation for the conversion.

Mechanical treatment of sand-shinnery oak is not considered feasible and because of its growth habit, manual removal is not considered. Scifres (1972) worked with a typical sand-shinnery oak stand in northwest Texas, 70 to 90 thousand stems per acre from 2 to 4 feet tall, which allowed production of only 150 to 190 lb per acre oven-day range forage. Since sand-shinnery oak occurs on sandy, unstable soils, essentially no soil disturbance can be tolerated without risk of serious erosion. Consequently, Scifres (1972) suggested that no more than 70 percent of the shinnery oak cover be removed with herbicides to protect against the possibility of soil losses. Since sand-shinnery oak reproduces vegetatively from a well-developed rhizome system, only temporary benefits are realized from practices such as shredding. Essentially all of the rhizome must be removed for sand-shinnery oak control so grubbing (whether by hand or with power equipment) is not feasible. Burning would have to be applied with extreme caution because of the low rainfall areas in which sand-shinnery grows. Consideration for maintaining a vegetative cover to stablize the sandy soils following control of sand-shinnery oak is critical to successful improvement of infested ranges. Therefore, the most feasible treatment for management of sand-shinnery oak stands in north Texas has been the aerial application of 0.5 to 1 pound per acre of 2,4,5-T in a 1:3 or 1:4 oil:water emulsion. Control of sand-shinnery oak and concomitant forage release is improved when the 2,4,5-T + picloram mixture is used in lieu of 2,4,5-T only (Scifres 1972). The herbicide mixture performs in a synergistic fashion, much in the same way as when applied for mesquite control. Retreatment schedules for maintenance of sand-shinnery oak control with herbicides depend upon livestock-management programs devised for infested rangeland.

CHAPTER 2: PART 2
ECONOMIC IMPLICATIONS OF 2,4,5-T USE ON PASTURE AND RANGELANDS

INTRODUCTION

A partial economic analysis was done for rangelands infested with mesquite, post-blackjack oak, and sand-shinnery oak. This section also discusses noxious plants in U.S. pastures and rangelands. These plants include mesquite, post-blackjack oaks, sand-shinnery oak, hardwoods, cactus, yucca, poisonous plants, desert shrub plants, fence-rows, and miscellaneous woody plants.

Sufficient data were not available to do more than narrowly describe the practices and benefits in controlling these minor species.

Costs and returns of chemical-control methods including 2,4,5-T, silvex, dicamba, and other noneffective herbicides were compared. Costs and returns of mechanical-control methods are presented to demonstrate the comparative costs of these alternatives. Using these costs and returns the economic impacts of the unavailability of 2,4,5-T and/or silvex are presented. A no-control alternative is presented for informational purposes.

METHODOLOGY AND ASSUMPTIONS

1. The analysis compared the economic effect of these scenarios; i.e., (1) availability of 2,4,5-T for use on rangeland versus nonavailability of 2,4,5-T; (2) availability of 2,4,5-T for use on rangeland versus nonavailability of 2,4,5-T and silvex; (3) availability of 2,4,5-T for use on rangeland versus no-control measures.

2. The economic analysis was limited to the rangeland areas that need 2,4,5-T for effective mesquite and brush management.

3. The 1973-77 average production and value of beef were assumed to be representative of production and value of beef that would occur in the 16-year analysis period, if 2,4,5-T were unavailable. The 16-year analysis period was selected because 16 years was the longest period between treatments. It was assumed that this period was adequate to demonstrate the short-term to mid-term effects of mesquite and brush on rangeland without 2,4,5-T.

4. Partial budgets, considering only materials and cultural practices that changed, were used to estimate cost differences of 2,4,5-T and alternative mesquite and brush-control programs. The partial budgets were developed by research and Agricultural Extension Service personnel in respective areas.

5. Only beef production effects of mesquite and brush on rangelands were considered in estimating economic losses associated with the lack of 2,4,5-T.

6. The analysis assumes that no new herbicides that control the mesquite and brush complex susceptible to 2,4,5-T will be registered for use in controlling mesquite and brush on rangeland during the time period considered in the analysis.

MESQUITE

Mesquite, Prosopis spp., occupies 93 million acres in the Southern Great Plains, Southern Rocky Mountains, and Pacific Southwest Range regions (Platt 1959) with the largest concentration occurring in Texas which has 56 million acres (Hoffman 1975b). Mesquite densities increased following the droughts of 1917-20, 1930-35 and 1951-57 (Hoffman et al. 1978). Before World War II, landowners could maintain the mesquite density by hand grubbing and pouring kerosene around the base of each individual tree. As available labor was reduced and oil became more expensive, these methods had to be abandoned because of economics. Following World War II, mechanical methods of chaining, tree grubbing, roller chopping, dozing, and root or rock raking were available (Scifres et al. 1973). Root plowing began in the 1950's. Mechanical methods used alone proved unsuccessful in that landowners had to apply another control method on the same area within 3-5 years except following root plowing (Hoffman et al. 1950-77). Range recovery by native forage species was very slow, and since root plowing disturbed the entire turf, artificial seeding had to be done. Establishment was slow and about 60 percent of the time unsuccessful. Each seeding operation of preparing a seedbed, cost of seed, and packing following seeding cost from $12 to $20 per acre in the 1960's. Current cost would be about $20 to $30 per acre.

More economical and faster control methods had to be obtained as mesquite density was increasing and reducing livestock-carrying capacity. The herbicide 2,4,5-T was tested in the late 1940's and early 1950's and proved highly successful for control of mesquite when applied by air-broadcast methods after leaves had matured in the spring.

From 1951 to 1977, county Extension personnel conducted 8,108 demonstrations for mesquite control comparing applications of 2,4,5-T herbicide and mechanical methods to determine which was most successful for a particular range site. (Hoffman et al. 1950-77). In these tests, 3,018,187 acres were controlled with 2,4,5-T and 1,603,207 acres were controlled by mechanical methods. The 2,4,5-T air-broadcast control program developed by the Extension staff and research workers was that an area treated one year did not receive another herbicide treatment for 5 to 10 years with the shortest treatment interval occurring in the east central part of Texas. Combinations of chemical and mechanical methods were demonstrated to determine the interval of each treatment. The customary sequence is to first treat the tree-type mesquite with 1/2 pounds per acre of 2,4,5-T air-broadcast method which allows fastest native forage plant recovery followed by mechanical chaining 3 to 5 years later, then air-broadcast treatment of 2,4,5-T at 5-to 10-year intervals following the chaining. Mechanical grubbing and/or individual spot treatment with 2,4,5-T are used when the mesquite density is reduced to 125 trees or less per acre (Scifres et al. 1973).

Root plowing in the tree-type mesquite area is limited to the more productive range sites that receive additional water which allows the plowed area to support tame pasture forage plants (Scifres et al. 1973). Areas that are root plowed generally would not receive broadcast applications of 2,4,5-T as the initial treatment. The application of 2,4,5-T would be used to control regrowth and seedlings. Root plowing is not considered an alternative control method and cannot be substituted for the acreage treated each year with 2,4,5-T because of total cost per acre and the high energy required to operate crawler-type tractors (Hoffman et al. 1978). A D-8 or equivalent size tractor can plow about 2 acres per hour.

Two-way chaining is a one-time control method for tree-type mesquite as the stems must be 4 inches or more in diameter for the tree to be uprooted by the chaining operation (Scifres et al. 1973). In areas with less than 22 inches of rainfall, it requires about 25 years before mesquite trees attain a 4-inch diameter before a second chaining operation would be successful (Hoffman et al. 1978).

Other mechanical methods, such as roller chopping, shredding, or dozing, remove top growth of mesquite, causing excessive crown sprouting and providing only temporary control. These methods are not considered alternatives to 2,4,5-T foliage sprays for control of mesquite. Generally all mechanical-control methods reduce forage production for 1 to 3 years unless annual broadleaf weeds are controlled with 2,4-D (Hoffman et al. 1978).

Use of fire is not effective for control of mesquite with stems over one inch in diameter. Many areas will not produce sufficient fuel to induce a hot fire to kill the root crown.

Research and demonstration results indicate that dicamba in areas 1, 4, and 5 (fig. 6) is erratic and this herbicide cannot be designated an alternative as it produced less control than 2,4,5-T at most locations, but costs about $2.50 per acre more than 2,4,5-T. In areas 2, 3, and 6 from the 100th meridian to Highway 90 in Texas, dicamba, (Banvel^{R}) has a potential to substitute as a foliage spray for 2,4,5-T or silvex at the same rate of application as 2,4,5-T. Wide-scale demonstration testing would need to be conducted to determine the real value for dicamba as an effective substitute for 2,4,5-T (Hoffman et al. 1978), particularly in the humid part of Texas.

Silvex can be substituted for 2,4,5-T for control of mesquite but the cost is at least $0.25 per acre more than 2,4,5-T, and silvex is less available than 2,4,5-T. Herbicides 2,4-D or 2,4-DP are not effective for control of mesquite. Picloram:2,4,5-T (Tordon 225[R]) mixture can be substituted for 2,4,5-T or silvex but picloram alone is not registered for use on rangelands. Tordon 225[R] is used on about 400,000 acres, but is not analyzed because it is only registered in mixture with 2,4,5-T.

1975-1977 AVERAGE COST PER ACRE FOR CONTROL METHODS

Root Plowing and Seeding

Root plowing	$22.50
Raking	10.00
Burning brush piles	2.00
Seedbed modification	7.00
Seed	15.00
Total	$56.50

Two-way chaining	$7 - 10
Rolling chopping	$6 - 10
Power grubbing (100 plants/A)	

Low energy	$ 7.50
High energy	12.50 - $15.00

Hand grubbing	$88.40
Burning	$0.50 - 3.00

Aerial spraying (includes herbicide, application, diesel oil, flaggers)

<u>2,4,5-T</u>

0.50 lb/a - $ 4.35
0.67 " - $ 4.75
1.00 " - $ 6.75
2.00 " - $11.00

Silvex

0.67 lb/a - $ 5.00
0.67 " - $ 5.00
1.00 " - $ 7.25
2.00 " - $12.00

Dicamba

0.50 lb/a - $ 6.85

2,4,5-T/gal - $15
Silvex/gal - $17
Dicamba/gal - $36
Diesel oil/gal - $0.45
Tordon 10K Pellet - $2.50/lb, individual spot treatment.
Individual spot treatment - (100 plants/A) (8 lb - 2,4,5-T/100 gal diesel oil - $61) - $6-10
AMS - $0.60/lb - 4 lb/gal H_2O - cut surface techniques 60 lb/100 gal H_2O foliage spray, individual spot treatment

Broadcast methods of applying herbicides were evaluated economically since over 88 percent of brush-infested rangelands contain over 100 plants per acre. Only registered herbicides were considered. In the future, new herbicides may be registered, but the cost and effectiveness of the compound will determine the use of any new chemical.

Rotation period varied because of plant growth conditions, forage and animal production differences, and the length of time that woody plants need to grow before canopy density would reduce forage production and where herbicide treatment would be effective on regrowth.

Each area was selected to be analyzed based on production, differences in woody plant species, life span of treatment, stocking rates, and rate that regrowth required treatment. No economic analysis will be made on the 75,000 acres of mesquite and 60,000 acres of oak on the 1,000,000 acres of pasture treated with ground equipment.

Beef production per acre during the rotation period was averaged to reduce additional calculations and the number of tables. We realize that forage and beef production will increase from year one to 4-5 years until woody plant density reduces forage production to justify another treatment. Also, we realize that the production on the untreated area would not remain the same, but decrease each year during the rotation because of reduced forage production and an increase in density of woody plants.

AREA 1 - CREEPING MESQUITE

Creeping or running mesquite, a low-growing multi-stemmed plant, is a problem on about 2 million acres of heavy saline clay range sites in the Nueces and Frio River watersheds of the South Texas Plains (fig. 6, area 1). Mechanical control methods of root plowing and seeding proved unsatisfactory since re-establishment of grasses was difficult after soil disturbance. Application of 2,4,5-T to about 40,000 acres each year offered the better solution for control. However, early research data indicated that standard application of 2,4,5-T for tree-type mesquite would not produce satisfactory control on creeping mesquite. After a five-year study, it was determined that 0.67 pound of 2,4,5-T mixed in one gallon of diesel oil and water to make five gallons of solution per acre, applied aerial broadcast for three consecutive applications produced satisfactory control. Sometimes two applications produced up to 90 percent control.

In a 3500-acre pasture approximately 1200 acres of creeping mesquite was sprayed with 2,4,5-T for 3 consecutive years (fig. 7). The treated acreage received no deferment but livestock numbers were kept at the same rate as before spraying, which was one animal unit to 25 acres plus deer. At the end of the third growing season, livestock numbers were increased one animal unit to 18 acres for a 28 percent increase (Hoffman et al. 1950-77, fig. 8).

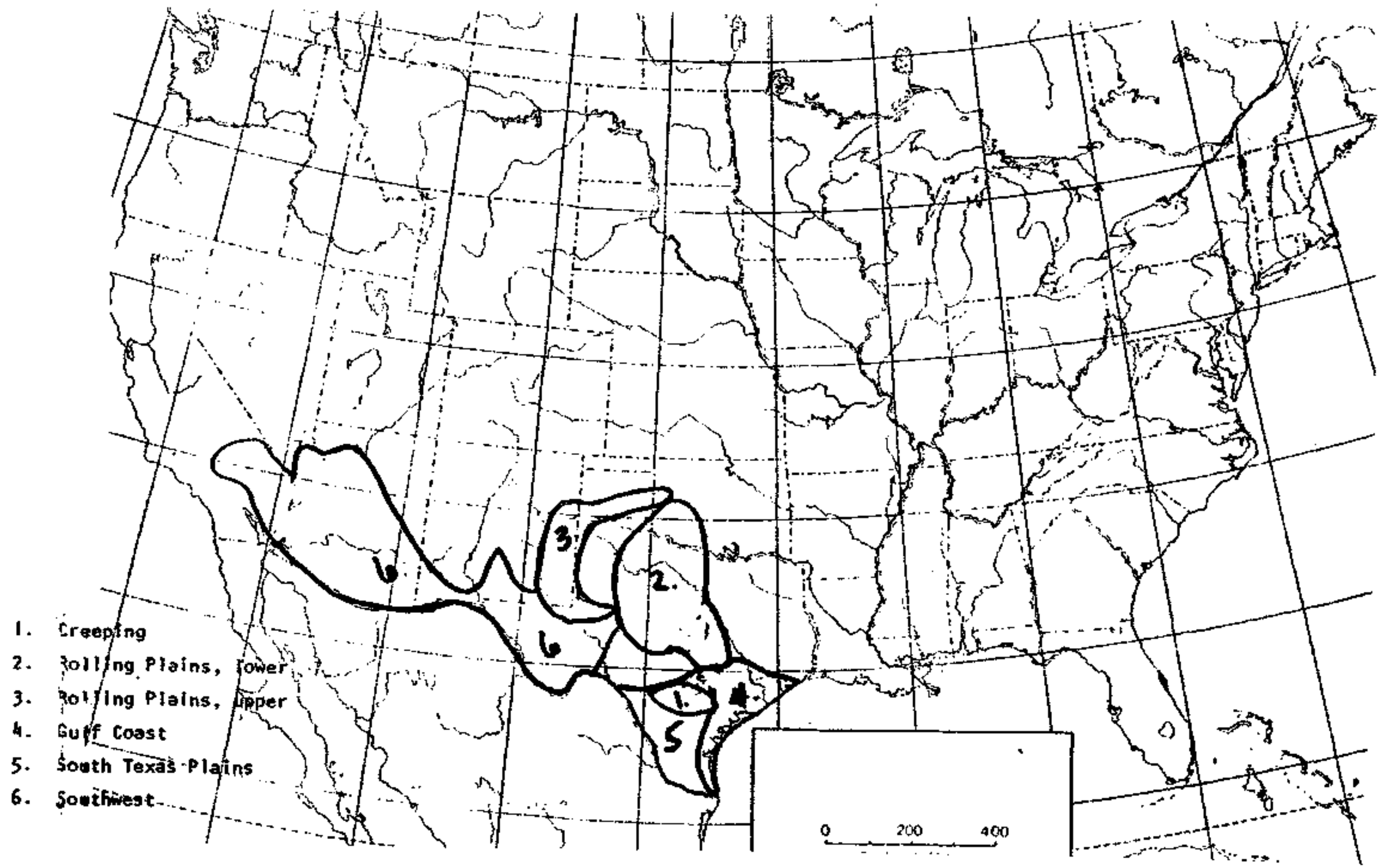


Figure 6. The 93,000,000 acres of Mesquite-dominated land in the Southwestern United States.

Figure 7. Creeping mesquite growing on a saline clay soil. Creeping mesquite becomes so dense because of root sprouting characteristics that forage grasses cannot grow. Stocking rate on this area was 1 animal unit to 40 acres.

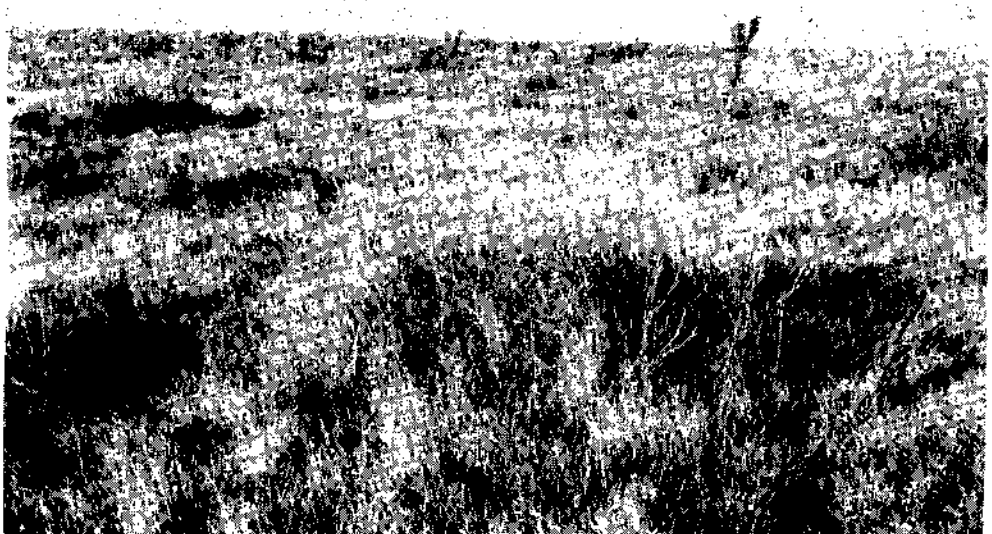


Figure 8. Three applications of 2,4,5-T a year apart. Control has lasted for 16 years. Note that woody plants suitable for wildlife were not affected. Stocking rate following control was 1 animal unit per 18 acres. This stocking rate has been maintained for 16 years and the range is in good condition.

Herbicide applications of 2,4,5-T did not control such plants as lotebush (Condalia spp.), agarito (Berberis trifolidata), granjeno (Celtis spp.), blackbrush (Acacia rigidula), and guajilio (A. berlandieri) that produce food and cover for wildlife animals (Hodgin 1974).

The sprayed area improved from poor to good condition during the three year spraying period. Wildlife numbers have increased along with the increase of livestock numbers. Calf weights increased 25 pounds per calf. Evaluation of the treated areas shows 3 applications of 2,4,5-T will control creeping mesquite for 16 years before another series of herbicide applications will be required. Stocking rate has remained constant throughout the control period according to statements from the landowner (Hoffman et al. 1978).

Beef production for the entire 3500 acre pasture was 21.9 pounds or $7.84 per acre where creeping mesquite was controlled, as compared to 14.4 pounds or $5.16 per acre on the uncontrolled area. Labor saved in working of livestock amounted to $.50 per acre and the increased hunting lease was $.50 per acre more on the sprayed pasture as compared to the unsprayed pasture (table 1, area 1). Total beef production loss would be 46,704,000 pounds or a net present value loss of $4,075,000 during the 16-year rotation period without the use of 2,4,5-T and silvex, (table 2).

The stocking rate on the 2,4,5-T sprayed pasture was 1 animal unit to 18 acres and remained at that number for 16 years. On the untreated area, stocking rates were 1 animal unit to 25 acres for the first 8 years and 1 animal unit to 35 acres from 9-16 years (Hoffman et al. 1978). Beef cattle production per acre is 14.4 pounds for the first 8 years and 10.3 pounds per acre for the years 9-16. It is estimated that stocking rates will remain at 1 animal unit to 35 acres for an indefinite period.

An area was root plowed and seeded to native grasses in 1960 for a total cost of $18 per acre to compare control methods. Results revealed that

Table I—Current use and benefits of 2,4,5-T, and potential alternatives, on 93 million acres of Mesquite

Area & alternative treatment	Acres in area	Acres treated annual[a]	Rotation period	Acres treated in rotation	Per acre treatment cost[b]	Total annual cost	Total rotation cost	Amortized per acre cost[c]	Beef yield per acre[d]	Value per pound[e]	Gross value per acre
			Years		----------Dollars----------				Pounds	------Dollars------	
Area 1:											
2,4,5-T	2,000,000	40,000	16	640,000	14.25[f]	190,000	9,120,000	1.51	21.9	.3580	8.84[h]
Silvex	2,000,000	40,000	16	640,000	15.00[g]	200,00	9,600,000	1.59	21.9	.3580	8.84[h]
Do nothing, 1-8 yrs	2,000,000	n/a	n/a	n/a	n/a	n/a	n/a	n/a	14.4	.3580	5.16
Do nothing, more than 8 yrs	2,000,000	n/a	n/a	n/a	n/a	n/a	n/a	n/a	10.3	.3580	3.69
Area 2:											
2,4,5-T	22,000,000	176,000	8	1,408,000	4.35	765,600	6,124,800	0.73	44.0	.3580	16.75[i]
Silvex	22,000,000	176,000	8	1,408,000	4.60	809,600	6,476,800	0.78	44.0	.3580	16.75
Dicamba	22,000,000	176,000	8	1,408,000	6.85	1,205,600	9,644,800	1.15	44.0	.3580	16.75
Do nothing	22,000,000	n/a	n/a	n/a	n/a	n/a	n/a	n/a	26.9	.3580	9.63
Area 3:											
2,4,5-T	22,000,000	176,000	10	1,760,000	4.35	765,600	7,656,000	0.62	21.9	.3580	8.84[i]
Silvex	22,000,000	176,000	10	1,760,000	4.60	809,600	8,096,000	0.65	21.9	.3580	8.84[i]
Dicamba	22,000,000	176,000	10	1,760,000	6.85	1,205,600	12,056,000	0.98	21.9	.3580	8.84[i]
Do nothing	22,000,000	n/a	n/a	n/a	n/a	n/a	n/a	n/a	14.4	.3580	5.16

continued

Table 1--Current use and benefits of 2,4,5-T, and potential alternatives, on 93 million acres of Mesquite (continued)

Area & alternative treatment	Acres in area	Acres treated annual[a/]	Rotation period	Acres treated in rotation	Per acre treatment cost[b/]	Total annual cost	Total rotation cost	Amortized per acre cost[c/]	Beef yield per acre[d/]	Value per pound[e/]	Gross value per acre
			Years		-----------	Dollars	-----------		Pounds	------	Dollars ------
Area 4:											
2,4,5-T	9,000,000	56,000	5	280,000	6.75	378,000	1,890,000	1.61	14.0	.3580	15.67[i/]
Do nothing	9,000,000	n/a	n/a	n/a	n/a	n/a	n/a	n/a	13.3	.3580	4.76
Area 5:											
2,4,5-T	15,000,000	41,000	5	205,000	6.75	276,750	1,383,750	1.61	28.0	.3580	11.02[i/]
Tordon 225[i/]	15,000,000	41,000	5	205,000	11.50	471,500	2,357,500	2.80	28.0	.3580	11.02[i/]
Do nothing	15,000,000	n/a	n/a	n/a	n/a	n/a	n/a	n/a	14.4	.3580	5.16
Area 6:											
2,4,5-T	23,000,000	81,120	10	811,200	4.35	352,872	3,528,720	0.62	6.5	.3580	2.33
Silvex	23,000,000	81,120	10	811,200	4.60	373,152	3,731,520	0.65	6.5	.3580	2.33
Dicamba	23,000,000	81,120	10	811,200	6.85	555,672	5,556,720	0.98	6.5	.3580	2.33
Do nothing	23,000,000	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4.2	.3580	1.50

a/ Brush & Weed Control Acreages, from State Range Specialist, 1978.

b/ Average cost from commercial applicators.

c/ Per acre cost of 2,4,5-T and alternative treatments amortized at 7% interest.

d/ CEA Result Demonstation Handbook and Range Specialists Annual Reports, TAEX.

continued

Table 1--Current use and benefits of 2,4,5-T, and potential alternatives, on 93 million acres of Mesquite (continued)

e/ Average beef cattle prices, Agri. Economics Dept., TAMU-TAEX.

f/ \$4.75 X 3 treatments.

g/ \$5.00 X 3 treatments.

h/ Control reduced labor in working livestock of \$0.50/A and return from hunting lease increased by \$0.50/A.

i/ Control reduced labor in working livestock of \$1.00/A.

j/ 50-50 mixture of picloram and 2,4,5-T, 2 lb. ae/gal.

SOURCE: Range Brush and Weed Control Specialists, Texas Agricultural Extension Service, Texas A&M University, College Station, Texas 77843.

Table 2—Estimated decrease in value of beef production due to the nonavailability of 2,4,5-T and silvex, area one, Texas, creeping mesquite, South Texas plains

No. years w/o 2,4,5-T	Treated area with remaining yield effects			Previously treated area w/o remaining yield effects			Total beef		Production loss w/o 2,4,5-T c/	Value of lost production b/	Amortized cost of lost production d/	Net value of lost production b/	Net present value of lost production e/
	Acres a/	Yield a/	Production	Acres	Yield a/	Production	Production	Value b/					
	Thous	Lbs	Thous lbs	Thous	Lbs	Thous lbs	Thous lbs	Dols	Thous lbs	Thousand dollars			
0	640	21.9	14,016	0	n/a	n/a	14,016	5,018	0	n/a	n/a	n/a	n/a
1	600	21.9	13,140	40	14.4	576	13,716	4,910	300	107	60	47	47
2	560	21.9	12,264	80	14.4	1,152	13,416	4,803	600	215	121	94	88
3	520	21.9	11,388	120	14.4	1,728	13,116	4,696	900	322	181	141	123
4	480	21.9	10,512	160	14.4	2,304	12,816	4,588	1,200	430	242	188	153
5	440	21.9	9,636	200	14.4	2,880	12,516	4,481	1,500	537	302	235	179
6	400	21.9	8,760	240	14.4	3,456	12,216	4,373	1,800	644	362	282	201
7	360	21.9	7,884	280	14.4	4,032	11,916	4,266	2,100	752	423	329	219
8	320	21.9	7,008	320	14.4	4,608	11,616	4,159	2,400	859	483	376	234
9	280	21.9	6,132	360	13.9	5,020	11,152	3,992	2,864	1,025	544	481	262
10	240	21.9	5,256	400	13.6	5,432	10,688	3,826	3,328	1,191	604	587	298
11	200	21.9	4,380	440	13.3	5,844	10,224	3,660	3,792	1,358	664	694	330
12	160	21.9	3,504	480	13.0	6,256	9,760	3,494	4,256	1,524	725	799	355
13	120	21.9	2,628	520	12.8	6,668	9,296	3,328	4,720	1,690	785	905	376
14	80	21.9	1,752	560	12.6	7,080	8,832	3,162	5,184	1,856	846	1,010	392
15	40	21.9	876	600	12.5	7,492	8,368	2,996	5,648	2,022	906	1,116	404
16	0	n/a	n/a	640	12.4	7,904	7,904	2,830	6,112	2,188	966	1,222	414
													4,075

continued

Table 2—Estimated decrease in value of beef production due to the nonavailability of 2,4,5-T and silvex, area one, Texas, creeping mesquite, south Texas plains (continued)

---

a/ Taken from table 1.

b/ Beef value at $0.3580 per pound, 1973-77 average.

c/ Production loss calculated from column 8; i.e., 14,016 - 13,716 = 300.

d/ Treatment cost amortized at 7% interest from table 1, column 9, times acres without remaining yield effects (column 5); i.e., $1.51 X 40,000 = $60,400.

e/ Present value calculated using 7% discount factor.

SOURCE: Natural Resource Economics Division, ES&CS, USDA, Corvallis, Oregon.

range recovery could not be achieved in 12 years but woody plants had increased in such density that the area was sprayed with herbicides to control woody plants (Hoffman et al. 1950-77).

There is no alternative-control method from the 2 million acres of creeping mesquite as it grows on dense clay soils with a high saline content (fig. 1, area 1). Once the saline clay soil is disturbed, it is nearly impossible to re-establish a forage grass cover (Hoffman et al. 1950-77). The range site is very productive when the creeping mesquite is controlled with 0.67 pound per acre of 2,4,5-T applied three consecutive years or two applications of 1/2 pounds per acre of picloram: 2,4,5-T (Tordon 225[R]) mixture (Hoffman et al. 1950-77). Dicamba: 2,4,5-T (Banvel 2+2[R]) mixture is not an effective control for creeping mesquite, is not considered an alternative and costs $2.50 per acre more than 2,4,5-T.

Fire cannot be used unless the area is first sprayed with 2,4,5-T to reduce competition of mesquite to produce forage grasses.

AREA 2 - ROLLING PLAINS, TEXAS AND OKLAHOMA, AND EDWARDS PLATEAU

A demonstration study was started in 1972 in Haskell County in the east central part of the Rolling Plains of Texas comparing 2,4,5-T treated and untreated pastures to determine economic returns and range condition change in that area (Welch et al. 1972-77). A 559-acre pasture with a heavy infestation of mesquite was treated with 2,4,5-T in May, 1972. A 640-acre pasture with similar soil, mesquite infestation, and livestock-carrying capacity was selected as a comparison check and untreated. The treated pasture was deferred from grazing for May, June, and July following the application of 2,4,5-T for mesquite control to improve range forage conditions. Silvex and dicamba can be substituted for 2,4,5-T in this area with comparable effects and greater cost.

Results from this demonstration are typical for about 22 million acres of mesquite-infested rangeland in the Rolling Plains. During the 5-year study, the treated area produced 34.3 pounds per acre per year from the sale of beef cattle while the untreated pasture produced 26.9 pounds of beef products for a return of $9.63 per acre (table 3). Two of the years the treated pasture produced sufficient forage that could be utilized by stockers to produce 1.25 pounds per day per head for 150 days. Stocker cattle weights increased beef production an additional 9.7 pounds per acre, making a year-beef production of 44 pounds for a return of $15.75 per acre (table 1). Ease of working livestock amounts to $1 per acre saving in labor required for roundups on the treated area (Hoffman et al. 1978 and Hoffman 1975). Beef production loss would be 108,346,000 pounds or a net percent value loss of $25,137,000 during the first 8-year period if 2,4,5-T, silvex or dicamba could not be used (table 4). Production loss may be insignificant if dicamba proves to be an adequate substitute. However, treatment cost would increase $73,900 annually.

Tordan 225® was assumed not to be an alternative because it contains 2,4,5-T. Root plowing could not be used as an alternative as it is difficult to re-establish a forage grass cover in this area. Chaining cannot be used as trees have stems that are too small to be uprooted. Trees are too dense for tree grubbing. As herbicide prices continue to increase, the only economical alternative in this part of the Rolling Plains is not to carry out any control practice; do nothing and reduce livestock numbers as range condition deteriorates year after year (Hoffman et al. 1978).

AREA 3 - ROLLING PLAINS OF TEXAS AND NEW MEXICO

A well-planned mesquite management program has been carried out on an Oldham County, Texas, ranch since 1957 (Hoffman et al. 1950-77). Broadcast application of 2,4,5-T was used first and, if root kills were good, the area was retreated with ground power equipment using 2,4,5-T mixed in diesel oil applied with a hand gun as individual spot treatment. The mixture and rate used controlled regrowth mesquite, pricklypear (<u>Opuntia</u> <u>spp</u>.), cholla (<u>O</u> . <u>spp</u>.), yucca (<u>Yucca</u> <u>spp</u>.), catclaw (<u>Acacia</u> <u>spp</u>.), and lotebush not controlled by 2,4,5-T aerial

Table 3—Five year summary of economic returns in Rolling Plains of Texas from treated and untreated pastures

	Per acre					5 year	Average
	1973	1974	1975	1976	1977	total	yr. total
	Sprayed pasture						
Income:							
Beef produced (lbs.)	35.9	32.3	35.7	37.6	30.2	171.7	34.34
Value of beef produced	$18.67	$ 9.69	$12.14	$12.98	$11.29	$64.77	$12.96
Value of beef/lb.	($0.52)	($0.30)	($0.34)	($0.345)	(S.$0.3950) (H.$0.3475)		
Specified expense:							
Seeding	—	—	—	—	$ 0.17		
Feed	$ 0.27	$ 0.36	$ 1.37	$ 0.49	$ 1.58		
Cost of spraying brush	$ 0.67	$ 0.67	$ 0.67	$ 0.67	$ 0.67	$11.29	$ 2.26
Cost of spraying weeds	—	$ 0.75	$ 0.75	$ 0.75	$ 1.09		
Cost of chaining	—	—	—	—	$ 0.36		
Income above feed and spraying cost	$17.73	$ 7.91	$ 9.35	$11.07	$ 7.42	$53.48	$10.70
	Untreated pasture						
Income:							
Beef produced (lbs.)	28.8	25.7	23.3	28.1	28.44	134.3	26.86
Value of beef produced	$14.97	$ 7.70	$ 7.92	$ 9.68	$10.53	$50.80	$10.16
Value of beef/lb.	($0.52)	($0.30)	($0.34)	($0.345)	(S.$0.3950) (H.$0.3475)		
Specified expense:							
Feed	$ 2.26	$ 1.52	$ 1.23	$ 0.49	$ 3.61	$ 9.11	$ 1.82
Income above feed cost	$12.71	$ 6.18	$ 6.70	$ 9.19	$ 6.92	$41.70	$ 8.34
Labor saving working stock treated pasture	$ 1.00	$ 1.00	$ 1.00	$ 1.00	$ 1.00	$ 5.00	$ 1.00
Economic advantage of spraying	$ 6.02	$ 2.73	$ 3.65	$ 2.88	$ 1.50	$16.78	$ 3.36

SOURCE: Welch et al. 1972-77.

Table 4—Estimated decrease in value of beef production if 2,4,5-T and silvex become unavailable and Dicamba proves ineffective, area 2, Texas and Oklahoma, Rolling Plains

No. years w/o 2,4,5-T	Treated area with remaining yield effects: Acres a/	Yield a/	Production	Previously treated area w/o remaining yield effects: Acres	Yield a/	Production	Total beef: Production	Value b/	Production loss w/o 2,4,5-T c/	Value of lost production b/	Amortized cost of lost production d/	Net value of lost production b/	Net present value of lost production e/
	Thous	Lbs	Thous lbs	Thous	Lbs	Thous lbs	Thous lbs	Dols	Thous lbs	Thousand dollars			
0	1,408	44	61,952	0	26.9	n/a	61,952	22,179	0	n/a	n/a	n/a	n/a
1	1,232	44	54,208	176	26.9	4,734	58,942	21,101	3,010	1,078	128	950	950
2	1,056	44	46,464	352	26.9	9,469	55,933	20,024	6,019	2,155	257	1,890	1,766
3	880	44	38,720	528	26.9	14,203	52,923	18,946	9,029	3,232	385	2,847	2,487
4	704	44	30,976	704	26.9	18,938	49,914	17,869	12,038	4,310	514	3,796	3,099
5	528	44	23,232	880	26.9	23,672	46,904	16,792	15,048	5,387	642	4,745	3,620
6	352	44	15,488	1,056	26.9	28,406	43,894	15,714	18,058	6,465	771	5,694	4,060
7	176	44	7,744	1,232	26.9	33,141	40,885	14,637	21,067	7,542	899	6,643	4,427
8	0	n/a	n/a	1,408	26.9	37,875	37,875	13,559	24,077	8,620	1,028	7,592	4,728
													25,137

a/ Taken from table 1.

b/ Beef value at $0.3580 per pound, 1973-77 average.

c/ Production loss calculated from Column 8; i.e., 61,952 - 58,942 = 3,010.

d/ Treatment cost amortized at 7% interest from table 1, column 9, times acres without remaining yield effects (column 5); i.e., $0.73 X 176,000 = $128,480.

e/ Present value calculated using 7% discount factor.

SOURCE: Natural Resource Economics Division, ES&CS, USDA, Corvallis, Oregon.

spraying. Results from the long-term demonstration indicate the following (Hoffman et al. 1950-77).

Increased calf weights of 40 pounds per animal per year.
Increased stocking rate of 30 percent.
Increase of better forage grasses.
Labor saved in working livestock - $1 per acre per year.

Mature cows weighed 49 pounds more than on untreated area for a value of $17.54 per head (Pallmeyer 1971-76).

The 2,4,5-T treated pasture produced 23.2 pounds of beef products per acre while the untreated area produced 14.4 pounds for a value of $5.16 per acre (table 1). Beef production per acre of 21.9 pounds for a value of $7.84 per acre was selected for all of Area 3 because of growth condition variations.

Production loss would amount to 72,600,000 pounds of beef for net present value loss of $13,484,000 during the first 10-year rotation period if 2,4,5-T, silvex, or dicamba could not be used (table 5). Production loss may be insignificant when dicamba is used as a substitute; however, treatment cost would increase $63,400 annually.

Stocking rate has remained at 1 animal unit to 18 acres on the treated area. By 1970, the uncontrolled area stocking rate was reduced to 1 animal unit to 35 acres as range conditions deteriorated. Also labor cost has increased as the density of mesquite increased. Controlling mesquite appears to have increased the bobwhite quail population, and antelope have moved into the area since mesquite cover has been reduced.

Controlling

Dicamba is very effective in controlling broadleaf weeds, and if it were substituted for 2,4,5-T, some weeds would be controlled reducing the amount of food for game birds. Silvex can be substituted for 2,4,5-T in the Rolling Plains of Texas and New Mexico. Use of fire is not effective as sufficient fuel cannot be produced to cause a hot fire.

Table 5--Estimated decrease in value of beef production if 2,4,5-T and silvex become unavailable and Dicamba proves ineffective, area 3, Texas and New Mexico Rolling Plains

No. years w/o 2,4,5-T	Treated area with remaining yield effects: Acres a/	Treated area with remaining yield effects: Yield a/	Treated area with remaining yield effects: Production	Previously treated area w/o remaining yield effects: Acres	Previously treated area w/o remaining yield effects: Yield a/	Previously treated area w/o remaining yield effects: Production	Total beef: Production	Total beef: Value b/	Production loss w/o 2,4,5-T c/	Value of lost production b/	Amortized cost of lost production d/	Net value of lost production b/	Net present value of lost production e/
	Thous	Lbs	Thous lbs	Thous	Lbs	Thous lbs	Thous lbs	Dols	Thous lbs	---Thousand dollars---			
0	1,760	21.9	38,544	0	n/a	n/a	38,544	13,813	0	n/a	n/a	n/a	n/a
1	1,584	21.9	34,690	176	14.4	2,534	37,224	13,326	1,320	473	109	364	364
2	1,408	21.9	30,835	352	14.4	5,069	35,904	12,854	2,640	945	218	727	679
3	1,232	21.9	26,981	528	14.4	7,603	34,584	12,381	3,960	1,418	327	1,091	953
4	1,056	21.9	23,126	704	14.4	10,138	33,264	11,909	5,280	1,890	436	1,454	1,162
5	880	21.9	19,272	880	14.4	12,672	31,944	11,436	6,600	2,363	546	1,817	1,386
6	704	21.9	15,418	1,056	14.4	15,206	30,624	10,963	7,920	2,835	655	2,180	1,554
7	528	21.9	11,563	1,232	14.4	17,741	29,304	10,491	9,240	3,308	764	2,544	1,695
8	352	21.9	7,709	1,408	14.4	20,275	27,984	10,018	10,560	3,780	873	2,907	1,810
9	176	21.9	3,854	1,584	14.4	22,810	26,664	9,546	11,880	4,253	982	3,271	1,904
10	0	n/a	n/a	1,760	14.4	25,344	25,344	9,073	13,200	4,726	1,091	3,635	1,977
													13,484

a/ Taken from table 1.

b/ Beef value at $0.3580 per pound, 1973-77 average.

c/ Production loss calculated from column 8; i.e., 38,544 - 37,224 = 1,320.

d/ Treatment cost amortized at 7% interest from table 1, column 9, times acres without remaining yield effects (column 5); i.e., $0.62 X 176,000 = $109,120.

e/ Present value calculated using 7% discount factor.

SOURCE: Natural Resource Economics Division, ES&CS, USDA, Corvallis, Oregon.

Root plowing cannot be used because of low rainfall to establish plant cover and soil erosion is increased on plowed areas. Trees are too small for effective chaining. Tordon 225[R] can be substituted for 2,4,5-T but would increase control costs.

AREA 4 - GULF COAST AND COASTAL PRAIRIE

About 9 million acres of the Gulf Coast area have become heavily infested with mesquite, as a dense overstory, and other species of granjeno, blackbrush, colima (Zanthoxylum spp.), Brazil (Acacia spp.), huisache, lotebush, retama (Parkinsonia spp.), and macartney rose (Rosa bracteata) in layers of shorter brush causing the area to be unprofitable for beef cattle production (Gould 1969). Mesquite in the Gulf Coast area is original stands or regrowth following chaining. Ranges were in poor condition with 15 percent decreaser forage plants, producing less than a third to a half of their potential.1/

To give ranchers an answer to this problem, a 10-year result demonstration cooperative project began in 1963 on two large ranches. The test plots included 100 acres of 5-year-old regrowth mesquite which had been chained in 1959 and 100 acres with original growth mesquite (Hoffman et al. 1969).

In May, 1964, all of the acreage on both ranches was sprayed aerially with 2,4,5-T low-volatile ester at 1/2 and 1 pound per acre mixed in 1 gallon diesel oil and sufficient water to make 5 gallons total solution per acre (fig. 9). Each year thereafter, about 15 acres were resprayed on each ranch to have plots with all combinations of retreatment years. Starting in 1965, the rate of 2,4,5-T was 0.67 pound per acre to obtain annual broomweed control. Currently, 1 pound per acre 2,4,5-T is recommended for control of regrowth mesquite and broomweed.

All plots were deferred each year from mid-March until mid-October. Before cattle were allowed to graze, forage clippings were made with the production per acre expressed on an air-dry basis. Woody plants with any green foliage were considered live.

1/Decreaser - a range management term describing a particular group of plants.

Figure 9. Aerial application of a dense stand of regrowth mesquite which was chained 10 years previously.

Clipping results indicated the tremendous suppressing effect that mesquite, mixed brush and weeds had on grass production. The greatest increase in forage production in the Gulf area seems to have occurred during the first and second years following the first aerial spraying. To express forage production in terms of stocking rates, it was assumed that a cow's requirement for maintenance, pregnancy, and lactation was 12,000 pounds of 45 percent digestible air-dry material, plus an additional 12,000 pounds for grass plant maintenance. Based upon these assumptions, the estimated stocking rate for the 6 years in the untreated regrowth mesquite area was 26.5 acres per animal unit, compared to 9.7 acres per animal unit in the treated plot. Repeated applications maintained the stocking rate at 5.7 acres per animal unit (table 6).

Grass on the original growth mesquite had less vigor; thus the first year's response was less than on the regrowth mesquite area (table 7). Stocking rate on the untreated area was 37.6 acres per animal unit compared to 11.5 acres per animal unit on the treated area. Repeat applications maintained a stocking rate at 7.0 acres per animal unit (fig. 10 and 11).

Stocking rate in the untreated areas increased tremendously in 1967-70. The reasons were an extremely wet fall and increased plant vigor resulting from deferment for the four previous growing seasons. Forage production per acre during 1966 was less than other years since rainfall was less and especially so during the growing season.

The maximum life of one treatment was 5 years. With retreatment the third or fourth years, the life of the treatment can be 12 or more years based on evaluations made in 1977. Maximum forage increase appears to be in the year of treatment and the following year if rainfall is normal.

Figures 12 and 13 illustrate forage production per acre by years on a graph to show total effect from aerial broadcast applications of 2,4,5-T.

Table 6--Evaluation, Melon Creek Ranch, Refugio County, Texas, mesquite control result demonstrations, area 4, Gulf Coast and Coastal Prairie

Date sprayed	Kill in October 64	65	66	67	68	70	Forage production Oct. 64	Oct. 65	Oct. 66	Oct. 67	Oct. 68	Oct. 70	Actual stock. rate	Forage available for grazing 64	65	66	67	68	70	Ave. stock rate 64 - 70
	Percent						Lbs/acre						Acres/AU	Acres/AU						
Plot 1																				
May 64																				
June 65																				
June 66	32	25	30	92	92+	96	3075 lbs.	4220 lbs.	2800 lbs.	5310 lbs.	7300 lbs.	8030 lbs.	20	8	6	8.6	5.1	3.3	3.0	5.7
June 67																				
June 68																				
Plot 2																				
May 64	32	38	30	20	10	85	3075	1655	1710	3220	3665	7430	20	8	15	14.0	7.5	6.6	3.2	9.1
June 68																				
Plot 3																				
May 64																				
June 68	32	38	30	20	10	85	3075	1655	1710	3220	3665	7110	20	8	15	14.0	7.5	6.6	3.4	9.1
Tordon																				
Plot 4																				
May 64	32	38	30	20	10	0	3075	1655	1710	3220	3665	3488	20	8	15	14.0	7.5	6.6	7.0	9.7
Plot 5																				
Check	0	0	0	0	0	0	590# grass 3680# weeds	Same as 64	600# grass 2200# weeds	1250# grass 800# weeds	2050# grass 2000# weeds	2300	20	39	39	39.0	19.0	11.7	11.0	26.5

Table 7--Evaluation, Scott Creek Ranch, Refugio County, Texas, mesquite control result demonstrations, area 4, Gulf Coast and Coastal Prairie

Date sprayed	Kill in October 64	65	66	67	68	70	Forage production Oct. 64	Oct. 65	Oct. 66	Oct. 67	Oct. 68	Oct. 70	Actual stock. rate	Forage available for grazing 64	65	66	67	68	70	Ave. stock rate 64 - 70
	Percent						Lbs/acre						Acres/AU	Acres/AU						
Plot 1																				
May 64																				
June 65																				
June 66	10	24	50	88	90+	85	2350	3165	3170	3453	6083	5820	25	11	8	8.0	7	4.0	4.1	7.0
June 67																				
June 68																				
Plot 2																				
May 64																				
June 68	10	24	25	14	14	40	2350	2545	1590	1750	1750	3485	25	11	10	15.3	14	11.3	7.0	11.4
Plot 3																				
May 64																				
June 68	10	24	25	14	14	70	2350	2545	1590	1750	1750	4900	25	11	10	15.3	14	11.3	5.0	11.1
(Tordon)																				
Plot 4																				
May 64	10	24	25	14	14	0	2350	2545 #	1590 #	1750 #	2130 #	3303	25	11	10	15.3	14	11.3	7.3	11.5
Plot 5																				
Check	0	0	0	0	0	0	200# grass 1120# weeds	590# grass 3680 weeds	600# grass 2400# weeds	1250# grass 800# weeds	2050# grass 2000# weeds	2300	25	106	39	39	19	11.7	11.0	37.6

Figure 10. Original growth mesquite on the Gulf Coast and Coastal Prairie area. Stocking rate on this area over the 8-year study was 37.6 acres per animal unit.

Figure 11. Original growth mesquite 18 months following control. Note the heavy layer of herbaceous grass cover that has re-established following control. Wildlife habitat was improved following control. Stocking rate was 7 acres per animal unit. Range conditions improved from poor to good in two growing seasons.

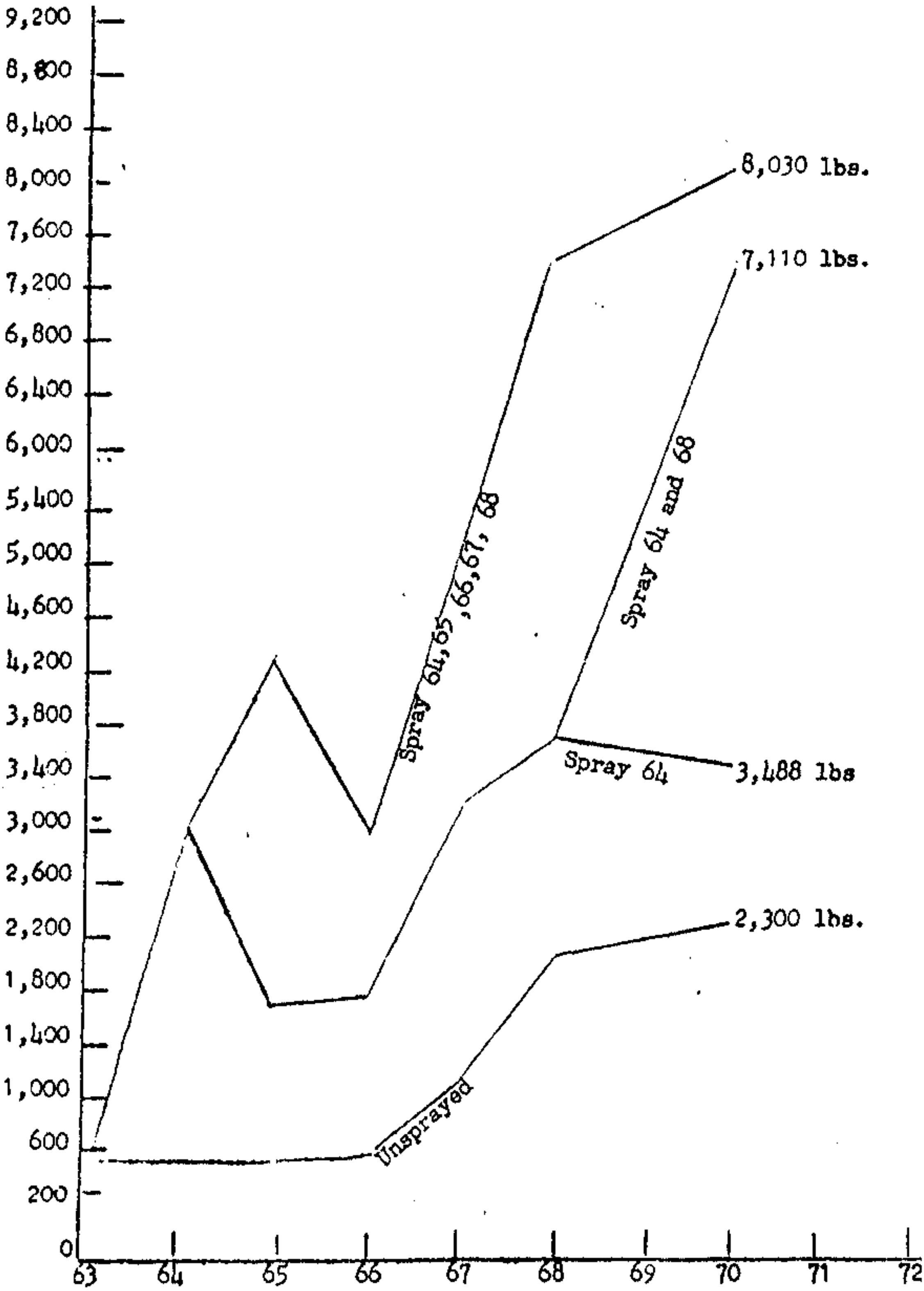


Figure 12. Forage production following 2,4,5-T treatments - regrowth mesquite.

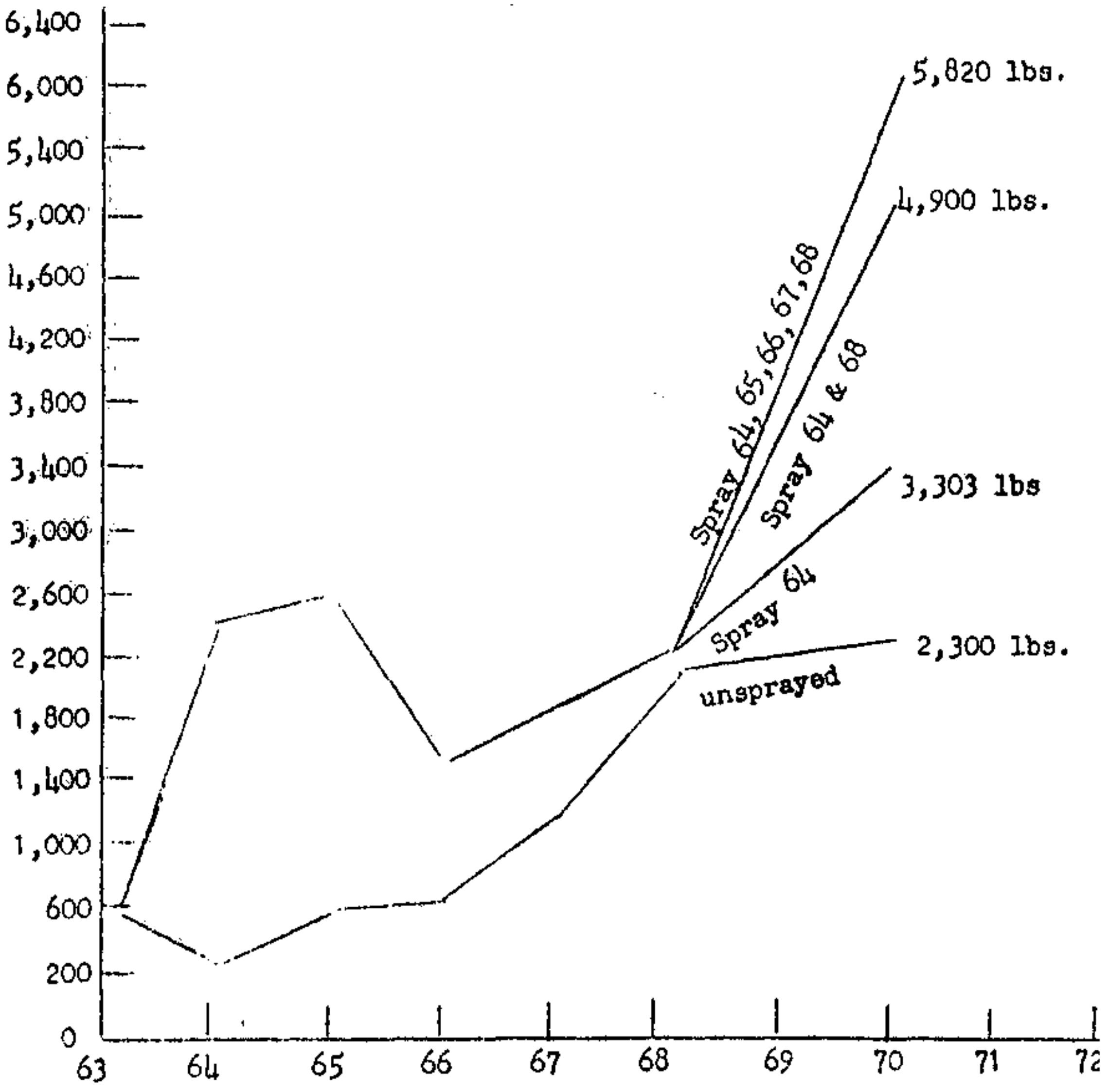


Figure 13. Forage production following 2,4,5-T treatments - original growth mesquite.

The stocking rate maintained on each ranch was 20 and 25 acres per animal unit. This rate of stocking left no forage residue for maintenance for forage plants. Stocking rate with aerial broadcast of 2,4,5-T and rapid range improvement would be 13 acres per animal unit on each area.

Landowners indicated that at least $1 per acre was saved when working livestock on the treated area when compared to the untreated area. The treated area could be worked with fewer cowboys on the ground, and the helicopter pilot could see and direct livestock better. The helicopter pilot has to be directly over the animals before he can see them in dense mesquite with a heavy canopy. Animals are more docile in treated pastures when compared to untreated pastures. Also, there is less injury to cowboys and horses when working livestock in the treated pastures.

The 2,4,5-T treated area could produce 41 pounds of saleable beef for a value of $14.67 per acre while the untreated area could produce 13.3 pounds for a value of $4.76 per acre. Beef production loss would amount to 23,268,000 pounds for a net present value loss of $5,854,000 during the first 5-year rotation without the use of 2,4,5-T (table 8).

About 4 million acres of mesquite-infested land has the potential for conversion to cultivated crop production, but the remaining five million acres are suited only for grazing lands (Hoffman et al. 1978).

On the other five million acres, root plowing cannot be considered an alternative control method because of high cost and disturbance of turf. Brush could be sprayed by aerial broadcast, and burning the area 18 months later would remove much of the dead top growth. Burning would allow livestock more access to forage plants and reduce wildlife cover. Burning can be used only with an application of herbicide to reduce woody plant competition to produce grass for a fuel (Gordon and Scifres 1978). Two-way chaining could be used on the small acreage that is remaining with original stands of mesquite. Effective control would

Table 8--Estimated decrease in value of beef production due to the nonavailability of 2,4,5-T, area 4, Texas Gulf Coast and Coastal Prairie

No. years w/o 2,4,5-T	Treated area with remaining yield effects: Acres a/	Treated area with remaining yield effects: Yield a/	Treated area with remaining yield effects: Production	Previously treated area w/o remaining yield effects: Acres	Previously treated area w/o remaining yield effects: Yield a/	Previously treated area w/o remaining yield effects: Production	Total beef: Production	Total beef: Value b/	Production loss w/o 2,4,5-T c/	Value of lost production b/	Amortized cost of lost production d/	Net value of lost production b/	Net present value of lost production e/
	Thous	Lbs	Thous lbs	Thous	Lbs	Thous lbs	Thous lbs	Dols	Thous lbs	Thousand dollars			
0	280	41.0	11,480	n/a	13.3	n/a	11,480	4,110	n/a	n/a	n/a	n/a	n/a
1	224	41.0	9,184	56	13.3	745	9,929	3,555	1,551	555	90	465	465
2	168	41.0	6,888	112	13.3	1,490	8,378	2,999	3,102	1,111	179	932	871
3	112	41.0	4,592	168	13.3	2,234	6,826	2,444	4,654	1,666	269	1,397	1,220
4	56	41.0	2,296	224	13.3	2,979	5,275	1,888	6,205	2,221	358	1,863	1,521
5	0	n/a	n/a	280	13.3	3,724	3,724	1,333	7,756	2,777	448	2,329	1,777
													5,854

a/ Taken from table 1.

b/ Beef value at $0.3580 per pound, 1973-77 average.

c/ Production loss calculated from column 8; i.e., 11,480 - 9,929 = 1,551.

d/ Treatment cost amortized at 7% interest from table 1, column 9, times acres without remaining yield effects (column 5); i.e., $1.61 X 56,000 = $90,160.

e/ Present value calculated using 7% discount factor.

SOURCE: Natural Resource Economics Division, ES&CS, USDA, Corvallis, Oregon.

last for 4 years causing the chained area to be more dense with mesquite.

Dicamba is not effective for mesquite control in the humid areas of Texas. Silvex control data are not available to indicate a valid alternative. If 2,4,5-T were banned, it would appear that it is more economical to not do any mechanical control methods. Mechanical control methods would increase the density of mesquite. Tordon 225[R] could be substituted for 2,4,5-T but would increase control costs.

AREA 5 - SOUTH TEXAS PLAINS

The South Texas Plains contain about 15 million acres of mixed brush species which are not effectively controlled with 2,4,5-T or silvex (Gould 1969). Picloram:2,4,5-T (Tordon 225[R]) mixture controls both mesquite and mixed brush species. The 2,4,5-T alone at the rate of 1 pound per acre removes only the overstory of mesquite while the mixed species continue to increase in density. One application lasts about 5 years, and range conditions can be maintained for an indefinite period with periodic applications of Tordon 225[R] mixture. Without control, stocking rates can be up to 1 animal unit per 40 acres within 15 years based on observation in the South Texas Plains area (Hoffman 1967, fig. 14 and 15).

The most productive range sites are root plowed and established to a tame pasture forage crop; therefore, root plowing and seeding are not alternative-control methods as the acreage that is root plowed is not subject to be treated with 2,4,5-T. Lands root plowed in South Texas could be potential for dryland farming (Hoffman et al. 1978).

In 1970, a state label was granted for commercial applications of the herbicide picloram:2,4,5-T, (Tordon 225[R]), mixture. Picloram: 2,4,5-T herbicide mixture produces from 25 to 100 percent more kill on mesquite than when 2,4,5-T alone is used (Fisher et al. 1972). Herbicide mixture gives control on blackbrush, granjeno, huisache, cacti, lotebush, whitebrush, catclaw, while 2,4,5-T alone produces

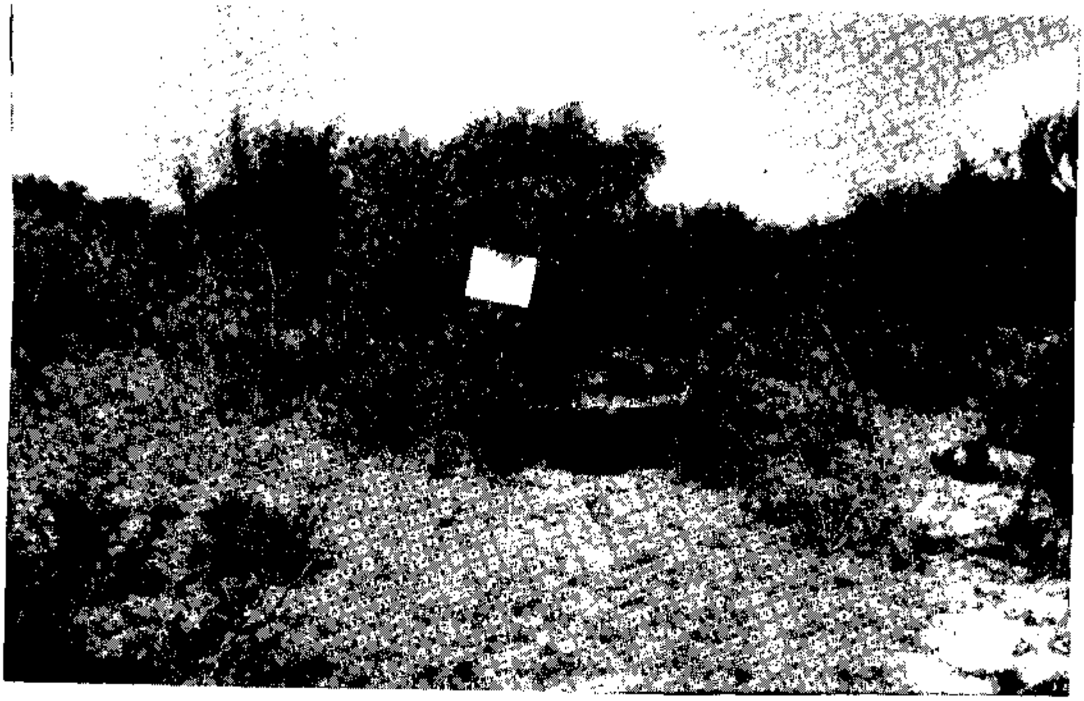


Figure 14. A brush infested area in the South Texas Plains. Note the absence of desirable forage plants. Stocking rate on this area was estimated to be 40 acres per animal unit.

Figure 15. A brush area two years following herbicide application had a stocking rate of 10 acres per animal unit. Note that woody plants suitable for browsing were not affected.

control on mesquite only. No harmful effects to grasses or native legumes have resulted.

Livestock production and brush control were good on treated areas for South Texas Plains when compared to uncontrolled areas. The following table indicates benefits of treated pasture. Comparison was made with one sire herds on treated and untreated pasture in Jim Wells County in October, 1971 (Hoffman et al. 1971).

	Treated	Untreated	Difference
Stocking Rate/A/AU	8	25	17A
Avg. Calf Wt. Lbs. - 205 days	532	471	61
Supplemental feed/animal/90 days	2 lb. CSC	2 lb. CSC + burned pear	$15
Interest on investment/AU	$3	---	$3

Treated pasture cattle required no additonal supplemental feed while cattle in untreated pasture had to have burned pricklypear for 90 days (fig. 16). Cost of burning spines off pricklypear pads was about $5 per animal unit per month in 1970-71 which is a $15 saving per animal unit per year in favor of treated pasture. Interest on investment for control cost and purchase of additional cattle is estimated at $3 per animal unit.

Considering increased calf weight differences, supplemental feed, and interest on investment, treated pastures produce $33.84 more per animal unit per year than untreated pasture. Cost of treatment was $11.50 per acre or a $92 per animal unit cost. Treatment life lasted 5 years and treatment cost was recovered in less than three years.

Brush control plus stocking rates to obtain proper use of natural resources are profitable in the South Texas Plains. Also wildlife has increased on treated pasture. Browse and cover for wildlife were not affected by control measures.

Figure 16. Pricklypear can be utilized by cattle when the spines are burned off by using a butane pear burner. Cost is about $5 per month per animal unit. Plants regrow following the burning.

Since the above results were obtained from an area that received more than normal rainfall, the stocking rate for the South Texas Plains was set at 14 acres per animal unit on the treated area. The untreated area would have had a stocking rate of 1 animal unit per 25 acres. These stocking rates were derived from landowners and the long time experience of the Extension Range Brush and Weed Control Specialist.

The herbicide-treated area could produce $10.02 per acre as compared to $5.16 per acre for the untreated (table 1). Beef production loss would be 8,364,000 pounds for a net present value loss of $1,680,000 during the first 5-year rotation if 2,4,5-T or Tordon 225[R] cannot be used (table 9).

Dicamba is not an effective control alternative for Area 5 mesquite or other brush species. Silvex has not been tested to know if it could be an alternative. Tordon 225[R] is the only herbicide alternative for 2,4,5-T. Picloram alone is not a registered use. Fire would have to be used in combination with aerial spraying of 2,4,5-T to reduce competition and grow fuel.

AREA 6 - SOUTHWEST

Mesquite in the southwest occupies about 23 million acres of arid rangeland which has a low potential production (Platt 1959, fig. 1, area 6). Any disturbance of the soil destroys the existing forage plants. The 2,4,5-T or silvex application at 1/2 pound per acre is the only practical way to keep mesquite-infested rangeland in a productive state.

Stocking rates vary from 40 to 80 acres per animal unit with the average being 60 acres per animal unit for the treated area and 94 acres per animal unit for the untreated area.

Dicamba is a potential alternative control method, but increased cost per acre may eliminate it because of low production of southwestern rangelands in Area 6.

Table 9--Estimated decrease in value of beef production due to the nonavailability of 2,4,5-T and Tordon 225[R], area 5, Texas, South Texas Plains

No. years w/o 2,4,5-T	Treated area with remaining yield effects: Acres a/	Treated area with remaining yield effects: Yield a/	Treated area with remaining yield effects: Production	Previously treated area w/o remaining yield effects: Acres	Previously treated area w/o remaining yield effects: Yield a/	Previously treated area w/o remaining yield effects: Production	Total beef: Production	Total beef: Value b/	Production loss w/o 2,4,5-T c/	Value of lost production b/	Amortized cost of lost production d/	Net value of lost production b/	Net present value of lost production e/
	Thous	Lbs	Thous lbs	Thous	Lbs	Thous lbs	Thous lbs	Dols	Thous lbs	Thousand dollars			
0	205	28.0	5,740	n/a	n/a	n/a	5,740	2,055	n/a	n/a	n/a	n/a	n/a
1	164	28.0	4,592	41	14.4	590	5,182	1,855	558	200	66	134	134
2	123	28.0	3.444	82	14.4	1,181	4,625	1,656	1,115	399	132	267	250
3	82	28.0	2,296	123	14.4	1,771	4,067	1,456	1,673	599	198	401	350
4	41	28.0	1,148	164	14.4	2,362	3,510	1,257	2,230	798	264	534	436
5	0	n/a	n/a	205	14.4	2,952	2,952	1,057	2,788	998	330	668	510
													1,680

a/ Taken from table 1.

b/ Beef value at $0.3580 per pound, 1973-77 average.

c/ Production loss calculated from column 8; i.e., 5,740 - 5,182 = 558.

d/ Treatment cost amortized at 7% interest from table 1, coumn 9, times acres without remaining yield effects (column 5); i.e., $1.61 X 41,000 = $66,010.

e/ Present value calculated using 7% discount factor.

SOURCE: Natural Resource Economics Division, ES&CS, USDA, Corvallis, Oregon.

Forage yields in the mesquite-dune area of New Mexico increased from 23 pounds per acre on the untreated to 192 pounds per acre on the sprayed part. The treated area could carry 1 animal unit per 107 acres with much reduction in soil loss because of wind erosion while the untreated area could support 1 animal unit per 640 acres. Once the soil is disturbed, it is subject to rapid erosion. Re-establishing a plant cover is less than 20 percent successful. Table 1 shows results from the accepted control method and the best alternative. Beef production loss would be 102,595,000 pounds for a net present value loss of $6,133,000 during the first 10-year rotation period that 2,4,5-T, silvex, and dicamba could not be used (table 10). Production loss may be insignificant if dicamba is used as a substitute; however, treatment cost would increase $29,200 annually.

POST-BLACKJACK OAK SAVANNAH

The Post Oak Area occupies 35 million acres in Texas, Arkansas, Oklahoma, Kansas, and Missouri (Platt 1959, fig. 17). The area was once a savannah-type vegetation, but mismanagement caused oak species to increase in density which reduced carrying capacity making livestock operations unprofitable. Brush management can balance native plants and return grazing to a profitable enterprise and improve the grassland ecosystem (fig. 18 and 19).

The Post Oak Savannah Vegetation Area in Texas contains 11.3 million acres composed of overstory woody species of post oak, blackjack oak, and winged elm with an understory of yaupon and tall-growing native forage plants (Darrow and McCully 1959).

In Oklahoma, the Oak Savannah occupies some 6.0 million acres with 4.5 million acres having dominate species of post and blackjack oaks. In the remainder of the area, winged elm and hickory are a part of the overstory (Elwell et al. 1974).

Table 10--Estimated decrease in value of beef production if 2,4,5-T and silvex become unavailable and Dicamba proves ineffective, area 6, Texas, New Mexico, Arizona and California

No. years w/o 2,4,5-T	Treated area with remaining yield effects: Acres a/	Yield a/	Production	Previously treated area w/o remaining yield effects: Acres	Yield a/	Production	Total beef: Production	Value b/	Production loss w/o 2,4,5-T c/	Value of lost production b/	Amortized cost of lost production d/	Net value of lost production b/	Net present value of lost production e/
	Thous	Lbs	Thous lbs	Thous	Lbs	Thous lbs	Thous lbs	Dols	Thous lbs	Thousand dollars			
0	8,110	6.5	52,715	n/a	n/a	n/a	52,715	18,872	n/a	n/a	n/a	n/a	n/a
1	7,299	6.5	47,443	811	4.2	3,406	50,849	18,204	1,866	668	503	165	165
2	6,488	6.5	42,172	1,622	4.2	6,812	48,984	17,536	3,731	1,336	1,006	330	308
3	5,677	6.5	36,900	2,433	4.2	10,218	47,118	16,868	5,597	2,004	1,508	496	433
4	4,866	6.5	31,629	3,244	4.2	13,625	45,254	16,201	7,461	2,671	2,011	660	539
5	4,055	6.5	26,357	4,055	4.2	17,031	43,388	15,533	9,327	3,339	2,514	825	629
6	3,244	6.5	21,086	4,866	4.2	20,437	41,523	14,865	11,192	4,007	3,017	990	706
7	2,433	6.5	15,814	5,677	4.2	23,843	39,657	14,197	13,058	4,675	3,520	1,155	770
8	1,622	6.5	10,543	6,488	4.2	27,250	37,793	13,530	14,922	5,342	4,023	1,319	821
9	811	6.5	5,271	7,299	4.2	30,656	35,927	12,862	16,788	6,010	4,525	1,485	864
10	0	n/a	n/a	8,110	4.2	34,062	34,062	12,194	18,653	6,678	5,028	1,650	898
													6,133

a/ Taken from table 1.

b/ Beef value at $0.3580 per pound, 1973-77 average.

c/ Production loss calculated from column 8, i.e., 52,715-50,849 = 51,866

d/ Treatment cost amortized at 7% interest from table 1, column 9, times acres without remaining yield effects (column 5); i.e., $0.62 X 811,000 = $502,820.

e/ Present value calculated using 7% discount factor.

SOURCE: Natural Resource Economics Division, ES&CS, USDA, Corvallis, Oregon.

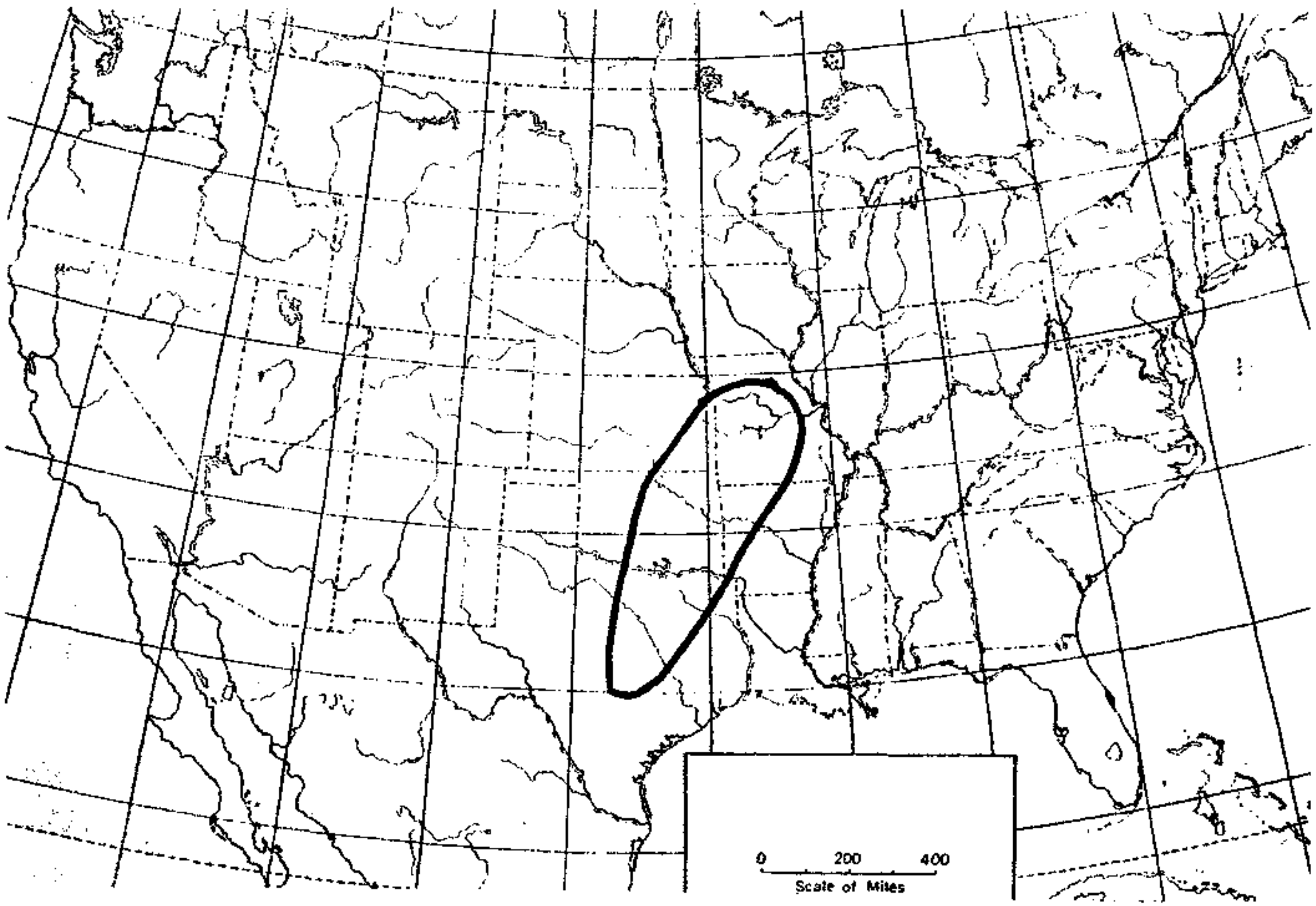


Figure 17. Post-Blackjack Oak area, 35,000,000 acres.

Figure 18. Post Oak Savannah range which has degraded because of the increase of overstory oaks and an understory of shorter growing woody plants. Stocking rate on this area was 40 acres per animal unit. Oak leaf buds are toxic to livestock.

Figure 19. Post Oak Savannah range which had one application of 2,4,5-T. Tall native grasses re-established the first growing season following application of 2,4,5-T. Stocking rate on this area was 8 acres per animal unit.

Oaks occupy 2.8 million acres in Arkansas, 0.3 million acres in Kansas, and Missouri contains about 16.1 million acres with hickory being an associated species in this area.

Throughout much of the Post-Blackjack Oak Savannah Area, forage grass release occurs in the first year following an application of 2,4,5-T or silvex. In areas with heavy brush densities, re-establishment is slower with greatest production occurring 3-5 years following the application of a herbicide. A single application of 2 pounds a.e. of 2,4,5-T per acre is satisfactory for forage release. However, woody plant root kill and resulting longevity of treatment is more dependable with two applications of 2,4,5-T or silvex applied in consecutive years.

In Texas, the Agricultural Extension Service personnel conducted 2,189 oak demonstrations involving 210,853 acres by chemical control and 240,586 acres with mechanical control from 1950-1977 (Hoffman 1978b). Range improvement was slow when mechanical control methods were used. In the 1950's 2,4,5-T was used as a comparative control method of broadcast and spot treatment which proved very successful for fast range improvement and a better method to balance the native plant community.

Individual plant treatments using phenoxy herbicides provided satisfactory control but density of plants made these methods impractical except for maintenance control. Aerial broadcast sprays of 2,4,5-T began in 1952 with 2,4,5-T and silvex producing the greatest control of the herbicides tested. It required 2 pounds per acre as first application, followed the next year with 1 1/2 to 2 pounds per acre. This produced up to 80 percent woody plant reduction and life span of the treatment was at least 10 years.

Demonstrators stated that stocking rates increased from 30 acres per animal unit to 11 acres per animal unit and ranges improved from poor to good condition in two years following control with 2,4,5-T (Hoffman et al. 1950-77). Stocking rates were doubled in Texas and Oklahoma on most treated areas (Stritzke 1965-72). Calves marketed from 2,4,5-T treated areas average 100 pounds per head more than calves grazing on untreated pastures. Landowners liked the advantage of oak brush management with 2,4,5-T over mechanical methods because (1) it did not disturb the soil, (2) better range forage plants re-established faster as partial protection was offered by standing dead trees, (3) there was less sprouting from stumps, and (4) it was not a complete shock to soil and plants ecosystem (Hoffman et al. 1950-77).

RESULTS OF BRUSH CONTROL DEMONSTRATIONS

In Erath County of Texas a treated and untreated pasture were compared to determine benefits from chemical control of oak. Post oak has value for firewood and possibly a source of emergency fuel, but economical harvesting methods have not been developed. Many result demonstrations have been conducted using 2,4,5-T and/or mechanical methods followed by grazing with goats to control sprout growth. However, recent increases of predators, such as coyotes, bobcats, fox, lynx, and wild dogs, prevented landowners from stocking goats. A solution of 2,4,5-T and straight diesel oil to make one gallon per acre was demonstrated in 1972-73 and results compared with standard volume per acre. Low volume application saved $0.75 per acre over the standard volume and appeared to deposit 2,4,5-T spray on the target area equally as well as the standard volume.

Stocker cattle gained 2.5 pounds per day for 270 days from October 15 to July 15. The uncontrolled area could carry only 43 animals per 640 acres (15A/AU) while the controlled areas carried 80 animals per 640 acres (8 A/AU). The 2,4,5-T sprayed area produced an increase of 24,975 pounds of cattle weight in favor of controlled area (table 11). Ease of working livestock on controlled areas amounted to about $1 per acre in labor saved during roundups. Also, wildlife habitats appear not to be affected.

About two-thirds of the post-oak area is managed as cow-calf operations and one-third as stocker operations. Some land owners carry over calves to make maximum utilization of the increased native forage on controlled

Table 11--Current use and benefits of 2,4,5-T, and potential alternatives, on 35 million acres of oaks, Texas, Oklahoma, Arkansas, Missouri, and Kansas

Use & alternative treatment	Acres in area a/	Acres treated annual	Rotation period	Acres treated in rotation	Per acre treatment cost 1975-77 b/	Total annual cost	Total rotation cost	Amortized per acre cost c/	Beef yield per acre d/	Value per pound 1975-77 e/	Gross value per acre
			Years		Dollars				Pounds	Dollars	
Cow-calf operations:											
2,4,5-T	35,000,000	360,700	5	1,803,500	11.00	3,967,700	19,838,500	2.68	28.5	.3580	11.20[f/]
Silvex	35,000,000	360,700	5	1,803,500	12.00	4,328,400	21,642,000	2.93	28.5	.3580	11.20[f/]
Do nothing	35,000,000	NA	NA	NA	NA	NA	NA	NA	11.2	.3580	4.01
Stocker operations:											
2,4,5-T	35,000,000	180,300	5	901,500	11.00	1,983,300	9,916,500	2.68	84.4[g/]	.3580	31.22[f/]
Silvex	35,000,000	180,300	5	901,500	12.00	2,163,600	10,818,000	2.93	84.4[g/]	.3580	31.22[f/]
Do nothing	35,000,000	NA	NA	NA	NA	NA	NA	NA	45.4[g/]	.3580	16.25

a/ Range Specialist each state.

b/ Average cost from commercial applicators.

c/ Per acre cost of 2,4,5-T and alternative treatment amortized over-year rotation period at 7% interest; i.e.

d/ Percent calf crop 85%, stocking rate treated 15 A/AU and 500 lb calves, stocking rate untreated 30 A/AU and 400 lb calves.

e/ Agri. Eco. Dept., Marketing, TAEX-TAMU, College Station, Texas.

f/ Labor savings of $1 per acre on treated area.

g/ Treated, stocking rate 8 A/AU, 675 lb gain/hd; untreated, stocking 15 A/AU, 675 lb gain/hd.

SOURCE: Range Brush and Weed Control Specialists, Texas Agricultural Extension Service, Texas A&M University, College Station, Texas 77843.

areas. These cow-calf operators that carry over their calves increase their profits by finishing their calves to higher grades and heavier weights. Analyses of cow-calf and stocker operations are presented in table 11.

Goats have been used for brush control with only limited success in Oklahoma. It took 100 head of goats per 150 acres to keep brush suppressed, and resprouts would come into the area as soon as the goats were moved. There was little or no profit in the operation because of increased losses from coyotes (Stritzke 1965-72).

Mechanical removal has also been used. It took an average of 53 man-hours to hand clear brush from an acre (Elwell et al. 1974). Part of this labor expense can be recovered by selling firewood. This is only temporary because without 2,4,5-T treatment of the stumps, resprouts are a major problem. Mowing of these sprouts was not effective and after 3 annual mowings, there was a significant increase in stems (Elwell et al. 1974). Dozing and converting to an improved pasture is an alternative on some of the better sites but is not recommended for sites with steep slopes and shallow soils (McMurphy et al. 1975). Most of the good sites have already been converted so only a small percent of existing area could be root plowed or bulldozed. Chaining was not effective for oak control in Oklahoma as three years after chaining, resprouts were 6-8 feet tall (Stritzke 1965-72). Use of fire will control the tops of oak sprouts but it will not control trees with stem diameters over 2 inches without prior herbicide treatment.

There is no satisfactory or economical alternative control method that can be substituted for the current broadcast application of 2,4,5-T or silvex (Hoffman et al. 1978). Herbicides such as 2,4-D or 2,4-DP are not as effective as 2,4,5-T or silvex for oak control. Both 2,4-D and dicamba are registered for oak brush control but neither are extensively used. Early work comparing 2,4-D and 2,45-T showed that results with

2,4,5-T were more effective and more consistent than with 2,4-D (Elwell et al. 1974).

Little extensive research work has been conducted with 2,4-D for oak brush control. However, numerous investigators have observed and worked with 2,4-D over the years and they usually rate the oaks as intermediate to resistant to foliar sprays of 2,4-D (Bovey 1977). These same workers rated the oaks as susceptible or resistant to dicamba, depending on the individual oak species. Some of the early work with dicamba on seedling oaks indicated that as foliage spray it was only at high rates of 4 pounds per acre that dicamba approached the effectiveness of 2,4,5-T. Dicamba was evaluated in aerial studies as an additive to 2,4,5-T for oak control and increased kill was noted only in one of seven studies (Hoffman et al. 1978).

An additional example of economical benefits concerned a ranchman in Young County in 1954 who had this to say about aerial control of oak with 2,4,5-T, "Stocking capacity of grass was at least 450 percent greater than before spraying. The cost of two applications was $10.00 per acre. If good hay were selling for $20.00 per ton, you had better spend your money for chemicals for brush control because you will get more than a half ton of dry forage per acre and the benefits will be continuous. The stocking rate on 800 acres increased from 27 head before brush control to 74 head afterwards." He estimated a kill of 62 percent was obtained from two sprayings and 34 percent kill from one spraying (Hoffman et al. 1950-1977).

The Jack County agent reported in 1954 about range recovery following aerial spraying of oak. "In spite of four years of drouth, spraying of oak trees on two ranches increased climax grass growth 100 percent." On a demonstration of 100 acres, oak growth was so dense at the start that nothing but wild animals could get through. Now, in spite of drouth, he is running a cow to every 10 acres and they are in excellent shape. No supplemental feeding has been given to these animals. Oak-controlled areas had a stocking rate of 14-16 acres per animal unit while untreated areas had a stocking rate of 30-40 acres per animal unit (Hoffman et al. 1950-77).

The Young County agent reported in 1957 that brush and weeds cause more production loss than soil erosion or all insects combined. Results from 2,4,5-T aerial spraying showed that oak kill ranges from 90 to 95 percent. The grass production on controlled areas was doubled when compared to uncontrolled areas. This means more livestock products produced per acre, with the cost of the improved practice being paid for in four years. Brush control usually lasts seven to eight years in this county (Hoffman et al. 1950-77).

A Robertson County agent reported in 1958 that good perennial grasses completely covered an area after the oak trees and brush were individually treated and controlled with chemicals (Hoffman et al. 1950-77).

The Camp County agent in 1958 stated one of his demonstrators reported that control of weeds and brush resulted in an increased stocking rate of 25 percent (Hoffman et al. 1950-77).

A Leon County agent stated that grass production increased several fold on areas where brush was controlled with chemicals and proper management followed (Hoffman et al. 1950-77).

Based on the results obtained and presented, it appears that 2,4,5-T and/or silvex are needed to balance the native plant community and return it to the original savannah-type vegetation. If the oaks are not controlled, the oaks on many areas will be so dense as to make livestock production unprofitable. This could cause a shortage of red meat since many of the oak areas are now supporting cow-calf operations.

Table 11 shows results for the accepted control method and the best alternative. Beef production loss would be 93,602,000 pounds for cow-calf and 105,478,000 pounds for stocker operation for a net present value loss of $15,929,000 for cow-calf and $25,568,000 for stocker operation during the first 5-year rotation period that 2, 4, 5-T or silvex could not be used (table 12).

SAND-SHINNERY OAK

Sand-shinnery oak, Quercus havardii, occupies 14,331,000 acres of sandy soils in New Mexico, Oklahoma, and Texas (Platt 1959). Sand-shinnery oak is a low-growing shrubby oak usually less than six feet tall. It grows very dense because it sprouts along the lateral roots. Sand-shinnery oak density reduces forage grass species but if the seed source is available, forage production is great following control with 2,4,5-T or silvex. Sand-shinnery oak causes livestock poisoning losses when cattle consume the leaf buds in spring.

The normal practice for controlling sand-shinnery oak is to apply 2 successive sprayings of 1/2 pounds per acre a.e. of 2,4,5-T or silvex in the spring after the leaves are fully developed for maximum stem kill for a life span of 10 years (Hoffman et al. 1978). Some landowners spray with only one application for forage production and small percentage stem kill followed with a repeat treatment at 4 to 5-year intervals.

In Oklahoma, stocking rates have increased from 10.5 to 5.5 acres per animal unit following control of sand-shinnery oak with 2 applications of 2,4,5-T or silvex (Stritzke 1965-72). In Texas and New Mexico, stocking rates have increased from 20-25 acres to 12-14 acres per animal unit following control. Livestock weight and death losses are reduced following control, but this will not be considered in the economic analysis of the control practice even though economic gain is great. Also, beef calf weight was about 65 pounds more per head on controlled areas than on uncontrolled areas.

Table 12A--Estimated decrease in value of beef production due to the nonavailability of 2,4,5-T and silvex, post-blackjack oak rangeland, cow-calf operation

No. years w/o 2,4,5-T	Treated area with remaining yield effects: Acres a/	Yield a/	Production	Previously treated area w/o remaining yield effects: Acres	Yield a/	Production	Total beef: Production	Value b/	Production loss w/o 2,4,5-T c/	Value of lost production b/	Amortized cost of lost production d/	Net value of lost production b/	Net present value of lost production e/
		Lbs	Thous lbs		Lbs	Thous lbs	Thous lbs	Dols	Thous lbs	Thousand dollars			
0	1,803,500	28.5	51,400	0	n/a	n/a	51,400	18,401	0	n/a	n/a	n/a	n/a
1	1,442,800	28.5	41,120	360,700	11.2	4,040	45,160	16,167	6,240	2,234	967	1,267	1,267
2	1,082,100	28.5	30,840	721,400	11.2	8,080	38,920	13,933	12,480	4,468	1,933	2,535	2,369
3	721,400	28.5	20,560	1,082,100	11.2	12,120	32,680	11,699	18,720	6,702	2,900	3,802	3,321
4	360,700	28.5	10,280	1,442,800	11.2	16,159	26,439	9,465	24,961	8,936	3,867	5,069	4,138
5	0	n/a	n/a	1,803,500	11.2	20,199	20,199	7,231	31,201	11,170	4,833	6,337	4,834
													15,929

a/ Taken from table 11.

b/ Beef value at $0.3580 per pound, 1973-77 average.

c/ Production loss calculated from column 8; i.e., 51,400 - 45,160 = 6,240.

d/ Treatment cost amortized at 7% interest from table 11, column 9, times acres without remaining yield effects (column 5); i.e., $2.68 X 360,700 = $966,676.

e/ Present value calculated using 7% discount factor.

SOURCE: Natural Resource Economics Division, ES&CS, USDA, Corvallis, Oregon.

Table 12B--Estimated decrease in value of beef production due to the nonavailability of 2,4,5-T and silvex, post-blackjack oak rangeland stocker operation

No. years w/o 2,4,5-T	Treated area with remaining yield effects: Acres a/	Treated area with remaining yield effects: Yield a/	Treated area with remaining yield effects: Production	Previously treated area w/o remaining yield effects: Acres	Previously treated area w/o remaining yield effects: Yield a/	Previously treated area w/o remaining yield effects: Production	Total beef: Production	Total beef: Value b/	Production loss w/o 2,4,5-T c/	Value of lost production b/	Amortized cost of lost production d/	Net value of lost production b/	Net present value of lost production e/
		Lbs	Thous lbs		Lbs	Thous lbs	Thous lbs	Dols	Thous lbs	Thousand dollars			
0	901,500	84.4	76,087	0	n/a	n/a	76,087	27,239	0	n/a	n/a	n/a	n/a
1	721,200	84.4	60,869	180,300	45.4	8,186	69,055	24,722	7,032	2,517	483	2,034	2,034
2	540,900	84.4	45,652	360,600	45.4	16,371	62,023	22,204	14,064	5,035	966	4,069	3,803
3	360,600	84.4	30,435	540,900	45.4	24,557	54,992	19,687	21,095	7,552	1,450	6,102	5,330
4	180,300	84.4	15,217	721,200	45.4	32,742	47,959	17,169	28,128	10,070	1,933	8,137	6,642
5	0	n/a	n/a	901,500	45.4	40,928	40,928	14,652	35,159	12,587	2,416	10,171	7,759
													25,568

a/ Taken from table 11.

b/ Beef value at $0.3580 per pound, 1973-77 average.

c/ Production loss calculated from column 8; i.e., 76,087-69,055 = 7,032

d/ Treatment cost amortized at 7% interest from table 11, column 9, times acres without remaining yield effects (column 5); i.e., $2.68 X 180,300 = $483,204.

e/ Present value calculated using 7% discount factor.

SOURCE: Natural Resource Economics Division, ES&CS, USDA, Corvallis, Oregon.

Burning has not been effective for control of shinnery oak (Stritzke 1965-72). However, burning every 3rd year did release some grass with a resulting increase in cattle gains. Over an 8-year span, grass production was increased an average of 20 percent. Since shinnery oak occurs on sandy lands that are easily eroded by wind, precautions will need to be taken with any burning program (Stritzke 1965-72).

Mowing, even in combination with spraying was not effective for shinnery oak control (Stritzke 1965-72). Deep plowing to reclaim shinnery oak land is an alternative that is practiced to a limited extent (Stritzke 1965-72). It involves several years of farming and then converting to lovegrass. It is expensive and needs to be limited to those areas having clay soil in the top two feet of the profile. These soils are limited to a small percentage in the sand-shinnery oak area.

Dicamba and 2,4-D are not alternatives as these two herbicides may not produce defoliation of sand-shinnery oak even when applied at two pounds a.e. per acre. Silvex, 2,4,5-T and 2,4,5-T:picloram (Tordon 225^{R}) are the only herbicides that produce satisfactory control in the order named. Economically 2,4,5-T is favored over silvex or 2,4,5-T:picloram mixture. Picloram alone is not registered.

Controlled areas can produce 26.9 pounds of saleable beef products or $9.63 per acre as compared to the untreated area producing 14.0 pounds or $5.01 per acre (table 13). Beef production loss without the use of 2,4,5-T or silvex would amount to 319,275,000 pounds for a net present value loss of $56,508,000 the first 10-year rotation period that 2,4,5-T or silvex is not used (table 14).

CACTUS

Cactus species, Opuntia spp., infests 78.6 million acres of rangelands in the U.S. (Platt 1959), with the greatest concentration in the Southern Great Plains with Texas having nearly 31 million acres (Smith and Rechentin 1964). Cactus species are natural components of native grasslands

Table 13--Current use and benefits of 2,4,5-T, and potential alternatives, on 14.3 million acres of sand-shinnery oak, New Mexico, Texas, and Oklahoma

Area & alternative treatment	Acres in area a/	Acres treated annual a/	Rotation period	Acres treated in rotation	Per acre treatment cost 1975-77 b/	Total annual cost	Total rotation cost	Amortized per acre cost c/	Beef yield per acre	Value per pound d/	Gross value per acre
			Years		----------Dollars----------				Pounds	------Dollars------	
Sand-shinnery oak:											
2,4,5-T	14,331,000	450,000	10	4,500,000	8.70	1,957,500	39,150,000	1.24	26.9	.3580	9.63
Silvex	14,331,000	450,000	10	4,500,000	9.20	2,070,000	41,400,000	1.31	26.9	.3580	9.63
Do nothing	14,331,000	NA	NA	NA	NA	NA	NA	NA	14.0	.3580	5.01

a/ Range Specialist each state.

b/ Average cost from commerical applicators.

c/ Per acre cost of 2,4,5-T and alternative treatment amortized over-year rotation period at 7% interest; i.e.

d/ Agri. Eco. Dept., Marketing, TAEX-TAMU, College Station, Texas.

SOURCE: Range Brush and Weed Control Specialists, Texas Agricultural Extension Service, Texas A&M University, College Station, Texas 77843.

Table 14--Estimated decrease in value of beef production due to the nonavailability of 2,4,5-T and silvex, on 14.3 million acres of sand-shinnery oak - Texas, Oklahoma and New Mexico

No. years w/o 2,4,5-T	Treated area with remaining yield effects: Acres a/	Yield a/	Production	Previously treated area w/o remaining yield effects: Acres	Yield a/	Production	Total beef: Production	Value b/	Production loss w/o 2,4,5-T c/	Value of lost production b/	Amortized cost of lost production d/	Net value of lost production b/	Net present value of lost production e/
	Thous	Lbs	Thous lbs	Thous	Lbs	Thous lbs	Thous lbs	Dols	Thous lbs	Thousand dollars			
0	4,500	26.9	121,050	0	n/a	n/a	121,050	43,336	0	n/a	n/a	n/a	n/a
1	4.050	26.9	108,950	450	14.0	6,300	115,245	41,258	5,805	2,078	558	1,520	1,520
2	3,600	26.9	96,840	900	14.0	12,600	109,440	39,180	11,610	4,156	1,116	3,040	2,841
3	3,150	26.9	84,735	1,350	14.0	18,900	103,635	37,101	17,415	6,235	1,674	4,561	3,984
4	2,700	26.9	72,630	1,800	14.0	25,200	97,830	35,023	23,220	8,313	2,232	6,081	4,964
5	2,250	26.9	60,525	2,250	14.0	31,500	92,025	32,945	29,025	10,391	2,790	7,601	5,799
6	1,800	26.9	48,420	2,700	14.0	37,800	86,220	30,867	34,830	12,469	3,348	9,121	6,503
7	1,350	26.9	36,315	3,150	14.0	44,100	80,415	28,789	40,635	14,547	3,906	10,641	7,091
8	900	26.9	24,210	3,600	14.0	50,400	74,610	26,710	46,440	16,626	4,464	12,162	7,574
9	450	26.9	12,105	4,050	14.0	56,700	68,805	24,632	52,245	18,704	5,022	13,682	7,963
10	0	n/a	n/a	4,500	14.0	63,000	63,000	22,554	58,050	20,782	5,580	15,202	8,269
													56,508

a/ Taken from table 1.

b/ Beef value at $0.3580 per pound, 1973-77 average.

c/ Production loss calculated from column 8; i.e., 121,050 - 115,245 = 5,805.

d/ Treatment cost amortized at 7% interest from table 13, column 9, times acres without remaining yield effects (column 5); i.e., $1.24 X 450,000 = $ 558,000.

e/ Present value calculated using 7% discount factor.

SOURCE: Natural Resource Economics Division, ES&CS, USDA, Corvallis, Oregon.

and become major invaders when improper range-management practices are used. The three major problem species of cacti are pricklypear, tasajillo, and cholla.

In September, 1963, Starr County Program Building Committee selected 100 acres for a demonstration-research test. Additional test areas were selected at Zapata, McMullen, and Jim Hogg Counties to include all range sites in the South Texas Plains to compare results before recommending specific methods of control. During the past 26 years Extension personnel conducted 1,281 demonstrations to show various methods for control of cacti in different areas of Texas (Hoffman 1978c).

The demonstration area was root plowed and seeded to buffelgrass (*Cenchrus ciliaris*) in spring of 1959. Root plowing produced excellent control of mesquite but not for mixed brush or pricklypear. The root plowed area contained over 3,000 pricklypear plants per acre which reduced grazing greatly (fig. 20). Stocking rates were (Hoffman 1967):

Prior to 1959 - 1 AU/40 a	
1959-62 - 1 AU/16 a	
1962-64 - 1 AU/40 a	Root plowed and seeded to buffelgrass
1964-66 - 1 AU/16 a	
1967-71 - 1 AU/6 a	Cactus and mixed brush controlled with herbicides or a combination

The demonstration was carried on for sufficient time to include wet and dry years and area stocked to use forage growth properly.

METHODS OF CONTROL

Based on results obtained at four locations, dense stands of pricklypear can be controlled effectively and economically by broadcast methods. Following are 1977 projected cost per acre for methods which have produced satisfactory control:

Figure 20. Dense stand of pricklypear cactus which established within three years following mechanical control methods. The area contained over 3,000 plants per acre and stocking rate was 40 acres per animal unit.

(1)	Double dragging + 2.0 lb/A of 2,4,5-T or silvex	$18.50
(2)	Double dragging only - 3 times over 18 months period	24.00
(3)	Chemical only - 1.0 lb/A picloram: 2,4,5-T mixture	12.50
(4)	Double dragging + 1/2 lb/A picloram: 2,4,5-T mixture	16.50
(5)	Double dragging + 2 lb/A hexaflorate (not registered)	13.00
(6)	Shredding + 1/2 lb/A picloram: 2,4,5-T mixture	16.00
(7)	Shredding + 2 lb/A dicamba: 2,4,5-T mixture	21.50
(8)	Individual plant spray - 8 lb., 2,4,5-T/100 gal. oil	30.00
(9)	Mechanical front-end stacking	12.00
10)	Mechanical front-end stacking + 1/2 lb/A picloram: 2,4,5-T	20.50
11)	Stacking + root plowing + seeding	52.00
12)	Mechanical front-end stacking + ind. plant treatment	20.00

Methods 1, 2, 8, 9, and 11 required followup maintenance in 1971 for a cost of about $2 per acre. Methods 3, 4, 5, 6, 7, 10, and 12 did not require additional treatments at last evaluation in 1977. Method 3 requires two years following application of Tordon 225^{R} before all cactus species are controlled. Treated area improved from poor to good range condition in three years (fig. 21).

Pricklypear should not become a problem for 20 years on areas where complete control was done and proper grazing management carried out. A dense stand of tall grass produces sufficient competition that pricklypear seedings would have difficulty in establishing. Sufficient areas of pricklypear must be left to provide food for wildlife such as the javelina population.

One of the 12 methods can be used to control the 31 million acres of rangeland infested with different species of cacti. In many areas of the 78.6 million acres, returns per acre will not be as great as in the South Texas Plains. On many ranches, controlling cacti will not increase stocking rate, but will allow more area to produce forage for grazing thus reducing cost of supplemental feed which is of great economic benefit.

Figure 21. Pricklypear controlled with dragging followed with application of 2,4,5-T or silvex. Area improved in range condition within three growing seasons. Controlled area now supports 1 animal unit per 6 acres.

Broadcast spray of 2, 4, 5-T: Picloram, (Tordon 225[R]) mixture at 1 pound per acre is the only method that can be used throughout the Great Plains for cacti control. There is strong indication that 1/2 pounds per acre of Tordon 225[R] will produce satisfactory control of cacti about the 32° latitude.

Individual plant treatment using 2,4,5-T mixed in diesel oil or picloram pellets (Tordon 10K[R]) costs from $250 to $350 per acre on areas with over 125 plants per acre and is considered non-economical (Hoffman et al. 1978).

Mechanical methods of dragging, shredding, stacking, and root plowing plus seeding can be used only on areas with woody plants less than 3 inches in diameter, and these methods alone are suitable on about 10 million acres of the Great Plains (Hoffman et al. 1978).

Hand grubbing is a very limited alternative because of the $85 to $340 cost per acre and the unavailable source of labor (Norris et al. 1979 and Hoffman et al. 1978). Fire is not an alternative as sufficient fuel cannot be produced to cause a fire hot enough to control cacti species.

BENEFITS

Areas where pricklypear was controlled in South Texas Plains produced 69.8 pounds per acre of beef while untreated dense stand of cacti area produced only 9.6 pounds per acre of beef products. On the treated acres, variable cost, gross returns, and net returns per acre from beef production were $15.23, $23.86, and $8.63, respectively. On the untreated acres variable cost, gross returns, and net returns per acre were $2.38, $3.28, and $0.90, respectively. In the area re-established to native grasses, the stocking rate would be 1 animal unit per 16 acres while the uncontrolled area would be stocked at 1 animal unit per 40 acres. Beef production on native grass rangelands would be 26.2 pounds per acre while the uncontrolled area would be 9.6 pounds per acre.

One or more cactus species can become a major problem on rangeland or pastureland adjacent to the Atlantic and Gulf Coasts and on rangeland west of the 95° longitude. The herbicides 2,4,5-T, silvex, and 2,4,5-T: picloram mixture will be needed for control of cacti. Picloram liquid alone is not registered. No economic analysis will be made for the cacti species as it was difficult to determine the number of acres treated each year.

HARDWOODS WITHIN THE POST-BLACKJACK OAK AND PINE AREA

Many acres of bottomland are occupied by various species of hardwoods, oaks, gums, hickory, and other species throughout the oak-hickory-pine areas. The canopy is so dense the area produces small amounts of forage for yearlong grazing. If hardwood species are not suitable for lumber and drainage is adequate, a small percentage of the area can be converted to tame pasture forage plants for a cost of about $120 per acre. The area could be managed for hardwood timber production when the species are desirable. The hardwood areas can be reestablished to native forage species with two treatments of 2 pounds of 2,4,5-T per acre applied a year apart. The life span is 10 years. Silvex is not as effective for control of many hardwoods as 2,4,5-T, and the life span of using silvex would be about 7 years (Hoffman et al. 1978).

The following chart shows results of beef production following control of bottomland hardwoods on 600 acres in Texas (Hoffman et al. 1950-77). These results would be similar to all bottomland areas east of the 95° longitude in the U.S.

Year	Rate A's/AU	Beef Produced/A	Return/A ($0.3580/lb)	Cost 2 Sprays/A	Return A/Yr Above Spray Cost
Before Control	20.0	20.9	$ 7.48	N/A	$ 7.48
2 Yrs. After	10.5	39.5	$14.14	$3.13	$11.01
4 Yrs. After	9.2	37.9	$13.57	$3.13	$10.44

Refer to the post-blackjack oak section for alternative-control methods. Bottomland hardwood areas will remain in an unproductive condition if herbicides cannot be used as a control measure.

YUCCA

Yucca, (Yucca spp.,) is a natural species occurring on millions of acres of native rangelands. Generally it is a problem species on limited range sites following severe droughts or over use of rangeland. Some yuccas have root-sprouting characteristics when the main portion of the plant is disturbed. During droughts yucca flower stems are cut so livestock can consume the nutritious heads. Removing the flower stalk has no effect upon the established plant.

METHODS OF TREATMENT

Yucca can be controlled by broadcast and individual spot treatment. Broadcast application in Texas should be made before the plant has fully bloomed, usually May 15 to June 30 using 0.67 pounds per acre a.e. of 2,4,5-T or silvex. The herbicide carrier should be a 1:4 oil-water emulsion and applied at 4 gallons total volume per acre by aircraft or 25 gallons per acre by ground broadcast. One application reduces the yucca population 35 to 80 percent with a life span of 10 to 15 years, depending upon the range site (Hoffman 1976).

Individual spot treatment is done by treating central bud with 2,4,5-T or silvex mixed at 8 pounds a.e. per 98 gallons of diesel oil. The application can be made throughout the year in the western U.S (Hoffman 1976).

Desirable forage species reestablish within the dead plant residue during the two growing seasons following control. Range condition improved from poor to good within two years following control.

Since yucca is not a major problem on all range sites, there have been little data collected to show economic benefits following control. In a study by Robison (1965), Yucca glauca occurred on 10 percent of the rangeland in a 54-county area of the Texas Plains in sufficient density to warrant control.

BENEFITS

Forage production on controlled areas increased by an average of 565 pounds per acre more than uncontrolled areas. Proper use of the increased forage production per acre would supply grazing for an extra 11 days per animal unit. In one study, controlled area produced 1,707 pounds per acre and uncontrolled produced 1,194 pounds per acre. The controlled area could have a stocking rate of 1 animal unit to 13 acres while uncontrolled would be 1 animal unit to 18 acres. The controlled area could produce 30 pounds per acre of beef while the uncontrolled could produce only 19 pounds per acre. The controlled area could have a return of $3.94 per acre more over a 10-year period than the uncontrolled area.

ALTERNATIVES FOR 2,4,5-T

At present there is no herbicide or mechanical method or biological method that will control yucca species other than silvex and/or 2,4,5-T either broadcast or individual spot treatment which is the only economical and satisfactory means of control.

No economic analysis will be made for this species since it was difficult to obtain acres treated each year. It is necessary that landowners have the herbicides 2,4,5-T and/or silvex available to control yucca when it becomes a problem on rangeland.

POISONOUS PLANTS

A poisonous plant is one which causes chemical or physiological disturbances when consumed by livestock. The effects may vary from mild sickness to death. The economic impact on the livestock industry caused by poisonous plants in the United States is enormous. Poisonous plants are estimated to kill from 3 to 5 percent of the livestock on western ranges. Loss from poisonous plants is one of the major economic problems in livestock production. A compilation of numerous reports indicates that the annual loss from poisonous plants in Texas is between 50 and 100 million dollars (Sperry et al. 1976). Approximately 80 species and varieties of poisonous plants growing in pastures and on range areas of Texas cause toxicity problems (Sperry et al. 1976).

Poisoning of livestock is more commonly the result of management, range conditions, or kinds of animals rather than the presence of the plants concerned. Poor range condition from overgrazing or other conditions resulting in a lack of palatable forage are the common causes of poisoning. The real danger is whether or not the toxic species is grazed. Many species are seldom eaten, but some are relished by certain animals and may be taken in preference to other forage. In some instances animals will select flowers or fruits or new growth; in other situations grazing is less discriminate. Many poisonous plants are green at a time of the year when other plants are dormant. Small amounts of plant material can be lethal shortly after consumption in some cases. In others, the toxic substances are cumulative and the species must be grazed over a period of time before signs of poisoning appear.

Frequent cases of poisoning occur when hungry animals are turned into new pastures or are given access to poisonous plants near pens, watering places, or along trails. Most poisonous plants are eaten because the animal is hungry and the poisonous plant is readily available (Sperry et al. 1976).

Many poisonous plants can be controlled with the application of a particular herbicide at specific plant growth stages. Phenoxy herbicides offer the most effective and economic control measures with 2,4,5-T or silvex being required to control certain species. Listed below are some poisonous plants that are best controlled with 2,4,5-T. Many of the plants would increase in density rapidly if allowed to go uncontrolled. Millions of acres of rangelands would go ungrazed at certain times during the year.

Poisonous Plants Controlled with 2,4,5-T or Silvex Only

Common Name	Scientific Name	States With Problem Area
Guajillo	Acacia berlandieri	Southwest
Buckeye	Aesculus glabra and A. pavia	Southeast and Southwest
Garbancillo	Astragalus wootonii	West and Plains
White snakeroot	Eupatorium rugosum	Southeast and Southwest
Larkspurs	Delphinium spp.	West
Coyotillo	Karwinskia humboldtiana	Southwest
Lantana	Lantana camara	Eastern and Southwest
Wild plum	Prunus spp.	All of United States
Shin oak	Quercus spp. and Quercus havardii	Southwest and Plains
Mescalbean	Sophora secundiflora	Southwest
Smartweed	Polygonum spp.	All of United States
Chinaberry	Melia azedarach	All of United States
Lechuguilla	Agave lecheguilla	Southwest
Black locust	Robinia pseudo-acacia	Eastern and Southwest
Poison hemlock	Conium maculatum	West and Southeast
Waterhemlock	Cicuta douglasii and C.maculata	West
Mountain laurel	Kalmia latiflolia	Northeast and Southeast
Buttonbush	Cephalanthus occidentalis	Southeast, Southwest, West
Sacahuista	Nolina microcarpa and N. texana	Southwest
Timber milkvetch	Astragulus miser.	West
Lupines	Lupinus spp.	West, Plains, Southeast

DESERT SHRUB AND SOUTHWESTERN SHRUB ECOSYSTEMS

Desert Shrub, Chaparral-Mountain Shrub, and Southwestern Shrub ecosystems contain 124.6 million acres of important western arid rangeland. Much of the area has low potential production for livestock but is very important for wildlife habitat and watershed yields.

Woody plant species that grow on the area to varying densities include blackbrush, Flourensia cernua; creosotebush, Larrea divaricata; saltbush, Atriplux spp.; greasewood, Larcobatus spp.; Palo Verde, Cercidium spp.; cactus, scrub oak, and mesquite. About 33 percent of the total acreage could be treated with 2,4,5-T to prevent the woody plants from increasing in density. Woody plants, if not controlled, will continue to increase in density to the point that the area may not be suitable as wildlife habitat or for supporting watershed yields.

There is no registered herbicide that can be substituted for 2,4,5-T to control all species to the same degree and as economically as does 2,4,5-T. Mesquite and scrub oak are the only species that are susceptible to broadcast foliage application of 2,4,5-T. The other woody species must be treated with 2,4,5-T mixed in diesel oil as individual spot application. Figure 22 shows the states covered by these ecosystems.

The herbicide 2,4,5-T is needed to treat large acreages economically to provide as much increase in water yields, due primarily to reduced transpiration, and improve wildlife habitat as possible. If the western range shrub ecosystems are not maintained, this would be a serious threat to future generations.

CULTIVATED PASTURES

Cultivated pastures are a most important part of the livestock industry for supplying hay and furnishing many months of grazing to allow deferment of native rangeland. Within the 48 states there are 101.1 million acres of cultivated pastures (Anonymous 1977a).

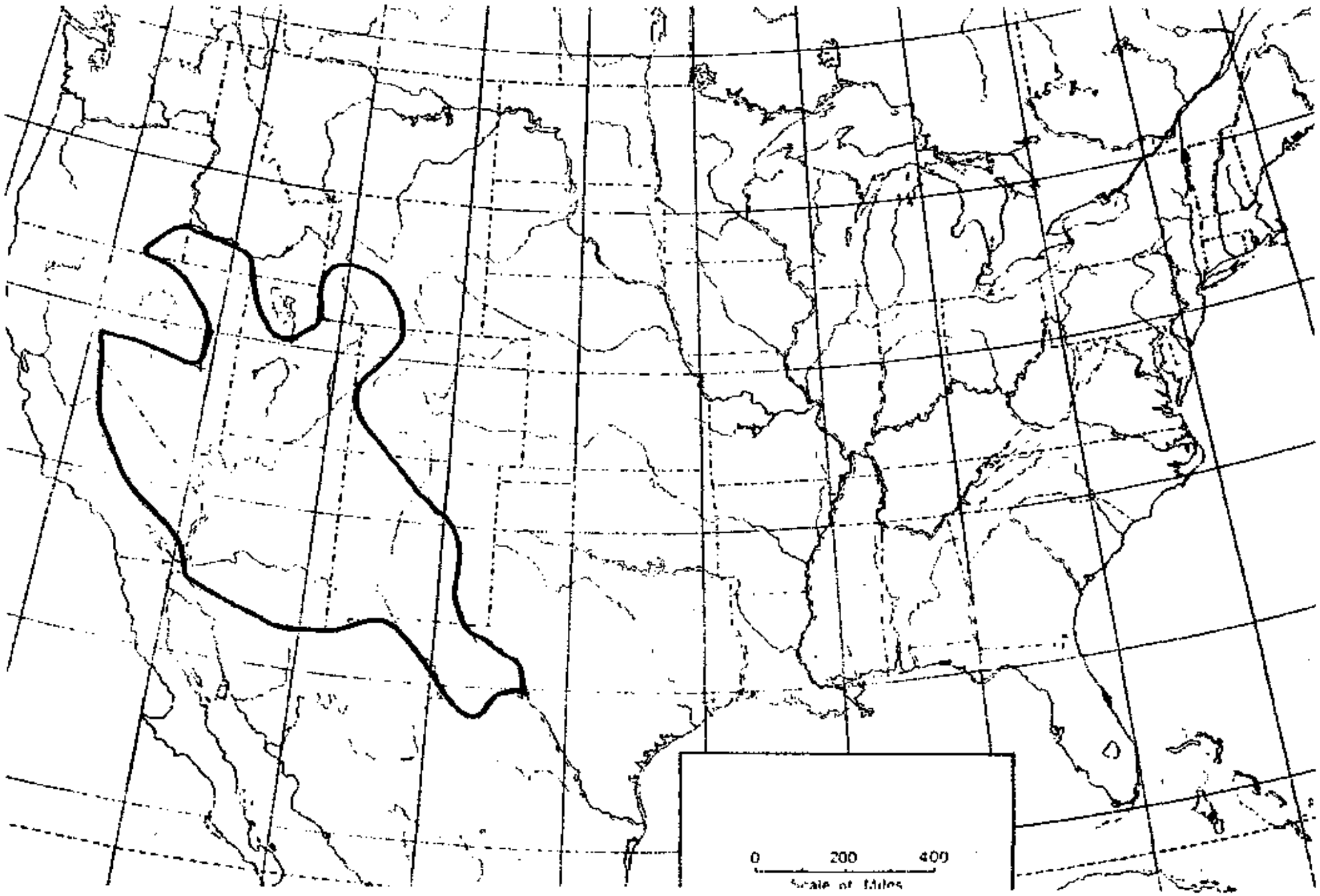


Figure 22. Desert shrub and southwestern shrub.

There are over 68 million acres of pastures in the eastern half of the U.S., with the Northeast having 39.9 million and Southeast with 28.3 million, where normal rainfall is adequate for forage production with minimum amounts of irrigation. The Plains States contain over 24 million acres and the majority of the pastures are located east of the 25 inch rainfall line. A minimum amount of acreage is under irrigation except for alfalfa. The Western states contain less than 9 million acres which are mostly irrigated to produce maximum amounts of high tonnage and quality hay which demands premium prices.

METHODS FOR CONTROL

Pastures in the Eastern three-fourths of the United States which are managed extensively are subject to being invaded by various species of woody plants (Hoffman et al. 1978). Many of these invaders cannot be controlled with the existing registered herbicides except for 2,4,5-T. The most widely used control method is individual spot treatment using 2,4,5-T mixed in diesel oil as a basal or cut surface treatment or as a foliage spray using 2,4,5-T mixed in water. In some cases a minimum acreage would be treated with broadcast using ground equipment. Generally, landowners treat woody plants in cultivated pastures as they appear. This allows the pasture to be maintained free of woody plants with a minimum amount of 2,4,5-T being used. Aerial application has limited use as many woody plant species are not controlled with small amounts of herbicide as with mesquite and the oaks.

Woody and herbaceous plants that occur widely on cultivated pastures as weed problems included blackberry, chokecherry, hawthorn, honeysuckle, horsenettle, ironweed, oaks, poison ivy, multiflora rose, sumac, willows, pricklypear, and juniper. Weed species occurring as a serious problem but in fewer states, include alder, American crabapple, American elm, aspen, birch, black cherry, black locust, cottonwood, elderberry, hazel, hickory, osage-orange, poison oak, poplar, sweetgum, sycamore, Virginia creeper, sassafras, dewberry, hackberry, persimmon, greenbrier, gallberry, honey locust, palmetto, redcedar, smooth sumac,

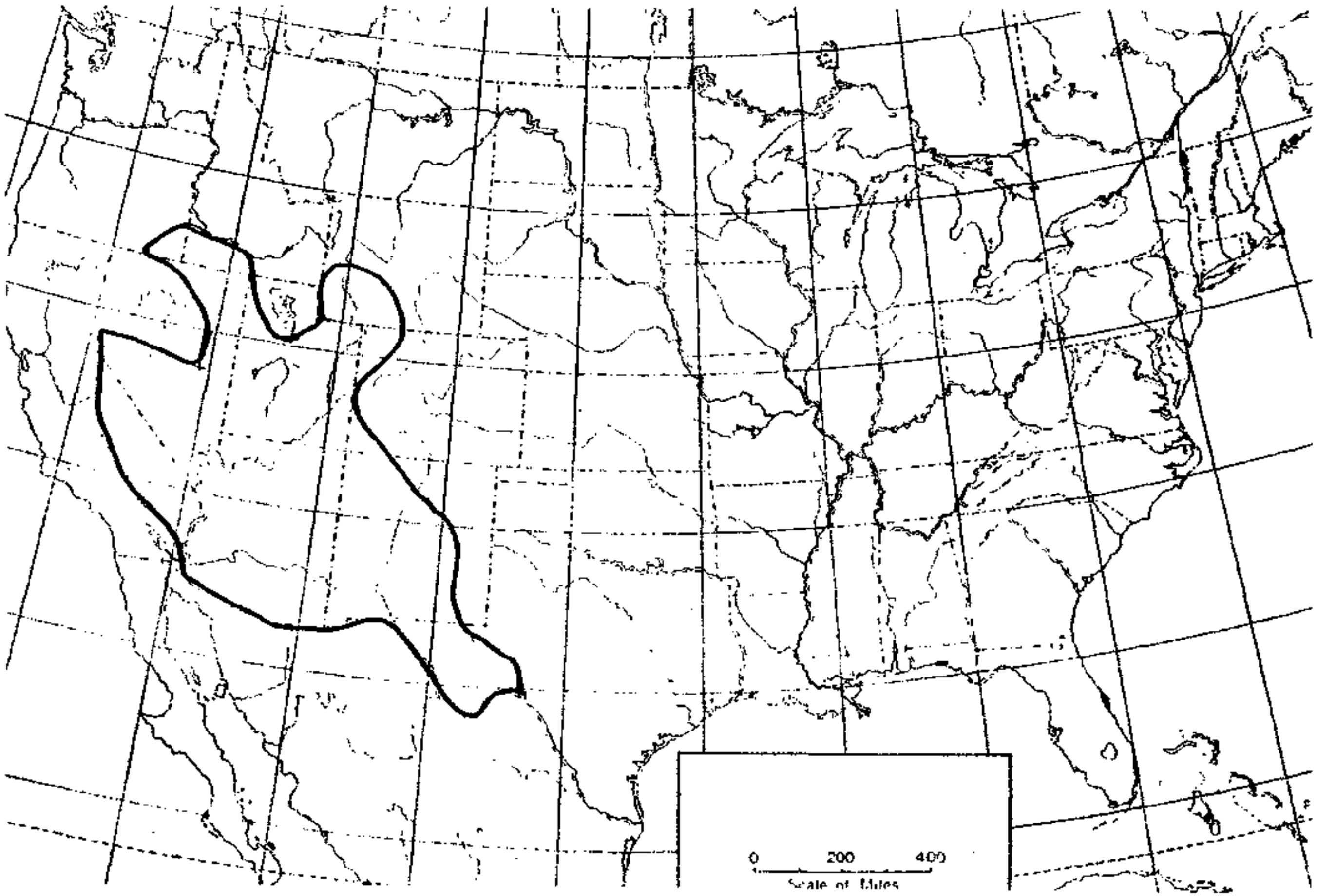


Figure 22. Desert shrub and southwestern shrub.

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Fire, when properly used, is an effective and economical control measure, but currently is discouraged because of atmospheric pollution. Mechanical control is widely used for pastureland improvement on extensively managed pastures but is expensive. Mechanical control leaves soil surface rough which is not suitable for intensively managed hay pastures. Biological control includes use of concentrating cattle to reduce undesirable vegetation. Planned grazing stimulates grass and forb production and improves the food supply for deer and birds. However, as indicated earlier, livestock can be used only in special situations and with care since they may graze the more desirable species.

In general, higher moisture conditions in eastern pastures may allow greater carrying capacity than western pastures, except under irrigated conditions. Woody plants and weeds may have a tendency to grow and recover faster under humid versus more arid conditions; consequently, more frequent treatment may be required for satisfactory pasture improvement.

Under the more humid climate, herbicides such as 2,4,5-T would also have a tendency to disappear more rapidly from the environment than drier climates. The same principles apply to the fate and toxicity of 2,4,5-T on eastern versus western range and pasturelands. The use of 2,4,5-T for woody plant control on eastern pastures is an important tool in grazing land management. It is estimated that at least one million acres of pastures are treated annually with 2,4,5-T.

ALTERNATIVES

Picloram (Tordon 10K^{R}) pellet is approved for use on grasslands in the southeast but for particular species such as kudz sumac, cacti, multiflora rose, white brush and huisache. If Tordon 10K[R] pellet label were expanded to include all woody species, the Tordon 10K[R] could be used as a substitute for 2,4,5-T except for control of mesquite. Dicamba liquid and granular have limited use in the humid areas. Additional testing would be necessary to determine how extensively dicamba could be used. Dicamba granular controls common persimmon effectively. Cut surface of frill and stump treatment using undiluted 2,4-D would control most woody plants except mesquite, huisache, cacti, and yucca to list a few (Elwell et al. 1974 and Hoffman 1978).

Mechanical shredding is not effective as the sprouting crowns are not removed from the soil. Mechanical grubbing leaves the soil surface rough and unsuitable for using expensive haying equipment. Burning at two year intervals would maintain woody plants at a low density.

The herbicide 2,4,5-T is needed to aid landowners in all of the United States in maintaining pastures free of woody plants. There appears to be only a small quantity of 2,4,5-T used for woody plant control each year.

Cultivated pastures were not included in the economic analysis as sufficient data were not available from all areas. It would be difficult to make a total economic assessment for the benefits of keeping pastures free of invading woody plants with periodic spot treatments with 2,4,5-T. Life span of treatment should be 10 years.

FENCE ROWS

Fence rows are an integral part of farming and ranching. Fence rows become infested with woody and herbaceous plants as weeds lodge during windstorms, and birds deposit seeds in their droppings while resting on the wires. Invading plants cause fences to deteriorate and increase labor cost for repairs. In some cases it would be necessary to rebuild a new fence at 10-year intervals in some areas of the U.S. Life span of a maintained fence is 20 to 45 years.

METHODS FOR CONTROL

Herbicide 2,4,5-T can be used to treat woody plants growing on fence rows thoughout the U.S. Application equipment for 2,4,5-T includes ground handsprayers. Diesel oil is used as a carrier for 2,4,5-T when a knapsack handsprayer is used while a 1:4 oil-water emulsion can be used with a power sprayer. Oil-water emulsion reduces cost, but more volume is needed to obtain satisfactory plant kill. Oil-water emulsion does not burn the existing forage grasses as much as does straight diesel oil.

Standard rate of application is 16 pounds of 2,4,5-T per 100 gallons of diesel oil when the knapsack handsprayer is used for a cost of $105. Each gallon of mixture should treat 20-4 inch diameter trees. The lower 12 inches of the stems are treated. Standard rate of application for a 1:4 oil-water emulsion is 8 pounds of 2,4,5-T per 100 gallons for a cost of $38.10. Each gallon should treat about 10-4 inch diameter trees. The lower 18-36 inches of the stems are treated. The degree of control on woody species would be comparable with each herbicide mixture. Life span of herbicide treatment would be 5 to 10 years depending on the rate of regrowth and re-infestation. Labor cost is in addition to the 2,4,5-T mixture.

Controlling woody plants with 2,4,5-T along fence rows aids in reducing sprouting woody plants from invading cultivated pastures. Basal sprouting of woody plants is reduced greatly when 2,4,5-T is used as compared to hand labor clearing. Also, treatment with 2,4,5-T allows forage grasses to reestablish and offers cover, food, and nesting areas for ground birds. Manual labor with axes is the only method for control if herbicides are not available. Manual labor causes greater repairs, as many times fence wires are cut during the clearing operation. Fences can remain intact during the full life span with minimum cost for maintenance when woody plants are controlled with 2,4,5-T.

ALTERNATIVES

There are no alternative-control methods that can be adapted nationwide other than hand-labor clearing.

Many herbicides are registered for control of plants on fence rows, but few are registered when the forage on the fence row is subject to being grazed by livestock. Soil-applied herbicides could cause injury to nearby shade trees or to valuable plants along rights-of-ways. Also soil-applied herbicides can move down slope before the chemical is set within the soil.

Picloram (Tordon 10K^{R}) pellet is approved for use in the southeast. If the label registration were expanded to include all of the U.S., then Tordon 10K could be used to control many species except mesquite. Silvex is not an alternative as it is ineffective on many species of woody plants (Bovey 1977).

ESTIMATED USE OF 2,4,5-T

Approximately 1.6 million acres of mesquite-infested rangelands, post-blackjack oak rangelands, and sand-shinnery oak rangelands are treated annually with 2,4,5-T (table 15). Treatment rates vary from .5 to 2 pounds per acre for a total use of about 1.9 million pounds of 2,4,5-T. Only minor quantities of silvex and dicamba are currently used.

If 2,4,5-T becomes unavailable and silvex remains available, silvex would be expected to be applied on 1.5 million of the 1.6 million acres currently treated with 2,4,5-T (table 16). Similar application rates would be used, and total silvex use would be about 1.8 million pounds.

If 2,4,5-T and silvex become unavailable, dicamba would be expected to be applied on approximately 433,000 acres of the 1.6 million acres currently treated with 2,4,5-T (table 16). Application rates similar to 2,4,5-T would be used and a total of about 217,000 pounds of dicamba would be used.

Table 15--Estimated acres of rangeland treated annually with 2,4,5-T and pounds of 2,4,5-T used

Area	Treated annually	2,4,5-T per acre	Total use of 2,4,5-T
	Acres	------Pounds----------	
Mesquite area:			
One..........................	40,000	.67	26,800
Two..........................	176,000	.50	88,000
Three........................	176,000	.50	88,000
Four.........................	56,000	1.0	56,000
Five.........................	41,000	1.00	41,000
Six..........................	81,120	.50	40,600
Post-blackjack oak rangeland:			
Cow-calf operation.........	360,700	2.00	721,400
Stocker operation..........	180,300	2.00	360,600
Sand-shinnery oak			
Rangeland..................	450,000	1.00	450,000
Total........................	1,561,120	xx	1,872,400

SOURCE: Natural Resource Economics Division, Economics, Statistics, and Cooperatives Service, U.S. Department of Agriculture, Corvallis, Oregon.

Table 16--Estimated acres of rangeland that may be treated annually with the alternatives Silvex and Dicamba if 2,4,5-T becomes unavailable, and amount of Silvex and Dicamba that may be applied

Area	Silvex[a/]			Dicamba[b/]		
	Treated annually	Silvex per acre	Total use of Silvex	Treated annually	Dicamba per acre	Total use of Dicamba
	Acres	Pounds	Pounds	Acres	Pounds	Pounds
Mesquite area:						
One....................	40,000	.67	26,800	--	--	--
Two....................	176,000	.50	88,000	176,000	.50	88,000
Three..................	176,000	.50	88,000	176,000	.50	88,000
Four...................	--	--	--	--	--	--
Five...................	--	--	--	--	--	--
Six....................	81,120	.50	40,600	81,120	.50	40,600
Post-blackjack oak rangeland:						
Cow-calf operation.....	360,700	2.00	721,400	--	--	--
Stocker operation......	180,300	2.00	360,600	--	--	--
Sand-shinnery oak rangeland.............	450,000	1.00	450,000	--	--	--
Total..................	1,464,120	xx	1,775,400	433,120	xx	216,600

a/ Estimates based on the assumption that silvex is the best alternative to 2,4,5-T.

b/ Estimates based on the assumption that 2,4,5-T and silvex would not be available.

SOURCE: Natural Resource Economics Division, Economics, Statistics, and Cooperatives Service, U.S. Department of Agriculture, Corvallis, Oregon.

USER IMPACTS SUMMARY

Expected revenue losses are estimated for three scenarios: (1) 2,4,5-T only becomes unavailable, (2) 2,4,5-T and silvex become unavailable, and (3) 2,4,5-T and silvex become unavailable and dicamba is not used. Partial analyses were accomplished on 93 million acres of mesquite-infested rangelands, 35 million acres of post-blackjack oak rangelands and 14.3 million acres of sand-shinnery oak rangelands. Sufficient data were not available to do more than narratively describe the uses of 2,4,5-T on the following species and problems in pastures, rangelands and farm, and other farm and ranchlands:

Species or problem	Area	Acres infested	Economic Importance of 2,4,5-T
		--thousands---	
Cactus	U.S.	78,600	Significant
Hardwoods	U.S.	Unknown1/	"
Yucca	U.S.	50,0002/	"
Poisonous plants	U.S.	Unknown3/	"
Desert shrub	West	124,600	"
Fence rows	U.S.	Unknown	"
Pastures	U.S.	101,061	"
Misc. woody plants4/	U.S.	1,000,000	"

1/10,000,000 or less.

2/Estimated - no known recorded acreage data exist.

3/Localized problem on many range and pasture lands. Annual losses are estimated to be between 50 and 100 million dollars in Texas and 14 million dollars for cattle alone in Idaho.

4/Agarito, alder, ash, catclaw, chinaberry, elm, gum, hackberry, hawthorne, herisache, ironwood, locust, lotebush, prickly ash, sumac, Texas persimmon, wax myrtle, yaupon, other oaks, osage-orange (this is not an all-inclusive. list).

Economic losses associated with these uses if 2,4,5-T becomes unavailable, are unknown. However, these uses are considered very important to affected land users.

To summarize the expected income losses on the mesquite-infested rangelands, post-blackjack oak rangelands, and sand-shinnery oak rangelands if 2,4,5-T and silvex become unavailable and dicamba proves ineffective in the future, it is necessary to express each year's loss in terms of value as of a base year. This is accomplished by discounting the estimated future revenue losses and reduced spray costs without 2,4,5-T back to a present value for 1978, using a rate of 7 percent. This is a reasonable procedure because a $1 loss in 1979 or any future year is worth less to a beef producer than a $1 loss in 1978.

Reductions in income to producers from beef production (given current prices) from lower production due to weed and brush competition on rangeland are expected to be $785,500 the first year without 2,4,5-T, if silvex and dicamba are available (table 17) ceteris paribus.[2/] Losses due to the unavailability of 2,4,5-T are projected to increase to a net present value of $1,153,900 in the sixteenth year. If silvex, which is similar to 2,4,5-T, becomes unavailable with 2,4,5-T, reductions in income to producers would be expected to increase to $5,633,500 the first year and are projected to have a net present value of $13,082,800 in the sixteenth year (table 18) ceteris paribus. Further, if 2,4,5-T and silvex become unavailable and dicamba is not used, reductions in income to producers would be expected to increase to $6,946,000 the first year and are projected to have a net present value of $17,690,000 in the sixteenth year (table 19) ceteris paribus.

Expected changes in beef production from the mesquite-infested rangelands, post-blackjack oak rangelands and sand-shinnery oak rangelands due to the lack of 2,4,5-T and possible alternative are shown in tables 20, 21, and 22. If 2,4,5-T becomes unavailable and silvex remains available, beef production would be expected to decrease 2.1 million pounds the first year without 2,4,5-T (table 20). Beef production losses would be maximized the fifth year without 2,4,5-T at 10.5 million pounds. Cumulative losses over the 16-year evaluation period are estimated to be 147.6 million pounds of beef without 2,4,5-T.

[2/] Means "all other things being equal or unchanged."

Table 17--Estimated increase in herbicide treatment cost and/or decrease in value of beef production if 2,4,5-T becomes unavailable for use on weed and brush infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest and Great Plains regions

No. years	Rangeland areas infested with mesquite						Post-blackjack oak rangeland		Sand-shinnery oak		Total impact discounted to
w/o 2,4,5-T	One[a]	Two[a]	Three[a]	Four[b]	Five[c]	Six[a]	Cow-calf[b]	Stocker[d]	rangeland[e]	Total	1978[f]
	Thousands of Dollars										
1	3.2	8.8	5.3	465	134	2.4	90.2	45.1	31.5	785.5	785.5
2	3.2	8.8	5.3	932	267	2.4	90.2	45.1	31.5	1,385.5	1,294.9
3	3.2	8.8	5.3	1,397	401	2.4	90.2	45.1	31.5	1,984.5	1,733.3
4	3.2	8.8	5.3	1,863	534	2.4	90.2	45.1	31.5	2,583.5	2,108.9
5	3.2	8.8	5.3	2,329*	668*	2.4	90.2*	45.1*	31.5	3,183.5	2,428.7
Sub-total 1 to 5 yrs.	16.0	44.0	26.5	6,986	2,004	12.0	451.0	225.5	157.5	9,922.5	8,351.3
6	3.2	8.8	5.3	2,329	668	2.4	90.2	45.1	31.5	3,183.5	2,269.8
7	3.2	8.8	5.3	2,329	668	2.4	90.2	45.1	31.5	3,183.5	2,121.3
8	3.2	8.8*	5.3	2,329	668	2.4	90.2	45.1	31.5	3,183.5	1,982.6
9	3.2	8.8	5.3	2,329	668	2.4	90.2	45.1	31.5	3,183.5	1,852.9
10	3.2	8.8	5.3*	2,329	668	2.4*	90.2	45.1	31.5*	3,183.5	1,731.6
Sub-total 6 to 10 yrs.	16.0	44.0	26.5	11,645	3,340	12.0	451.0	225.5	157.5	15,917.5	9,958.2

continued

Table 17--Estimated increase in herbicide treatment cost and/or decrease in value of beef production if 2,4,5-T becomes unavailable for use on weed and brush infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest and Great Plains regions (continued)

No. years w/o 2,4,5-T	Rangeland areas infested with mesquite						Post-blackjack oak rangeland		Sand-shinnery oak rangeland[e/]	Total	Total impact discounted to 1978[f/]
	One[a/]	Two[a/]	Three[a/]	Four[b/]	Five[c/]	Six[a/]	Cow-calf[b/]	Stocker[d/]			
	Thousands of Dollars										
11	3.2	8.8	5.3	2,329	668	2.4	90.2	45.1	31.5	3,183.5	1,618.4
12	3.2	8.8	5.3	2,329	668	2.4	90.2	45.1	31.5	3,183.5	1,512.5
13	3.2	8.8	5.3	2,329	668	2.4	90.2	45.1	31.5	3,183.5	1,413.5
14	3.2	8.8	5.3	2,329	668	2.4	90.2	45.1	31.5	3,183.5	1,321.1
15	3.2	8.8	5.3	2,329	668	2.4	90.2	45.1	31.5	3,183.5	1,234.6
16	3.2*	8.8	5.3	2,329	668	2.4	90.2	45.1	31.5	3,183.5	1,153.9
Sub-total 11 to 16 yrs.	19.2	52.8	31.8	13,974	4,008	14.4	541.2	270.6	189.0	19,101.0	8,254.0
Total	51.2	140.8	84.8	32,605	9,352	38.4	1,443.2	721.6	504.0	44,941.0	26,563.5

* Indicates first year with no remaining effects from previous use of 2,4,5-T.

a/ Increased cost of using the alternative Silvex (table 1).

b/ Value of lost beef produciton minus decrease in cost of herbicide treatment (tables 1 and 8).

c/ Value of lost beef produciton minus decrease in cost of herbicide treatment (tables 1 and 9).

d/ Increased cost of using the alternative Silvex (table 11).

e/ Increased cost of using the alternative Silvex (table 13).

f/ Total impact discounted to 1979 using a 7% discount factor.

SOURCE: Natural Resource Economics Division, Economics, Statistics and Cooperatives Service, U.S. Department of Agriculture, Corvallis, Oregon.

Table 18--Estimated increase in herbicide treatment cost and/or decrease in value of beef production if 2,4,5-T and Silvex become unavailable for use on weed and brush infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest and Great Plains regions

No. years w/o 2,4,5-T	Rangeland areas infested with mesquite: One[a/]	Two[b/]	Three[b/]	Four[c/]	Five[d/]	Six[b/]	Post-blackjack oak rangeland: Cow-calf[e/]	Stocker[f/]	Sand-shinnery oak rangeland[g/]	Total	Total impact discounted to 1978[h/]
	Thousands of Dollars										
1	47.0	73.9	63.4	465	134	29.2	1,267	2,034	1,520	5,633.5	5,633.5
2	94.0	73.9	63.4	932	267	29.2	2,535	4,069	3,040	11,103.5	10,377.1
3	141.0	73.9	63.4	1,397	401	29.2	3,802	6,102	4,561	16,570.5	14,473.3
4	118.0	73.9	63.4	1,863	534	29.2	5,069	8,137	6,081	22,038.5	17,990.0
5	235.0	73.9	63.4	2,329*	668*	29.2	6,337*	10,171*	7,601	27,507.5	20,985.5
Sub-total 1 to 5 yrs.	705.0	369.5	317.0	6,986	2,004	146.0	19,010	30,513	22,803	82,853.5	69,459.4
6	282.0	73.9	63.4	2,329	668	29.2	6,337	10,171	9,121	29,074.5	20,729.8
7	329.0	73.9	63.4	2,329	668	29.2	6,337	10,171	10,641	30,641.5	20,418.0
8	376.0	73.9*	63.4	2,329	668	29.2	6,337	10,171	12,162	32,209.5	20,058.8
9	481.0	73.9	63.4	2,329	668	29.2	6,337	10,171	13,682	33,834.5	19,692.4
10	587.0	73.9	63.4*	2,329	668	29.2*	6,337	10,171	15,202*	35,460.5	19,288.4
Sub-total 6 to 10 yrs.	2,055.0	369.5	317.0	11,645	3,340	146.0	31,685	50,855	60,808	161,220.5	100,187.4
11	694.0	73.9	63.4	2,329	668	29.2	6,337	10,171	15,202	35,567.5	18,081.1

continued

Table 18--Estimated increase in herbicide treatment cost and/or decrease in value of beef production if 2,4,5-T and Silvex become unavailable for use on weed and brush infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest and Great Plains regions (continued)

No. years w/o 2,4,5-T	Rangeland areas infested with mesquite: One[a]	Two[b]	Three[b]	Four[c]	Five[d]	Six[b]	Post-blackjack oak rangeland: Cow-calf[e]	Stocker[f]	Sand-shinnery oak rangeland[g]	Total	Total impact discounted to 1978[h]
	Thousands of Dollars										
12	799.0	73.9	63.4	2,329	668	29.2	6,337	10,171	15,202	35,672.5	16,948.0
13	905.0	73.9	63.4	2,329	668	29.2	6,337	10,171	15,202	35,778.5	15,886.4
14	1,010.0	73.9	63.4	2,329	668	29.2	6,337	10,171	15,202	35,883.5	14,890.6
15	1,116.0	73.9	63.4	2,329	668	29.2	6,337	10,171	15,202	35,989.5	13,957.4
16	1,222.0*	73.9	63.4	2,329	668	29.2	6,337	10,171	15,202	36,095.5	13,082.8
Sub-total 11 to 16 years	5,746.0	443.4	380.4	13,974	4,008	175.2	38,022	61,026	91,212	214,987.0	92,846.3
Total	8,506.0	1,182.4	1,014.4	32,605	9,352	467.2	88,717	142,394	174,823	459,061.0	262,493.1

* Indicates first year with no remaining effects from previous use of 2,4,5-T.

a/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 1 and 2).

b/ Increased cost of using the alternative Dicamba (table 1).

c/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 1 and 8).

d/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 1 and 9).

e/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 11 and 12A).

f/ Value of lost beef produciton minus decrease in cost of herbicide treatment (tables 11 and 12B).

g/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 13 and 14).

h/ Total impact discounted to 1979 using a 7% discount factor.

SOURCE: Natural Resource Economics Division, Economics, Statistics and Cooperative Service, U.S. Department of Agriculture, Corvallis, Oregon.

Table 19--Estimated increase in herbicide treatment cost and/or decrease in value of beef production if 2,4,5-T, and Silvex become unavailable and dicamba is not used for weed and brush control on infested rangeland in the Southern Rocky Mountains, Pacific Southwest and Great Plains regions

No. years w/o 2,4,5-T	Rangeland areas infested with mesquite: One[a]	Two[b]	Three[c]	Four[d]	Five[e]	Six[f]	Post-blackjack oak rangeland: Cow-calf[g]	Stocker[h]	Sand-shinnery oak rangeland[i]	Total	Total impact discounted to 1978[j]
	Thousands of Dollars										
1	47	950	364	465	134	165	1,267	2,034	1,520	6,946	6,946
2	94	1,890	727	932	267	330	2,535	4,069	3,040	13,884	12,976
3	141	2,847	1,091	1,397	401	496	3,802	6,102	4,561	20,838	18,200
4	188	3,796	1,454	1,863	534	660	5,069	8,137	6,081	27,782	22,678
5	235	4,745	1,817	2,329*	668*	825	6,337*	10,171*	7,601	34,728	26,494
Sub-total 1 to 5 yrs.	705	14,228	5,453	6,986	2,004	2,476	19,010	30,513	22,803	104,178	87,294
6	282	5,694	2,180	2,329	668	990	6,337	10,171	9,121	37,772	26,931
7	329	6,643	2,544	2,329	668	1,155	6,337	10,171	10,641	40,817	27,198
8	376	7,592*	2,907	2,329	668	1,319	6,337	10,171	12,162	43,861	27,315
9	481	7,592	3,271	2,329	668	1,485	6,337	10,171	13,682	46,016	26,782
10	587	7,592	3,635*	2,329	668	1,650*	6,337	10,171	15,202*	48,171	26,202
Sub-total 6 to 10 yrs.	2,055	35,113	14,537	11,645	3,340	6,599	31,685	50,855	60,808	216,637	134,428
11	694	7,592	3,635	2,329	668	1,650	6,337	10,171	15,202	48,278	24,543

continued

Table 19--Estimated increase in herbicide treatment cost and/or decrease in value of beef production if 2,4,5-T, and Silvex become unavailable and dicamba is not used for weed and brush control on infested rangeland in the Southern Rocky Mountains, Pacific Southwest and Great Plains regions (continued)

No. years w/o 2,4,5-T	Rangeland areas infested with mesquite						Post-blackjack oak rangeland		Sand-shinnery oak rangeland[i]	Total	Total impact discounted to 1978[j]
	One[a]	Two[b]	Three[c]	Four[d]	Five[e]	Six[f]	Cow-calf[g]	Stocker[h]			
	Thousands of Dollars										
12	799	7,592	3,635	2,329	668	1,650	6,337	10,171	15,202	48,383	22,987
13	905	7,592	3,635	2,329	668	1,650	6,337	10,171	15,202	48,489	21,530
14	1,010	7,592	3,635	2,329	668	1,650	6,337	10,171	15,202	48,594	20,165
15	1,116	7,592	3,635	2,329	668	1,650	6,337	10,171	15,202	48,700	18,887
16	1,222*	7,592	3,635	2,329	668	1,650	6,337	10,171	15,202	48,806	17,690
Sub-total 11 to 16 years	5,746	45,552	21,810	13,974	4,008	9,900	38,022	61,026	91,212	291,250	125,802
Total	8,506	94,893	41,800	32,605	9,352	18,975	88,717	142,394	174,823	612,065	347,524

* Indicates first year with no remaining effects from previous use of 2,4,5-T.

a/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 1 and 2).

b/ Value of lost beef produciton minus decrease in cost of herbicide treatment (tables 1 and 4).

c/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 1 and 5).

d/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 1 and 8).

e/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 1 and 9).

f/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 1 and 10).

g/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 11 and 12A).

continued

Table 19—Estimated increase in herbicide treatment cost and/or decrease in value of beef production if 2,4,5-T, and Silvex become unavailable and dicamba is not used for weed and brush control on infested rangeland in the Southern Rocky Mountains, Pacific Southwest and Great Plains regions (continued)

h/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 11 and 12B).

i/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 13 and 14).

j/ Total impact discounted to 1979 using a 7% discount factor.

SOURCE: Natural Resource Economics Division, Economics, Statistics and Cooperative Service, U.S. Department of Agriculture, Corvallis, Oregon.

Table 20—Estimated loss of beef production if 2,4,5-T becomes unavailable for use on weed and brush infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest and Great Plains regions

No. years w/o 2,4,5-T	Rangeland areas infested with mesquite						Post-blackjack oak rangeland		Sand-shinnery oak rangeland	Total
	One	Two	Three	Four[a]	Five[b]	Six	Cow-calf	Stocker		
	Thousands of Pounds									
1	—	—	—	1,551	558	—	—	—	—	2,109
2	—	—	—	3,102	1,115	—	—	—	—	4,217
3	—	—	—	4,654	1,673	—	—	—	—	6,327
4	—	—	—	6,205	2,230	—	—	—	—	8,435
5	—	—	—	7,756*	2,788*	—	—	—	—	10,544
Sub-total 1 to 5 yrs.	—	—	—	23,268	8,364	—	—	—	—	31,632
6	—	—	—	7,756	2,788	—	—	—	—	10,544
7	—	—	—	7,756	2,788	—	—	—	—	10,544
8	—	—	—	7,756	2,788	—	—	—	—	10,544
9	—	—	—	7,756	2,788	—	—	—	—	10,544
10	—	—	—	7,756	2,788	—	—	—	—	10,544
Sub-total 6 to 10 yrs.	—	—	—	38,780	13,940	—	—	—	—	52,720

continued

Table 20—Estimated loss of beef production if 2,4,5-T becomes unavailable for use on weed and brush infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest and Great Plains regions (continued)

No. years w/o 2,4,5-T	Rangeland areas infested with mesquite: One	Two	Three	Four[a/]	Five[b/]	Six	Post-blackjack oak rangeland: Cow-calf	Stocker	Sand-shinnery oak rangeland	Total
	Thousands of Pounds									
11	—	—	—	7,756	2,788	—	—	—	—	10,544
12	—	—	—	7,756	2,788	—	—	—	—	10,544
13	—	—	—	7,756	2,788	—	—	—	—	10,544
14	—	—	—	7,756	2,788	—	—	—	—	10,544
15	—	—	—	7,756	2,788	—	—	—	—	10,544
16	—	—	—	7,756	2,788	—	—	—	—	10,544
Sub-total 11 to 16 years	—	—	—	46,536	16,728	—	—	—	—	63,264
Total	—	—	—	108,584	39,032	—	—	—	—	147,616

* Indicates first year with no remaining effects from previous use of 2,4,5-T.

a/ Taken from table 8, column 10.

b/ Taken from table 9, column 10.

SOURCE: Natural Resource Economics Division, Economics, Statisitics and Cooperatives Service, U.S. Department of Agriculture, Corvallis, Oregon.

Table 21—Estimated loss of beef production if 2,4,5-T and Silvex become unavailable for use on weed and brush infested rangeland in the Southern Rocky Mountain, Pacific Southwest, Southwest and Great Plains regions

No. years w/o 2,4,5-T	Rangeland areas infested with mesquite: One[a]	Two	Three	Four[b]	Five[c]	Six	Post-blackjack oak rangeland: Cow-calf[d]	Stocker[e]	Sand-shinnery oak rangeland[f]	Total
	---Thousands of Pounds---									
1	300	—	—	1,551	558	—	6,240	7,032	5,805	21,486
2	600	—	—	3,102	1,115	—	12,480	14,064	11,610	42,971
3	900	—	—	4,654	1,673	—	18,720	21,095	17,415	64,457
4	1,200	—	—	6,205	2,230	—	24,961	28,128	23,220	85,944
5	1,500	—	—	7,756*	2,788*	—	31,201*	35,159	29,025	107,429
Sub-total 1 to 5 yrs.	4,500	—	—	23,268	8,364	—	93,602	105,478	87,075	322,287
6	1,800	—	—	7,756	2,788	—	31,201	35,159	34,830	113,534
7	2,100	—	—	7,756	2,788	—	31,201	35,159	40,635	119,639
8	2,400	—	—	7,756	2,788	—	31,201	35,159	46,440	125,744
9	2,864	—	—	7,756	2,788	—	31,201	35,159	52,245	132,013
10	3,328	—	—	7,756	2,788	—	31,201	35,159	58,050*	138,282
Sub-total 6 to 10 yrs	12,492	—	—	38,780	13,940	—	156,005	175,795	232,200	629,212
11	3,792	—	—	7,756	2,788	—	31,201	35,159	58,050	138,746

continued

Table 21--Estimated loss of beef production if 2,4,5-T and Silvex become unavailable for use on weed and brush infested rangeland in the Southern Rocky Mountain, Pacific Southwest, Southwest and Great Plains regions (continued)

No. years w/o 2,4,5-T	Rangeland areas infested with mesquite						Post-blackjack oak rangeland		Sand-shinnery oak rangeland[f/]	Total
	One[a/]	Two	Three	Four[b/]	Five[c/]	Six	Cow-calf[d/]	Stocker[e/]		
	Thousands of Pounds									
12	4,256	—	—	7,756	2,788	—	31,201	35,159	58,050	139,210
13	4,720	—	—	7,756	2,788	—	31,201	35,159	58,050	139,674
14	5,184	—	—	7,756	2,788	—	31,201	35,159	58,050	140,138
15	5,648	—	—	7,756	2,788	—	31,201	35,159	58,050	140,602
16	6,112*	—	—	7,756	2,788	—	31,201	35,159	58,050	141,066
Sub-total 11 to 16 years	29,712	—	—	46,536	16,728	—	187,206	210,954	348,300	839,436
Total	46,704	—	—	108,584	39,032	—	436,813	492,227	667,575	1,790,935

* Indicates first year with no remaining effects from previous use of 2,4,5-T.

a/ Taken from table 2, column 10.

b/ Taken from table 8, column 10.

c/ Taken from table 9, column 10.

d/ Taken from table 12A, column 10.

e/ Taken from table 12B, column 10.

f/ Taken from table 14, column 10.

SOURCE: Natural Resource Economics Division, Economics, Statistics and Cooperatives Service, U.S. Department of Agriculture, Corvallis, Oregon.

Table 22—Estimated loss of beef production if 2,4,5-T and silvex become unavailable and dicamba is not used for weed and brush infested rangeland in the Southern Rocky Mountains, Pacific Southwest and Great Plains regions (continued)

No. years w/o 2,4,5-T	Rangeland areas infested with mesquite						Post-blackjack oak rangeland		Sand-shinnery oak rangeland[i/]	Total
	One[a/]	Two[b/]	Three[c/]	Four[d/]	Five[e/]	Six[f/]	Cow-calf[g/]	Stocker[h/]		
	Thousands of Pounds									
13	4,720	24,077	13,200	7,756	2,788	18,653	31,201	35,159	58,050	195,604
14	5,184	24,077	13,200	7,756	2,788	18,653	31,201	35,159	58,050	196,068
15	5,648	24,077	13,200	7,756	2,788	18,653	31,201	35,159	58,050	196,532
16	6,112*	24,077	13,200	7,756	2,788	18,653	31,201	35,159	58,050	196,996
Sub-total 11 to 16 years	29,712	144,462	79,200	46,536	16,728	111,918	187,206	210,954	348,300	1,175,016
Total	46,704	300,962	151,800	108,584	39,032	214,513	436,813	492,227	667,575	2,458,210

* Indicates first year with no remaining effects from previous use of 2,4,5-T.

a/ Taken from table 2, column 10.

b/ Taken from table 4, column 10.

c/ Taken from table 5, column 10.

d/ Taken from table 8, column 10.

e/ Taken from table 9, column 10.

f/ Taken from table 10, column 10.

g/ Taken from table 12A, column 10.

h/ Taken from table 12B, column 10.

i/ Taken from table 14, column 10.

SOURCE: Natural Resource Economics Division, Economics, Statistics and Cooperatives Service, U.S. Depatment of Agriculture, Corvallis, Oregon.

Table 22--Estimated loss of beef production if 2,4,5-T and silvex become unavailable and dicamba is not used for weed and brush infested rangeland in the Southern Rocky Mountains, Pacific Southwest and Great Plains regions (continued)

No. years w/o 2,4,5-T	Rangeland areas infested with mesquite						Post-blackjack oak rangeland		Sand-shinnery oak rangeland[i]	Total
	One[a]	Two[b]	Three[c]	Four[d]	Five[e]	Six[f]	Cow-calf[g]	Stocker[h]		
	Thousands of Pounds									
13	4,720	24,077	13,200	7,756	2,788	18,653	31,201	35,159	58,050	195,604
14	5,184	24,077	13,200	7,756	2,788	18,653	31,201	35,159	58,050	196,068
15	5,648	24,077	13,200	7,756	2,788	18,653	31,201	35,159	58,050	196,532
16	6,112*	24,077	13,200	7,756	2,788	18,653	31,201	35,159	58,050	196,996
Sub-total 11 to 16 years	29,712	144,462	79,200	46,536	16,728	111,918	187,206	210,954	348,300	1,175,016
Total	46,704	300,962	151,800	108,584	39,032	214,513	436,813	492,227	667,575	2,458,210

* Indicates first year with no remaining effects from previous use of 2,4,5-T.

a/ Taken from table 2, column 10.

b/ Taken from table 4, column 10.

c/ Taken from table 5, column 10.

d/ Taken from table 8, column 10.

e/ Taken from table 9, column 10.

f/ Taken from table 10, column 10.

g/ Taken from table 12A, column 10.

h/ Taken from table 12B, column 10.

i/ Taken from table 14, column 10.

SOURCE: Natural Resource Economics Division, Economics, Statistics and Cooperatives Service, U.S. Depatment of Agriculture, Corvallis, Oregon.

If 2,4,5-T and silvex become unavailable, beef production would be expected to decrease 21.5 million pounds the first year without 2,4,5-T and silvex (table 21). Beef production losses would increase to 141.1 million pounds in the sixteenth year. Cummulative losses over the 16-year evaluation period are estimated to be 1.8 billion pounds of beef.

If 2,4,5-T and silvex become unavailable and dicamba is not used, beef production would be expected to decrease 27.7 million pounds the first year (table 22). In the sixteenth year, beef production losses would increase to 197.0 million pounds. Cummulative losses over the 16-year evaluation period are estimated to be 2.5 billion pounds.

Expected changes in beef production from the rangeland areas due to a lack of 2,4,5-T and/or effective alternatives for weed and brush control are small compared to U.S. beef production and range from .015 to .470 percent of U.S. beef production (table 23). The expected quantity change is certainly more significant to the affected producers.

AVERAGE PER ACRE RETURNS

Average per acre gross returns from beef production on rangeland treated with 2,4,5-T varied from $2.33 to $31.22 (table 24). These estimates are based on 1973-77 average prices received by producers. Average per acre production costs on the treated rangelands varied from $1.48 to $28.99. Thus, the average returns to land, overhead, risk, and management from beef production varies from $0.85 to $11.59 per acre with 2,4,5-T. With these low returns per acre, the decrease in returns, indicated in table 24 if 2,4,5-T and/or silvex become unavailable, will significantly reduce the income of affected producers. Beef production returns with no mesquite or brush control on the rangelands are also shown.

Returns and analysis were based on the production of beef and labor saved in working livestock. There are other items that producers

Table 23--Summary of estimated beef production loss if 2,4,5-T and silvex become unavailable and dicamba proves to be ineffective for controlling weeds and brush-infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest, and Great Plains regions

Alternatives and number of years without 2,4,5-T	Production loss each year	Percent of U.S. beef production[a/]
	Thousand pounds	Percent
Silvex and Dicamba:[b/]		
1-5	6,326	.015
6-10	10,544	.025
11-16	10,544	.025
Dicamba:[c/]		
1-5	64,457	.155
6-10	125,842	.302
11-16	139,906	.335
Do nothing:[d/]		
1-5	83,043	.199
6-10	173,596	.416
11-16	195,836	.470

a/ Calculations based on an average 1973-76 U.S. liveweight beef production of 41,706,229,000 pounds.

b/ Calculated from table 20.

c/ Calculated from table 21.

d/ Calculated from table 22.

SOURCE: Natural Resource Economics Division, Economics, Statistics, and Cooperatives Service, U.S. Department of Agriculture, Corvallis, Oregon.

Table 24--Average per-acre returns to land, overhead, risk, and management with and without 2,4,5-T, Silvex, and Dicamba on weed and brush-infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest, and Great Plains regions [a]

Area & alternative	Gross returns[b]	Production costs: Herbicide treatment[b]	Production costs: Beef[c]	Production costs: Livestock-handling labor[b]	Production costs: Total	Returns to land, overhead, risk, & management
	Dollars					
Mesquite area:						
One:						
2,4,5-T........................	7.84	1.51	4.75	-0.50	5.76	2.08[d]
Silvex.........................	7.84	1.59	4.75	-0.50	5.84	2.00[d]
Do nothing, 1-8 years..........	5.16	--	2.74	--	2.74	2.42
Do nothing, more than 8 years..	3.69	--	1.96	--	1.96	1.73
Two:						
2,4,5-T........................	15.75	0.73	4.43	-1.00	4.16	11.59[d]
Silvex.........................	15.75	0.78	4.43	-1.00	4.21	11.54[d]
Dicamba........................	15.75	1.15	4.43	-1.00	4.58	11.17[d]
Do nothing.....................	9.63	--	2.76	--	2.76	6.87
Three:						
2,4,5-T........................	7.84	0.62	5.69	-1.00	5.31	2.53[d]
Silvex.........................	7.84	0.65	5.69	-1.00	5.34	2.50[d]
Dicamba........................	7.84	0.98	5.69	-1.00	5.67	2.17[d]
Do nothing.....................	5.16	--	3.84	--	3.84	1.32

continued

Table 24--Average per-acre returns to land, overhead, risk, and management with and without 2,4,5-T, Silvex, and Dicamba on weed and brush-infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest, and Great Plains regions a/ (continued)

Area & alternative	Gross returns[b/]	Production costs: Herbicide treatment[b/]	Production costs: Beef[c/]	Production costs: Livestock-handling labor[b/]	Production costs: Total	Returns to land, overhead, risk, & management
	Dollars					
Four:						
2,4,5-T........................	14.67	1.61	6.06	-1.00	6.67	8.00[d/]
Do nothing.....................	4.76	—	3.29	—	3.29	1.47
Five:						
2,4,5-T........................	10.02	1.61	4.57	-1.00	5.18	4.84[d/]
Tordon 225.....................	10.02	2.80	4.57	-1.00	6.37	3.65[d/]
Do nothing.....................	5.16	—	2.57	—	2.57	2.59
Six:						
2,4,5-T........................	2.33	0.62	0.86	—	1.48	0.85[d/]
Silvex.........................	2.33	0.65	0.86	—	1.56	0.77[d/]
Dicamba........................	2.33	0.98	0.86	—	1.84	0.49[d/]
Do nothing.....................	1.50	—	0.55	—	0.55	0.95
Post-blackjack oak rangeland:						
Cow-calf operation:						
2,4,5-T........................	10.20	2.68	7.44	-1.00	9.12	1.08[d/]
Silvex.........................	10.20	2.93	7.44	-1.00	9.37	0.83[d/]
Do nothing.....................	4.01	—	3.71	—	3.71	0.30

continued

Table 24—Average per-acre returns to land, overhead, risk, and management with and without 2,4,5-T, Silvex, and Dicamba on weed and brush-infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest, and Great Plains regions a/ (continued)

Area & alternative	Gross returns[b]	Production costs: Herbicide treatment[b]	Production costs: Beef[c]	Production costs: Livestock-handling labor[b]	Production costs: Total	Returns to land, overhead, risk, & management
	Dollars					
Stocker operation:						
2,4,5-T........................	31.22	2.68	27.31	-1.00	28.99	2.23[d]
Silvex........................	31.22	2.93	27.31	-1.00	29.24	1.98[d]
Do nothing....................	16.25	--	14.56	--	14.56	1.69
Sand-shinnery oak rangeland:						
2,4,5-T........................	9.63	1.24	4.48	--	5.72	3.91[d]
Silvex........................	9.63	1.31	4.48	--	5.79	3.84[d]
Do nothing....................	5.01	--	2.99	--	2.99	2.02

a/ Returns to land, overhead, risk, and mangement were estimated assuming ceteris paribus conditions with respect to price and production levels.

b/ Taken from tables 1, 11, and 13, columns 9 and 12.

c/ Texas Agricultural Extension Service, Texas A&M University, College Station Texas. Mimeographed livestock production budgets, 1977-78. Adjusted to 1973-79 average.

d/ User treats to improve range conditions to have a cover of forage grass to reduce top soil erosion and sedimentation of steams and reserviors.

SOURCE: Natural Resource Economics Division, Economics, Statisitics, and Cooperatives Service, U.S. Department of Agriculture, Corvallis, Oregon.

consider in determining if controlling woody plants is profitable to the particular operation. These items are:

1) Improving wildlife habitat by selectively controlling woody plants, which in turn increases big game hunting lease income in all areas. In mesquite areas of two, three, and six, controlling woody plants also increases ground game bird populations and game bird hunting oportunities.

2) Maintainance of natural renewable rangeland resources by improving range conditions.

3) Keeping a herbaceous cover on the soil surface to reduce soil erosion and resulting sedimentation of reservoirs.

4) Controlling brush, growing forage, and keeping ranch-raised stocker cattle to utilize excess forage and allow marketing heavier livestock at a time when prices are more favorable.

5) Maintaining the ranch in a productive state for future generations.

If woody plants are not controlled, their density increases and as the brush-grass ratio becomes greater, livestock numbers must be reduced to maintain the herbaceous cover and proper use of forage plants. The operation may become unprofitable .

Without 2,4,5-T, landowners in the post-blackjack rangeland could not produce excess forage to carry out stocker operations with the calves from their cow-calf operations. Stocker operations allow landowners to carry animals to heavier weights, thus increasing overall returns to the total operation.

LIMITATIONS

The lack of a historical data base on some of the uses of 2,4,5-T and other herbicides on pasture and range, especially the uses on eastern pastures, fence rows, cactus, yucca, hardwoods, poisonous plants, desert shrub, and miscellaneous woody plants limited the completeness of this analysis. Collection of more complete herbicide use data on the many pasture and range problems is needed. Without these data, a full economic impact of canceling 2,4,5-T uses on herbaceous and woody plant problems on the approximately 1 billion acres of pasture and range can not be estimated. The inability to estimate the economic impacts on the majority of pasture and range acres indicates that the total impact of the loss of 2,4,5-T presented in this report is certainly understated.

CHAPTER 3: THE BIOLOGICAL AND ECONOMIC ASSESSMENT OF 2,4,5-T USE IN THE MANAGEMENT OF RIGHTS-OF-WAY IN THE UNITED STATES

SUMMARY

The ribbon corridors of rights-of-way criss-crossing this nation form an interlocking network which literally enables this nation and its people to carry out their daily productive functions. Rights-of-way serve in the transport of people's needs: energy, fuel, food, communications--innumerable goods and services. The safe, continuous uninterrupted flow of goods and services over these right-of-way systems is a universal objective of those responsible for managing them. Vegetation-management programs are inherent to the accomplishment of that objective.

Major right-of-way types include railroads, highways, pipelines, and electric transmission lines. Estimated total right-of-way acreage associated with each of these are: railroads - 2.4 million acres; highways - 21.7 million acres; pipelines - 2.2 million acres; and electric utilities - 5 million acres; for a U.S. total of 31.3 million acres (approximately 1 percent of the total U.S. acreage). More than half this acreage occurs in the eastern third of the U.S. Acres treated annually with 2,4,5-T for each type are approximately 127 thousand for railroads, 22 thousand for pipelines, 68 thousand for highways, and 465 thousand for electric. About 4.1 million pounds of 2,4,5-T are applied to these 682,000 acres, annually. These acres are not usually treated with 2,4,5-T alone (14 percent), but rather 2,4,5-T in combination with other herbicides.

With 2,4,5-T applications, broadcast foliar ground treatment is most utilized by railroads and highways. Pipeline rights-of-way are predominantly treated with aerial methods. Aerial and selective basal are the dominant application methods for electric rights-of-way.

The Eastern United States where most of the right-of-way acreage is located, is dominated by deciduous woody plant species which also are susceptible to 2,4,5-T. The drier climate of the Central Plains and

Rocky Mountain region restricts woody plant growth, thus reducing need for intensive management. The abundant rainfall of the Pacific Northwest enables rapid plant growth which necessitates intensive rights-of-way vegetation-control programs.

The use of 2,4,5-T or any other chemical, mechanical, or manual methods will alter floristic composition. Resultant changes in plant communities may be beneficial to some organisms such as wildlife, and detrimental to others. For example, removal of mast-producing tree species in right-of-way clearance or periodic vegetation maintenance may be detrimental to squirrel habitat, and in contrast, the more diverse and dense vegetation cover resulting from vegetation management may be beneficial to deer, birds, and small mammals. This obvious relationship occurs under natural as well as man-induced changes in the environment. The magnitude of plant community change due to 2,4,5-T treatment is related to application technique. Selective methods cause the least disturbance to nontarget vegetation and community composition. Even with severe plant community alterations resulting from broadcast application methods, the ground layer of lesser vegetation may return to original composition over a period of years.

Habitat diversity created by use of 2,4,5-T generally enhances wildlife activity on rights-of-way. Because of rapid revegetation and the lack of site disturbance, there are minimal amounts of soil erosion and compaction following 2,4,5-T treatment. The aquatic environment receives little impact from 2,4,5-T usage. Water exposure is very limited.

The degree of control of many plant species is an important criteria in the selection of any herbicide treatment. 2,4,5-T is more effective on more species than 2,4-D, dichlorprop, or silvex. 2,4,5-T is less costly and less persistent than dicamba. It is not as corrosive to equipment as ammonium sulfamate (AMS), nor as persistent as picloram and, in contrast to glyphosate, does not kill all vegetation; i.e., 2,4,5-T is more selective.

Fire is essentially unused as a right-of-way management tool. Mechanical and manual methods generally are much more expensive than an application of 2,4,5-T and must be repeated more frequently. In many instances 2,4,5-T is used because mechanical and manual methods are physically impossible.

If 2,4,5-T use on all rights-of-way is canceled, use of alternative herbicides is expected to increase annual vegetation management costs by $33.9 million. Additional costs of manually controlling species of woody plants that may not be controlled with alternative herbicides were not estimated. Electric utilities would have increased vegetation-management costs of $25.2 million followed by railroads at $6.3 million. Annual vegetation-management costs are estimated to increase about $1.0 million for highway and pipeline rights-of-way. For all rights-of-way, vegetation-management costs with alternatives would increase by 35 percent over the current 2,4,5-T vegetation-management program, ranging from a high of 55 percent for railroads to a low of 32 percent for electric and pipeline rights-of-way.

INTRODUCTION

Rights-of-way in this section will be used to denote those lands managed to insure the safety, security, and reliability of rights-of-way systems. These lands are a necessary part of the system, but are not the dominant theme of that system. Highways, railroads, pipelines, and electric utilities need these right-of-way lands to support roads, rails, pipelines, and towers, and the lands must be managed so as to contribute to the system for which acquired.

These ribbon corridors traverse varied soil, topographic, and climatic conditions. The vegetation occurring thereon pose differing management problems depending both on the dominant and secondary use of the rights-of-way. Rights-of-way traversing state gamelands, for example, may also be managed to conform with regulations of a state wildlife agency.

The level of use of 2,4,5-T as a vegetation-management tool within the right-of-way area reflects: (1) the presence of vegetation susceptible to the herbicide, (2) the extent to which this vegetation is a problem, and (3) the geographic occurrence of this vegetation across the U.S. While this report will cover rights-of-ways of different types, it should be clear from the outset that vegetation management is accomplished in distinctly different ways on different kinds of right-of-way and the use of 2,4,5-T will vary with type of rights-of-way and geographic location usually the areas where 2,4,5-T is used on rights-of-way resemble forest and range sites in topography, soils, climate factors, and vegetation complexes. Thus rights-of-way, and forest and range sites have many ecological and environmental properties in common.

In this section, four general types of rights-of-way will be of primary interest:

1. Electric lines - electric transmission.

2. Pipelines - transmission of oil, natural gas, and coal slurry.

3. Highways - rural roads, including Interstate, primary, and secondary roads.

4. Railroads.

THE NUMBER AND LOCATION OF RIGHTS-OF-WAY IN THE UNITED STATES

Right-of-way occurrence can be illustrated by arbitrarily dividing the United States into four regions. This division is based on vegetation types according to Bailey's ecoregions (1976), and will be further explained in a succeeding section. For discussion purposes, the four regions are as follows (fig. 1):

1. Eastern Region (all states east of and including Minnesota, Iowa, Missouri, Arkansas, and Louisiana).

2. Central Plains and Rocky Mountain Region (all states east of and including Idaho, Nevada, and Arizona, and excluding the Eastern Region).

3. West Coast Region (Washington, Oregon, and California).

4. Alaska and Hawaii Region.

Using these regions, i.e., grouping of states, data were compiled to illustrate the occurrence of rights-of-way across the United States (table 1). Some of the information was available by states, some by industries, and some by both. Where possible, the data are presented by region of occurrence. Regionalization of data was necessary for two reasons. First, 2,4,5-T would only tend to be used where susceptible vegetation occurs. Second, it was evident early in this assessment

Figure 1. Arbitrary regions of the U.S.

Table 1--Location of rights-of-way (ROW) by type and U.S. region

ROW type	Eastern region	Central Plains & Rocky Mountain region	West Coast region	Alaska & Hawaii	Total U.S.
Area (sq. miles)[a/]	1,197,047	1,506,348	323,866	592,862	3,613,123
Percent of U.S. area	33%	42%	9%	16%	
Railroads (miles)[b/]	124,199	59,485	15,057	670	199,411
Percent of U.S. area	62%	30%	8%	1%	
Highways--rural (miles)[c/,d/]					
Interstate[e/]	18,242	12,159	2,505	15	32,921
Primary[f/]	222,505	147,293	36,525	4,210	410,533
Secondary[g/]	1,572,146	970,844	260,835	6,746	2,765,571
Total rural highways	1,767,893	1,130,296	299,865	10,971	3,209,025
Percent of U.S. miles	55%	35%	9%	1%	
Pipeline-interstate (miles)[h/]					
Oil & coal slurry	64,017	107,107	2,869	79	174,072
Percent of U.S. miles	37%	62%	2%	1%	
Natural gas[i/]	68,745	115,017	3,081	84	186,927
Total pipelines	132,762	222,124	5,950	163	360,999
Electric transmission					
REA[j/] (circuit miles)	36,120	32,851	2,083	758	71,812
Public utilities[k/] (circuit miles)	5,076	11,459	5,853	34	22,422
Federal projects[l/] (circuit miles)	17,515	13,999	14,645	87	46,246
Total circuit miles	58,711	58,309	22,581	879	140,480
Circuit miles converted to structure miles[m/]	49,904	49,563	19,194	747	119,408

continued

Table 1--Location of rights-of-way (ROW) by type and U.S. region

ROW type	Eastern region	Central Plains & Rocky Mountain region	West Coast region	Alaska & Hawaii	Total U.S.
Private utilities[n/]					
(structure miles)					
31 KV	5,522	1,872	143	85	7,622
31-50 KV	47,780	16,911	400	560	65,651
51-131 KV	79,889	35,863	22,482	308	138,542
132-188 KV	37,860	17,555	904	117	56,436
189-253 KV	18,408	5,699	8,056	-	32,163
254-400 KV	12,370	5,925	-	-	18,295
401-600 KV	4,669	1,845	2,343	-	8,857
601-850 KV	1,415	-	290	-	1,705
Total private structure miles	207,913	85,670	34,618	1,070	329,271
Total electric structure miles	257,817	135,233	53,812	1,817	448,679
Percent of U.S. miles	57%	30%	12%	1%	
Overall summary					
Total miles of ROW	2,283,017	1,548,107	375,341	13,537	4,218,114
Percent of ROW in U.S.	54%	37%	9%	1%	

a/ Source: The Hammond World Atlas, Superior Edition. Hammond, Inc., Maplewood, NJ 184 p. 1975.

b/ Source: Handy Railroad Atlas of the United States. Rand McNally and Co. Chicago. 1978.

c/ Source: U.S. Dept. of Transportation News Release. Feb. 13, 1978.

d/ Rural roads are all roads except those within incorporated places, densely populated New England towns and certain of the more populous unincorporated areas. This includes the Interstate system.

e/ Source: U.S. DOT News Release of Feb. 13, 1978. Table FM-1.

f/ Source: U.S. DOT News Release of Feb 13, 1978. Table M-1. Primary highway miles = Col. 2 + Col. 4 - Interstate miles for state from Table FM-1.

g/ Source: U.S. DOT News Release of Feb. 13, 1978. Table M-1. Secondary highway miles = Col. 3 + Col. 9 + Col. 10.

h/ Source: Inter. Commerce Comm. 1978. Transport statistics in the U.S. for the year ended December 31, 1976. Part 6. Pipelines. (These data obviously do not include the recently completed Alaska pipeline).

i/ Source: Fed. Power Comm. 1974. Statistics of interstate natural gas pipeline companies. (Gas pipeline mileage apportioned to regions in same ratio as oil pipeline mileage).

j/ Source: 1976 Annual Statistical Report, Rural Electric Borrowers, Calendar Year Ended December 31, 1976. REA Bull. 1-1.

k/ Source: Federal Power Comm. 1976. Statistics of publicly owned electric utilities in the U.S. 1974.

l/ Source: See footnote k. Comment: Eastern region includes TVA and 1/2 Southwestern Pow. Admin.; Alaska and Hawaii region include Alaska Pow. Admin.; West Coast Region includes Bonn. Power Admin., Columbia River Basin Project, 1/2 Colorado River Station Project, and Central Valley Project; all others included in Central Plains and Rocky Mountain region.

m/ For private utilities, the ratio of structure miles to circuit miles for lines greater than 132 KV = 0.85. Since all the circuit miles data are for transmission lines, this same conversion factor was assumed for REA, public utilities and federal projects.

n/ Source: Fed. Power Comm. 1976. Statistics of privately owned electric utilities in the U.S. 1974. Classes A and B companies.

preparation that the different classes of right-of-way do not occur in equal ratio across the nation.

MILES OF RIGHTS-OF-WAY

The Eastern Region accounts for 33 percent of the area of the U.S., the Central Plains and Rocky Mountain Region 42 percent, the West Coast Region 9 percent, and Alaska and Hawaii 16 percent (table 1). However, of the nearly 200 thousand miles of railroads in the U.S., 62 percent is located in the Eastern Region. The nation's pipeline system is more concentrated in the Central Plains and Rocky Mountain Region, 62 percent, with three-fourths of this located in Kansas, Oklahoma, and Texas. Natural gas lines were apportioned to the regions in the same ratio as oil pipelines since mileage was not available by states. The nation has some 3.2 million miles of rights-of-way in its rural highway system, with 55 percent located in the Eastern Region. This includes the Federal Interstate system. Electric transmission rights-of-way are also more concentrated in the Eastern Region, with nearly 60 percent.

There are approximately 4.2 million miles of railroad, pipeline, highway, and electric rights-of-way of various widths in the U.S. Fifty-four percent of this total occurs in the eastern one-third of the U.S., percent in the mid-section of the nation, and nine percent in the West Coast states. The small size of Hawaii and the vast wilderness of Alaska essentially eliminate these two states from the national rights-of-way picture. The importance of eastern U.S. in rights-of-way reflects the concentration of people. The dominant use of these rights-of-way is the transport of peoples' needs.

RIGHTS-OF-WAY ACREAGE

Table 2 presents the estimated acreage of rights-of-way by types for the four regions of the U.S. There are an estimated 2.4 million acres of railroad rights-of-way in the U.S. Of the total railroad rights-of-way, exclusive of yards and sidings, 80 percent (1.9 million acres) is

Table 2—Rights-of-way (ROW) acreage by type and region in the U.S.

ROW type	Assumed ROW width	Eastern region	Central Plains & Rocky Mountain region	West Coast region	Alaska & Hawaii	Total U.S.
	feet					
Railroad						
Total ROW	100a/	1,505,442	721,030	182,509	8,121	2,417,102
Brush control area (excludes road bed)	80b/	1,204,354	576,824	146,007	6,497	1,933,682
Highways-ruralc/						
Interstate						
Total ROW	300	663,345	442,145	91,091	545	1,197,127
Vegetation area	220d/	486,453	324,240	66,800	400	877,893
Primary						
Total ROW	75	2,022,772	1,339,028	332,046	38,272	3,732,118
Vegetation area	27e/	728,198	482,050	119,536	13,778	1,343,562
Secondary						
Total ROW	50	9,255,430	5,883,903	1,580,818	40,885	16,761,036
Vegetation area	18f/	3,331,955	2,118,205	569,095	14,719	6,033,973
Total highway ROW		11,941,547	7,665,076	2,003,955	79,702	21,690,280
Total highway vegetation area		4,546,606	2,924,495	755,431	28,897	8,255,428
Pipelines	50g/	804,618	1,346,206	36,061	988	2,187,873
Electric transmissionh/,i/						
REA, public utilities and Federal projects	100j/	604,897	600,763	232,654	9,055	1,447,368
Private utilitiesk/						
<31 KV	40	26,773	9,076	693	412	36,955
31-50 KV	50	289,576	102,491	2,424	3,394	397,885
51-131 KV	75	726,264	326,027	204,382	2,800	1,259,473
132-188 KV	110	504,800	234,067	12,053	1,560	752,480
189-253 KV	125	278,909	86,348	122,061	-	487,381
254-400 KV	150	224,909	107,727	-	-	332,636
401-600 KV	180	101,869	40,254	51,120	-	193,244
601-850 KV	225	38,591	-	7,909	-	46,500

Continued.

Table 2— Rights-of-way (ROW) acreage by type and region in the U.S. (Continued)

ROW type	Assumed ROW width	Eastern region	Central Plains & Rocky Mountain region	West Coast region	Alaska & Hawaii	Total U.S.
	feet					
Total Electric ROW		2,796,588	1,506,753	633,296	17,221	4,953,858
Overall summary						
Total ROW acres		17,048,195	11,239,065	2,855,821	106,032	31,249,113
Percent of ROW in U.S.		55%	36%	9%	1%	
Total vegetation acres		9,352,166	6,354,278	1,570,795	53,603	17,330,842

a/ ROW width based on discussions with railroad weed control contractors.

b/ Excludes 20 feet for road bed which is generally treated with soil sterilants rather than 2,4,5-T.

c/ ROW widths based on discussions with highway department officials in Indiana and Maryland, and Federal Highway Administration.

d/ Excludes two lanes, each consisting of 24' road, 12' and 4' shoulders or 40' per lane of divided highway.

e/ Excludes a 24' road and two 12' shoulders.

f/ Excludes a 24' road and two 4' shoulders.

g/ Source: 1975. U.S. Dept. Interior. The need for a national system of transportation and utility corridors. Table VIII-2.

h/ Only mileage designated as transmission considered. Assumes most distribution mileage occurs in populated areas or often on shared ROW with others such as rural roads; or generally of such low voltage that only narrow ROW required which tends to be trimmed rather than treated with herbicide. This eliminates 1.7 million miles of REA distribution lines.

i/ Transmission miles or structure miles = circuit miles x 0.85. This ratio derived from comparison of circuit miles and structure miles of private utility lines greater than 132 KV.

j/ ROW width suggested as average width for REA by REA official.

k/ ROW widths are assumptions made after discussions with electric utility and other knowledgeable personnel.

actually available for brush-control treatment or treatments where 2,4,5-T could be involved. The remaining 20 percent is in the roadbed ballast area and tends to be treated with soil sterilants for total vegetation control.

The rural highway system is divided into Interstate, primary, and secondary roads to better account for the differences in right-of-way width associated with each class of road. Assuming a 300 foot right-of-way for the Interstate system, there are 1.2 million acres included in Interstate right-of-way. Discounting paved surfaces and shoulders, only 73 percent of this Interstate right-of-way is actually available for vegetation treatment. Similarly, 36 percent of the primary and secondary rights-of-way is actually available for vegetation-control treatment. Within the U.S., rural highway rights-of-way account for more than 21 million acres. Of this, slightly more than half is located in the Eastern Region of the U.S.

Interstate pipeline systems account for 2.2 million acres of right-of-way which are largely concentrated in the Central Plains and Rocky Mountain Region. Electric transmission rights-of-way occupy nearly 5 million acres. Of this, approximately 56 percent is located in the Eastern Region.

In summary, rights-of-way utilize more than 31 million acres of land in the U.S. Of this, 17.3 million acres are located such that they could be potentially treated with 2,4,5-T. As has been the consistent trend throughout the data assimilation on rights-of-way, the Eastern Region, which accounts for only one-third of the U.S. area, accounts for greater than one-half of the right-of-way acreage.

MINOR RIGHTS-OF-WAY

There are also rights-of-way which are difficult to firmly quantify in terms of potential herbicide usage, but sheer magnitude demands mention (table 3). For lack of a better term, these might be considered as

Table 3—Additional miles and acres of "minor" rights-of-way (ROW) types

ROW type	Assumed ROW width (ft)	Eastern region	Central Plains & Rocky Mountain region	West Coast region	Alaska & Hawaii	Total U.S.
REA-distribution						
Structure miles[a]		1,018,177	645,307	33,722	4,611	1,701,817
ROW acres	30[b]	3,702,462	2,346,571	122,625	16,767	6,188,425
Telephone						
Structure miles[c],[d]		855,260	178,250	155,492	2,848	1,191,850
ROW acres	10	1,036,679	216,061	188,475	3,452	1,444,667
Pipelines - natural gas						
Field miles[e]		20,442	34,254	1,105	-	55,248
ROW acres	50[f]	123,891	207,600	6,697	-	334,836
Totals						
miles		1,893,879	857,811	190,319	7,459	2,948,915
acres		4,863,032	2,770,232	317,797	20,219	7,967,928

a/ Source: 1976 Annual Statistical Report, Rural Electric Borrowers, Calender Year Ended December 31, 1976. REA Bull. 1-1.

b/ ROW width suggested by REA official.

c/ Source: Statistics of Communications Common Carriers. Federal Communications Commision. 1976.

d/ Mileage estimated by proportioning the number of poles in the U.S. (42,187,906) to each state in accordance with the percent of miles of aerial cable and wire. Assumed span distance of 150 feet between poles and ROW width suggested by official of Chesapeake and Potomac Telephone Company of Virginia.

e/ Source: Fed. Power Comm. 1974. Statistics of interstate natural gas pipeline companies. (Gas pipeline mileage apportioned to regions in same ratio as oil pipeline mileage).

f/ Same width as used for interstate gas transmission.

"minor" right-of-way types although, in terms of potential miles or acres, they may be far from minor. The rights-of-way considered in tables 1 and 2 are almost totally rural. REA distribution lines (<34.5 kv), 1.7 million miles (table 3), are almost four times the total electrical structure miles (table 1) and 25 percent greater than total transmission acreage (table 2). Portions of these lines are known to be treated with herbicides, but manual tree trimming is also very important. These lines obviously integrate into urban conditions, and may occur as shared rights-of-way with highways and telephones, all in uncertain ratios.

Similarly, based on the number of telephone poles in the U.S. (42.2 million), there are approximately 1.2 million miles of telephone pole lines in this nation. Assuming a 10 foot right-of-way width, there are almost 1.5 million acres of telephone right-of-way. Again, unknown proportions are shared with highways, railroads, and electric, and unknown proportions are in urban locations.

There are an additional 55,248 miles of natural gas field lines. However, the proportion of multiple lines and actual amounts of unshared rights-of-way are unknown.

There also are extensive areas of drainage ditches, canals, channels, and other waterways where brush control is necessary. While these water-related rights-of-way are not currently treated with 2,4,5-T, as rights-of-way they are subject to vegetation management and were potentially treatable with 2,4,5-T until current restrictions were imposed prohibiting the use of 2,4,5-T for these purposes.

MANAGEMENT GOALS VERSUS VEGETATION PROBLEMS

One common goal throughout the various types of rights-of-way is maintenance of the security and reliability of the right-of-way system. The electrical transmission lines must transport electricity and railroads must transport goods safely. Pipelines must transport petroleum products and the highways must provide safe transportation for the users. For all of these systems, vegetation -- often woody and sometimes grass and herbaceous vegetation -- poses particular problems. Also common to all rights-of-way management is the maintenance of an aesthetically pleasing appearance, control of noxious weeds required by law, and soil stabilization.

Right-of-way vegetation management may, on the surface, appear to be a simple problem, particularly since crop residues are not involved. However, excluding total vegetation control in the ballast portion of railroads, selective and adequate vegetation control is the primary objective for all rights-of-way. The control program must be geared to the dominant problem plant or plant complex in each locale. This management program must fit within the management objectives and budgetary constraints of the industry concerned, be it electric, highway, pipeline, or railroad. As the problem vegetation changes with treatment, topography, soils, or climate, the specific control program must change accordingly.

All of the undesirable vegetation on a right-of-way site must be controlled. There is no single herbicide that will selectively and adequately control all undesired species, especially woody plants, with the species complex on a site. It is therefore necessary to have several herbicides available that can be used to supplement the main herbicide of choice for the confronting problem. Where a herbicide does not adequately control the vegetation or has undesired attributes, other herbicides or management methods are used to maintain the right-of-way site. Each of these also has advantages and disadvantages.

ELECTRIC TRANSMISSION

Vegetation problems for electric transmission systems center largely on tall-growing woody vegetation. Vegetation in the conductor security zone or in contact with the transmission lines will cause power outages. This disrupts service to homes and industries and can cause fires. Woody vegetation also hinders access for line and structure inspection and maintenance. The primary purpose for vegetation management on electric utility rights-of-way is for safe and uninterrupted transmission of electrical power. These problems are encountered over a variety of terrain conditions from flat to very steep and from uninterrupted forests to wooded lands interspersed with agricultural croplands. Development of low dense cover for wildlife habitat enhancement can be an important secondary objective.

RAILROADS

Because of the nature of railroad use, the control of vegetation on railroad rights-of-ways serves essential transportation purposes. Safety of train movement requires maintenance of sound track foundations. Uncontrolled weeds, vines, and brush will penetrate and undermine track structures and make them hazardous. Rights-of-way must be cleared of fire hazards created by the presence of weeds, vines, and brush.

Uncontrolled vegetation impedes visibility. Visibility along rights-of-way, especially on curves, and visibility of signals must be maintained in the interest of safe operations. Visibility must be maintained at highway grade crossings for the safety of motorists and train crews. There are 25,000 public crossings at grade in the United States. Uncontrolled vegetation at grade crossings seriously impairs visibility.

Rights-of-way must be cleared of vegetation to enable communications and signal systems to operate properly and to be maintained. These systems are essential to railroad transportation. Railroad employees need safe working conditions and the control of vegetation is necessary for that purpose. The control of vegetation on or adjacent to roadbeds is a duty imposed on railroads by Federal regulations (Welsh 1974).

HIGHWAYS

Vegetation problems along highway rights-of-way are similar to those of railroads. Control of vegetation on highway rights-of-way is essential for safety of vehicle movement and visibility along rights-of-ways especially at curves and road crossings. From table 1, 86 percent of our nation's highway system (2.8 million miles) is in the secondary road class with typically narrow rights-of-way. Vegetation control is necessary to prevent brush encroachment into the driving lanes, thus reducing visibility, to permit drainage ditches to function as intended, to reduce snow drifting, and to reduce shading, permitting more rapid drying of the road surface which reduces road maintenance costs as well as increasing safety. Vegetation control must be accomplished by some method which can be used on highly erodable cut and fill slopes, where stones and stumps or rock outcroppings may exist.

Highway rights-of-way are unique among the various rights-of-way because of the necessity for herbaceous weed control. Roadsides must be pleasing in appearance and must be free of noxious plants. Examples of noxious or otherwise undesirable weeds include Canada thistle, hemp, milkweed, chicory, leafy spurge, common mullin, field bindweed and poison ivy.

PIPELINES

Vegetation control on pipeline rights-of-way principally concerns reliability of the system. Woody plant control is necessary for visual inspection of the lines as well as access for maintenance.

BIOLOGY AND ECOLOGY OF PLANT COMMUNITIES

With the constraints of herbicide effectiveness or species susceptibility, and management intensity, the United States can be divided into relevant ecoregions (Bailey 1976, fig. 2 and table 4). This division was explained previously in the discussion of rights-of-

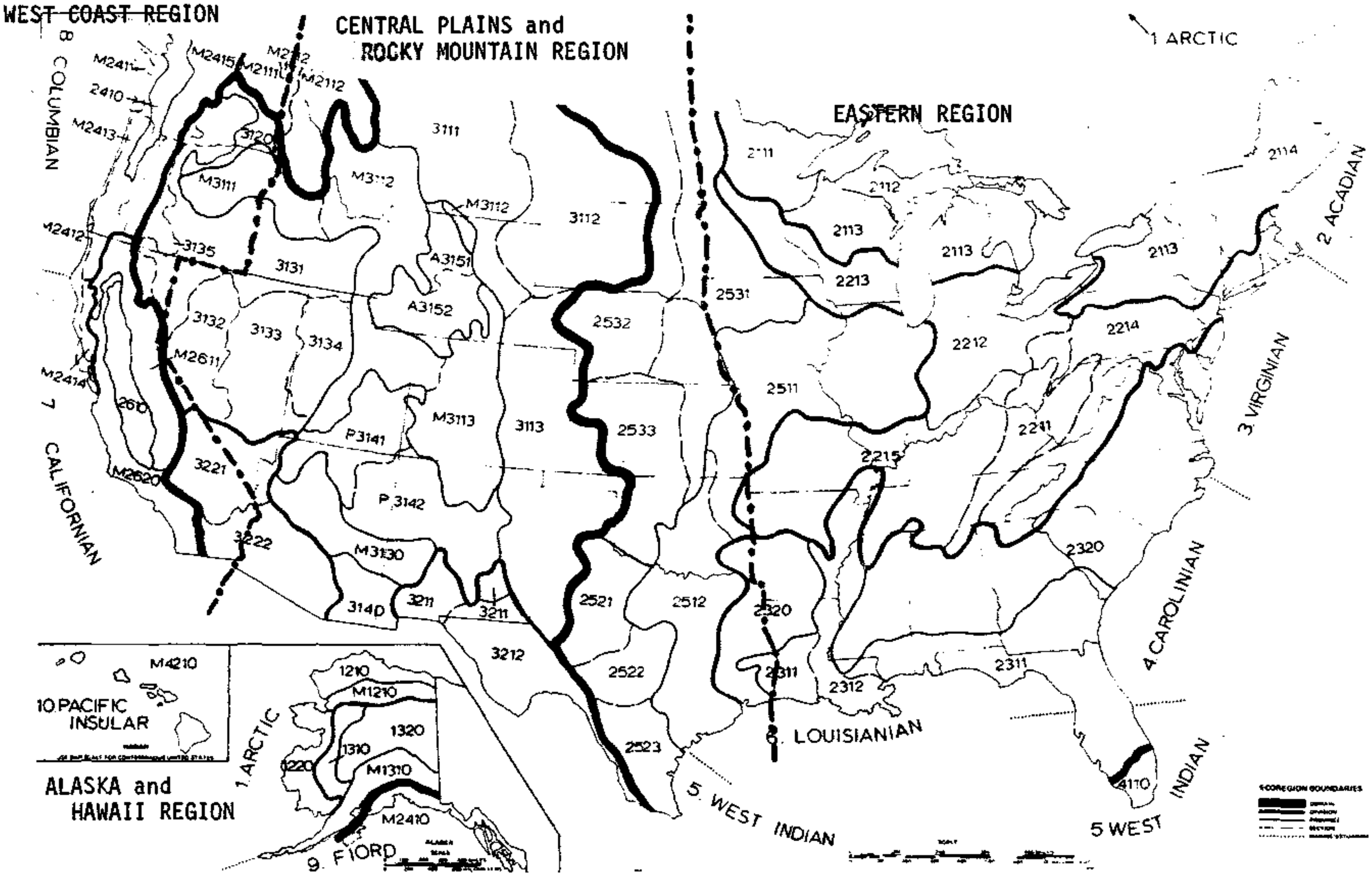

Figure 2. Relationship of ecoregions and arbitrary U.S. regions designated in Figure 1. (See table 3 for explanation of numerical symbols.

Table 4--Explanation of ecosystem numbers from figure 2 by U.S. regions

Eastern Region

Laurentian Mixed Forest

- 2211 Spruce-fir forest
- 2112 Northern hardwoods-fir forest
- 2113 Northern hardwoods forest
- 2114 Northern hardwoods-spruce forest

Eastern Deciduous Forest

- 2211 Mixed mesophytic forest
- 2212 Beech-maple forest
- 2213 Maple-basswood forest and oak savanna
- 2214 Appalachian oak forest
- 2215 Oak-hickory forest

Outer Coastal Plain Forest

- 2311 Beech-sweetgum-magnolia-pine-oak forest
- 2312 Southern flood plain forest

2320 Southeastern Mixed Forest

Prairie Parkland

- 2511 Oak-hickory-bluestem parkland

Tall-Grass Prairie

- 2531 Bluestem prairie

4110 Everglades

Central Plains and Rocky Mountain Region

Columbia Forest

- M2112 Cedar-hemlock-Douglas-fir forest

Prairie Parkland

- 2512 Oak-bluestem parkland

Prairie Brushland

- 2521 Mesquite-buffalograss
- 2522 Juniper-oak-mesquite savanna
- 2523 Mesquite-acacia savanna

Continued.

Table 4—Explanation of ecosystem numbers from figure 2 by U.S. regions (Continued)

Tall-Grass Prairie

2531 Bluestem prairie
2532 Wheatgrass-bluestem-needlegrass
2533 Bluestem-grama prairie

Great Plains Short-Grass Prairie

3111 Grama-needlegrass-wheatgrass
3112 Wheatgrass-needlegrass
3113 Grama-buffalograss

Intermountain Sagebrush

3131 Sagebrush-wheatgrass
3132 Lohantan saltbush-greasewood
3133 Great basin sagebrush
3134 Bonneville saltbush-greasewood

3140 Mexican Highlands Shrub Steppe

Rocky Mountain Forest

M3111 Grand fir-Douglas-fir forest
M3112 Douglas-fir forest
M3113 Ponderosa pine-Douglas-fir forest

M3130 Upper Gila Mountains Forest

Colorado Plateau

P3141 Juniper-pinyon woodland + sagebrush-saltbush mosaic
P3142 Grama-galleta steppe and juniper-pinyon woodland mosaic

Wyoming Basin

A3151 Wheatgrass-needlegrass-sagebrush
A3152 Sagebrush-wheatgrass

Chihuahuan Desert

3211 Grama-tobosa
3212 Tarbush-creosote bush

American Desert

3221 Creosote bush
3222 Creosote bush-bur sage

Continued.

Table 4—Explanation of ecosystem numbers from figure 2 by U.S. regions (Continued)

West Coast Region

Columbia Forest

M2111 Douglas-fir forest

Willamette-Puget Forest

2410 Willamette-puget forest

Pacific Forest

M2411 Sitka spruce-cedar-hemlock forest
M2412 Redwood forest
M2413 Cedar-hemlock-Douglas-fir forest
M2414 California mixed evergreen forest
M2415 Silver fir-Douglas-fir forest

2610 California Grassland

M2611 Sierran Forest

M2620 California Chaparral

3120 Palouse Grassland

Intermountain Sagebrush

3131 Sagebrush-wheatgrass
3135 Ponderosa shrub forest

Rocky Mountain Forest

M3111 Grand fir-Douglas-fir forest

American Desert

3221 Creosote bush
3222 Cretosote bush-bur sage

Alaska and Hawaii

1210 Artic Tundra
1220 Bering Tundra

M1210 Brooks Range

1310 Yukon Parkland
1320 Yukon Forest

Continued.

Table 4--Explanation of ecosystem numbers from figure 2 by U.S. regions (Continued)

M1310	Alaska Range
M2410	Pacific Forest
M4210	Hawaiian Islands

way occurrence. The compilation of the states by selected regions was based on major vegetational boundaries. Obviously 2,4,5-T will not be used in areas where nonsusceptible species make up the major plant communities, or where 2,4-D or other herbicides can attain the same objective more effectively or at a lower cost. Also, 2,4,5-T is not likely to be used in semi-arid, prairie, or other regions where woody plants do not grow rapidly or abundantly.

Woody vegetation, of particular concern on rights-of-way, develops in response to climatic, edaphic, and physiographic factors. Eastern U.S., as defined here, includes Minnesota, Iowa, Missouri, Arkansas, Louisiana, and all states east. Forest is the climax vegetation. The West Coast states include California, Oregon, and Washington where both forest and grasslands occur. The remaining contiguous states in the continental 48 will be referred to as the Central Plains and Rocky Mountain Region. Here grasslands predominate but woody plants are found at high elevations or other sites where climate and site conditions will support them.

One important ecoregion province included in the Eastern Region is the Laurentian Mixed Forest (Bailey 1976). The region covers 224,700 square miles across the northern portion of the Lake States, the Adirondacks, and New England Highlands. The woody plant communities in this province are transitional between the boreal forests of Canada and the deciduous forests to the south. Bailey recognized four sections in this province.

1. Spruce-fir forest
2. Northern hardwoods-fir forest
3. Northern hardwoods forest
4. Northern hardwoods-spruce forest

A second important ecoregion in Eastern U.S. is the Eastern Deciduous Forest, 367,800 square miles. Only a small part of this ecoregion lies outside Eastern U.S. as defined here. The Eastern Deciduous Forest Region extends from the New England lowlands through the Appalachian

Region to the Ozarks on the west. It also includes the southern portions of the Lake States. Five sections in this ecoregion are:

1. Mixed mesophytic forest
2. Beech-maple forest
3. Maple-basswood forest plus oak savanna
4. Appalachian oak forest
5. Oak-hickory forest

A third ecoregion province of importance in Eastern U.S. is the Outer Coastal Plain Forest. This province covers 150,100 square miles, most of which is in Eastern U.S. as herein defined. This ecoregion covers the extreme southern part of the Southeastern U.S., including nearly all of Florida, southern Georgia, Alabama, Mississippi, Louisiana, and extending up the Mississippi River to southern Missouri. Two distinct sections of this province are:

1. Beech-sweetgum-magnolia-pine-oak forest
2. Southern flood plain forest

A fourth province in this region is the Southeastern Mixed Forest Province covering 257,000 square miles across Southeastern U.S. The forests in this region are dominated by various southern pines with common hardwood associates such as oak, hickory, sweetgum, black gum, red maple, and winged elm.

Also of importance in the Eastern U.S. Region is the Prairie Parkland Province. A section of this province is the oak-hickory-blue stem parkland. This section occurs predominantly in Illinois, Iowa, and northern Missouri. Most of this section is included in the Eastern Region. It is the only part of the Eastern Region not characterized exclusively by woody climax vegetation.

An important segment of the Central Plains and Rocky Mountain Region as used in this discussion is the Prairie Division along the eastern edge of this region. The prairies of the U.S. extend from Texas to the northern U.S. border in a broad belt. This is a transitional zone between two forested areas. Moisture tends to be limiting for tree growth. The natural vegetation of the prairies is tall grasses with subdominant broadleaved herbs. Trees and shrubs occur only as occasional patches usually in river bottoms and drainage areas. While part of the Prairie Parkland Province is included in the Eastern U.S. region, one section, the Oak-Bluestem Parkland, occurs in the Central Plains and Rocky Mountain region.

Mixed hardwood-conifer stands occur across the northern and southern portion of the Eastern Region. Forests in the central part of the Eastern Region tend to be dominated by hardwood species. The Eastern Region also includes a transitional zone in Iowa and Illinois where hardwoods occur in mixture in parks and savannas with grasses. The climate is sufficient in the Eastern Region to support fairly lush woody plant growth and herbaceous vegetation throughout most of the region.

The Central Plains Region grades from tall and short grass prairies into the Pinyon-Juniper-Sagebrush communities of the Rocky Mountains. The Central Plains and Rocky Mountain Region can be generally characterized as having a net moisture deficit, limited occurrence of broadleaf species, often fairly sparse vegetation and woody plant vegetation which is typically very slow growing.

The West Coast Region east of the Cascade and Sierra Nevada Mountains is, for the most part, typified by vegetation types and growth conditions similar to the Rocky Mountain Region. The western third of Oregon, Washington, and northwestern California is an area greatly influenced by the Pacific Ocean. Lush, rapid growing woody vegetation is dominant throughout the coastal zone. This vegetation is typified by coniferous species; numerous broadleaf, deciduous hardwood species are also characteristic of the forest species in this particular area.

Following the initial disturbance necessitated by installation of a right-of-way system, natural plant successional trends constantly tend to convert the disturbed or right-of-way area back to naturally occurring seral woody vegetation. In the Eastern Region and Pacific Northwest, this leads to encroachment by broadleaf woody vegetation into rights-of-way. Woody vegetation would tend to occur to various degrees in the Central Plains and Rocky Mountain Region, but the climatic extremes, particularly moisture availability, generally cause development to be very slow.

IMPACT ON COMMODITY YIELD

Within the right-of-way area the nature of land management is totally different from that associated with crop production where yields and yield reductions as a function of weeds and weed growth can be reasonably well defined. On rights-of-way weed and brush control is either satisfactory or it is not. It does not involve a commodity that can be measured in terms of board feet, metric tons, or animal units, but rather uses such as power or fuel transmission and transportation which impact all of the U.S. or major segments of the country when serious problems arise. Therefore, a major objective of vegetation management on rights-of-way is to prevent plant growth from interfering with these functions which are the "commodities" in this case.

MANAGEMENT STRATEGIES

The ultimate objective for right-of-way managers is to maintain the reliability of the right-of-way system. Strategy, in the simplest terms, is to maintain that right-of-way in operable condition for the lowest costs per acre or mile of right-of-way. This involves vegetation manipulation to (1) prevent tall-growing woody plants from entering the conductor security zone on electric transmission rights-of-way, (2) provide visibility and reduce interference with vehicles and carriers on transportation rights-of-way, (3) reduce interference with fuel movement on pipeline rights-of-way, and (4) provide access for inspection and maintenance on all rights-of-way.

POTENTIAL SOLUTION OF THE PROBLEM

There are a variety of methods available to the right-of-way manager for controlling vegetation. In the broadest sense, these include chemical, mechanical, hand labor, fire, or a variety of combinations of these methods. Each method has advantages and disadvantages which may enhance or exclude its use in a particular locale, types of rights-of-way, or type of vegetation. Certainly all of these methods have associated costs and impacts on vegetation, wildlife, and services which must be continuously considered by the right-of-way manager in the selection of the particular method or combination of methods. Throughout the remaining portion of this report, the major methods will be compared, especially herbicides, mechanical, and hand labor.

Fire is seldom used in rights-of-way vegetation management. Managing small ribbons of land crossing a variety of soils, climates, physiographic features, and adjacent crop and noncrop situations severely limits the use of fire as a tool for controlling right-of-way vegetation. Not only are there problems with smoke emission, but also severe managerial problems associated with maintaining fire within very strict and narrow confines while also maintaining a fire of sufficient intensity to accomplish the prescribed objective, especially if this objective is woody plant control.

ALTERNATIVES FOR PROBLEM SOLUTION

2,4,5-T

Patterns of Use

During the summer of 1978, Asplundh Environmental Services surveyed the major right-of-way sectors that are actively involved in major vegetation management programs, i.e., railroads, pipelines, highways, and electric utilities. This survey was specifically designed to determine the role of 2,4,5-T in vegetation-management programs of these right-of-way groups. The survey results are based on responses from 469 electric utilities, 25 railroads, 66 pipeline companies, and 31 highway departments.

The estimated acres treated annually by rights-of-way type and method of application are presented in table 5. Electric utilities treat the greatest number of acres with 2,4,5-T annually, 465,339 acres or 68 percent of the total acres treated annually with 2,4,5-T. Railroads annually treat 127,425 acres or 19 percent, highways treat 68,167 or 10 percent, and pipelines 22,026 or 3 percent.

Railroads are heavily dependent on broadcast foliar treatments applied by ground equipment. This method of application accounts for more than 75 percent of treated railroad acres. Broadcast aerial application accounts for nearly 90 percent of the pipeline acreage treated. Broadcast foliar ground applications are most important for highway rights-of-way management, 86 percent of the treated acreage. One-half of the treated electric right-of-way acreage is treated with a selective basal treatment. An additional 34 percent of electric rights-of-way acreage is treated with broadcast aerial foliar application.

The acres treated annually with 2,4,5-T are relatively small when compared to the total right-of-way acres. Railroads treat only 7 percent annually, pipelines and highways only 1 percent annually and electric, 9 percent. However, if an average treatment cycle of 4 to 5 years is assumed, i.e., the number of years before the same acre is retreated, the importance of 2,4,5-T to rights-of-way management becomes more realistic. Pipelines and highways manage 4 to 5 percent of their rights-of-way with 2,4,5-T. Electric utilities depend on 2,4,5-T as a management tool for more than 40 percent of their rights-of-way and some 30 percent of railroad rights-of-way are managed with 2,4,5-T.

Methods of Application

The methods of application listed in table 5 have some elements of commonality as well as unique features when utilized on the different types of right-of-way. Foliar applications are generally best in situations having a high density of target species (Barnhart et al. 1975). Foliar applications are made during the growing season after full leaf development and until the target species cease active growth. This period may encompass May to September, depending on location. Basal treatments are applied to the bark and can be done year round, climate permitting.

Broadcast Foliar - Air

Aerial application is the most economical method of treating dense stands relatively inaccessible to conventional ground equipment. Size and density of brush have little effect on the volume of herbicide and carriers applied and the cost of applications (Barnhart et al. 1975). The volume of solution applied ranges from 15 to 25 gallons per acre with water or water-oil mixture as the carrier.

A typical aerial spray crew will include a pilot, two groundmen and possibly a mechanic (fig. 3). Equipment will include the helicopter and its maintenance truck, and a tank truck to store, mix and transfer the spray solution to the helicopter (Barnhart et al. 1975). Actual applications are generally restricted to the early morning and late afternoons -- periods of calm air. The nature of and actual accomplishment of aerial application is fairly standard, regardless of right-of-way type (fig. 4). Highways do not apply 2,4,5-T aerially (table 5).

Broadcast Foliar - Ground

Broadcast foliar ground applications are made during the growing season, as with aerial foliar treatments, but the actual application method will

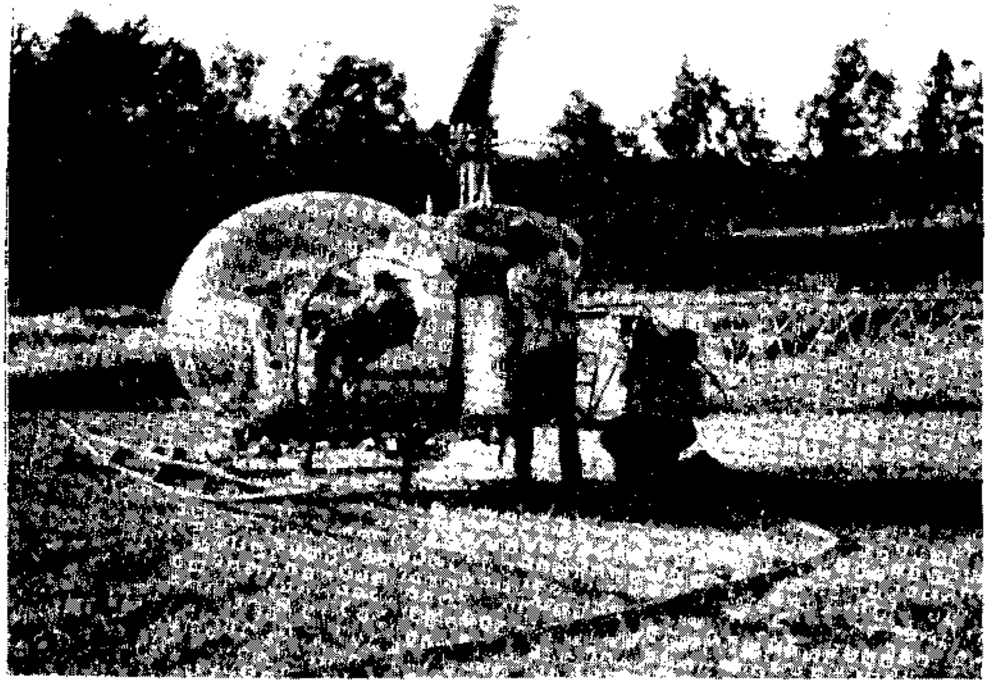

Figure 3. Herbicide mixture is pumped from mix truck to waiting helicopter.

Figure 4. Special equipment or spray additives produce large droplets which minimize drift. Aerial application controls woody plants in right-of-way and side-trims trees on the edge.

Table 5—Acres treated annually with 2,4,5-T by rights-of-way type and method of application[a/]

ROW type	Total treated annually	Broadcast foliar-air	Broadcast foliar-ground	Selective foliar	Selective basal	Stump spray after cutting
Railroad	127,425	27,386	99,996	0	43	0
Pipeline	22,026	19,391	0	2,635	0	0
Highway	68,167	0	58,447	5,614	733	3,373
Electric	465,339	159,479	43,927	21,151	234,254	6,528
Total acres	682,957	206,256	202,370	29,400	235,030	9,901

a/ Source: Asplundh Environmental Services 1978.

vary by rights-of-way type in response to differing physical constraints. Railroad and highway applications are somewhat similar in that it is possible for the equipment to drive along the right-of-way. However, highly specialized equipment is used for treating railroad rights-of-way.

Railroad brush control is accomplished with spray trains and Hyrail units. Spray train units are highly adapted railroad cars. These cars are self-contained with all necessary pumps, valves, controls, booms, and nozzles. Tank cars containing the major herbicides or herbicide mixtures separate the spray car from the locomotive engine. The entire unit is pushed by the engine with the spray car in front. Herbicide solution is pumped from the attached tank cars as the application is made. Tank cars or tanks in the spray car may contain specific undiluted herbicides which can be injected into the spray stream as needed for specific vegetation problems. These trains are used for road ballast as well as brush-control treatments. Nozzle configurations and types enable treatment across the right-of-way. A typical crew would consist of four people. Usually three handle the actual application and one supervisor monitors speed and pressures and looks out for sensitive crops. Herbicide mixtures are usually applied in a total volume of 300 gallons per acre with water as the carrier.

Railroad brush control is also done with Hyrail units, trucks modified with the addition of hydraulically operated rail wheels (fig. 5). These units can travel on highways as well as on railroads. A typical crew consists of two people - one to drive and one to operate a mobile boom. These units are particularly important for woody plant control on branch lines whereas spray trains tend to be used for treating mainlines. Herbicide solution is usually applied in a total volume of 25 gallons per acre with water as the carrier. Each unit is accompanied by a railroad employee as a safety precaution.

Highway rights-of-way by their very nature afford a certain degree of access which can facilitate herbicide application. Truck or trailer

Figure 5. Versatile Hyrail units increase flexibility in railroad vegetation control programs.

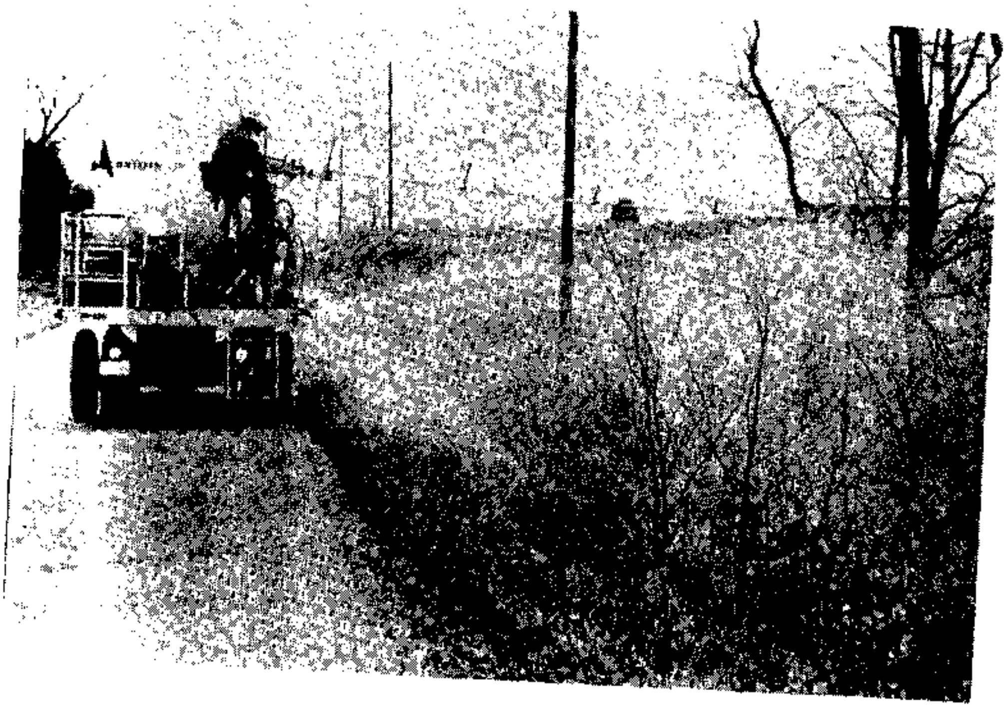

Figure 6. A highway application utilizing mobile boom and off-center nozzles.

mounted spray units can often treat adjacent vegetation with off-center nozzles (fig. 6). The road construction operation often creates broad areas which are readily accessible to tractor mounted sprayers with boom or boomless nozzles such as on the Interstate rights-of-way. However, this is probably a relatively small percentage of the total highway vegetation acreage--less than 10 percent. A typical crew with each spray unit would be two people--one to operate the sprayer and one to drive the equipment.

Ground foliar applications are somewhat different for electric rights-of-way since off-road capability is usually an equipment requirement and wide rights-of-way, 200 feet plus, may need to be treated. Four-wheel drive trucks, skidders, or track vehicles are preferred. These vehicles are equipped with high pressure pumps, tanks with hydraulic or mechanical agitation, 800 to 1,000 feet of hose, and two or three hand spray guns. Crew complements range from three to four men (figs. 7, 8 and 9). In some instances back-pack mist blowers may be used to treat small areas relatively inaccessible to heavy equipment (Barnhart et al. 1975) (figs. 10 and 11). The foliage and stem of the target plants are wet to the point of runoff. This is an effective and economical method for controlling medium to dense brush.

Selective Foliar

Selective foliar application is a modified broadcast foliar treatment. It is used with low to medium densities of target species. The spray is directed to the specified undesired species. In actual practice there is a constant gradation between selective and broadcast foliar treatments depending on species density.

Selective Basal

Selective basal application method is distinctly different from foliar methods. This method uses oil carriers, requires treatment of each individual stem, and can be used during any season of the year

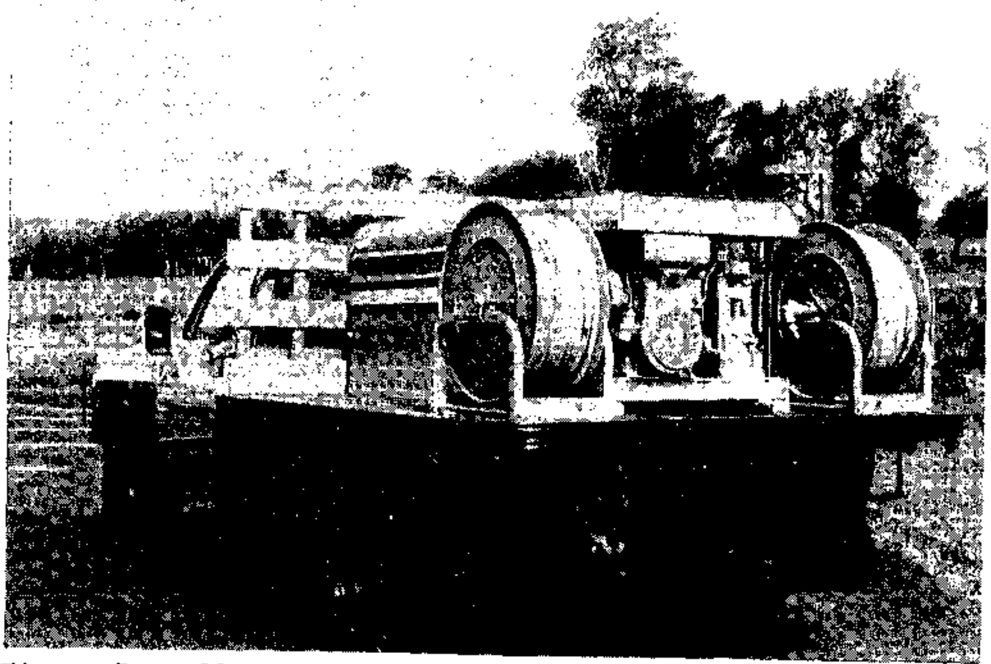

Figure 7. Off-road capability is a requirement for brush control on electric utility rights-of-way. Four wheel drive, high pressure pump and 800-1,000 feet of hose are typical equipment.

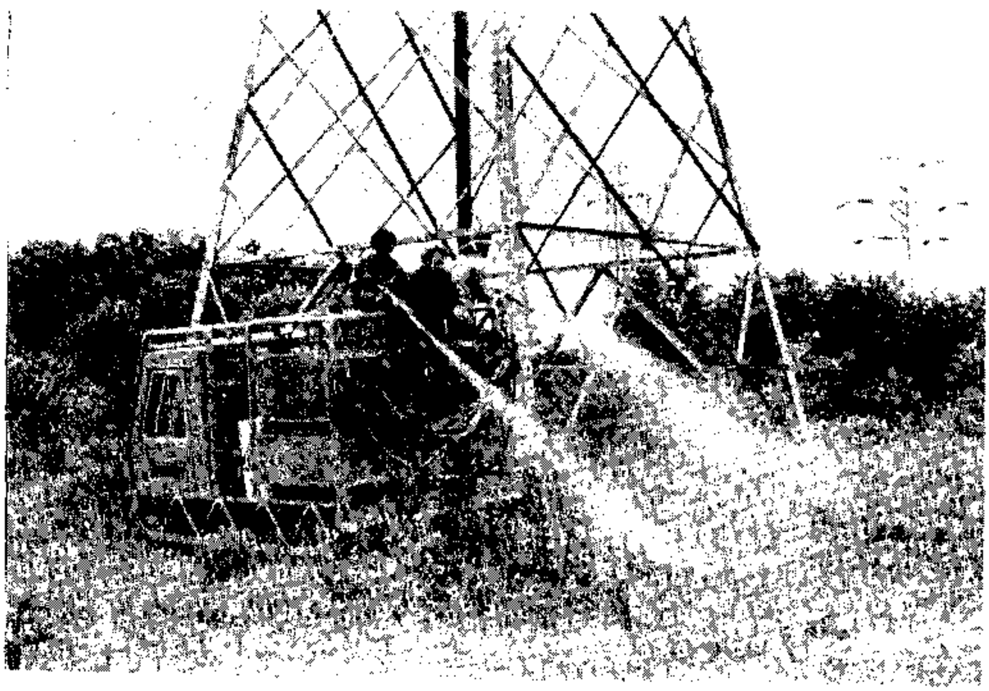

Figure 8. Tracked vehicles are necessary for some terrain conditions. Application may be made from equipment, as shown, but is more generally applied from the ground.

Figure 9. Broadcast foliar and selective foliar treatments differ only in the extent of vegetation treated. This ground application is typical of both treatments.

Figure 10. The knapsack sprayer is effective for spot treatments.

Figure 11. The backpack mist blower is modified for treating the base of stems or stumps. This equipment is used mainly for spot treatment of inaccessible areas.

(fig. 12). Although it is the most expensive per acre treatment for electric utilities, it is used on 50 percent of their treated acres annually (Asplundh Environmental Services 1978). The selective basal method is used where selective treatment of brush is desirable, where close control is necessary, and the density is such that a basal application is economical (Barnhart et. al. 1975). Stand density and stem diameter affect the volume applied and the thoroughness and cost of application. The lower 12-24 inches of each individual stem is completely sprayed to the point of runoff. The root collar area and any exposed roots are also thoroughly treated.

This treatment can be applied with a variety of equipment, from hand operated knapsack sprayers and back-pack mist blowers with special attachments to truck-mounted units such as used for other ground treatments. The personnel-carried sprayers are generally used only in light scattered brush, for spot treatments and areas with poor access (Barnhart et al. 1975).

Stump Spraying After Cutting

Stump spraying after cutting is used to prevent sprouting from the stumps of cut woody plants. This treatment is used extensively for initial rights-of-way clearing and reclearing. The same equipment and carriers used for basal treatments are used with this method to soak the cut stump (Barnhart et al. 1975). The crew complement may be much larger such as a crew of seven to eight cutters followed by two to three stump sprayers. Stand density and terrain have major impacts on productivity.

Environmental Effects

This section considers some indirect effects of using 2,4,5-T on rights-of-way. In contrast to the direct beneficial use effects of 2,4,5-T, there are a number of potential indirect effects that should be considered where this herbicide is used for vegetation management on rights-of-way. For example, spraying with 2,4,5-T, or use of any other

Figure 12. Basal applications require individual stem treatment and can be made during any season of the year.

chemical or mechanical method to remove woody plants from rights-of-way will result in modification of floristic composition of the remaining plant community. Such modifications occur due to removal of the overstory plant cover, regardless of methods employed, either chemical or mechanical. Some plant species such as lady slipper may decline or disappear under right-of-way conditions while others expand and flourish. Resultant changes in plant composition may be beneficial to some organisms such as certain wildlife species. This is an obvious relationship that occurs under natural as well as man-induced changes in the environment.

Indirect effects of 2,4,5-T application to target plants could occur in the terrestrial and aquatic environment and may influence future management options. Such indirect effects, however, are primarily related to application methods, i.e. nonselective versus selective techniques.

Terrestrial Environment

Vegetation

The short-term direct effect of 2,4,5-T application is the immediate response of the treated vegetation, both desired and undesired, to the herbicide. In the short term, approximately 1 to 2 years, the treated vegetation either dies or recovers. For broadcast foliage applications there is a rapid "brown out." Treated plants exhibit certain growth abnormalities such as bending, twisting of new stems and abnormal leaf development, particularly when herbicide has been applied at lower rates. Often the treated vegetation simply wilts and dies. Selective application techniques have similar effects on treated vegetation but with minimal disturbance to nontreated plants.

In contrast, indirect effects on vegetation may be evident over a longer term and generally are expressed as plant community changes, i.e., adjustments in floristic composition. Some community components may be altered for a period of time and others entirely removed and replaced by different species. The magnitude of plant community changes due to 2,4,5-T treatment is related to application technique. Selective methods cause the least disturbance to nontreated vegetation and ultimate community composition except for removal of undesired target plants such as tree species on the rights-of-way. Even with severe plant community alterations resulting from nonselective application methods, the vegetation may return to the original composition over a period of 10 to 20 years (Bramble and Byrnes 1972, 1974).

Generally, after repeated broadcast application of 2,4,5-T, the remaining plant community is typified by the near absence of broadleaf herbaceous plants and many woody species. The plants remaining tend to be grasses, ferns, sedges, and other species resistant to the herbicide treatment (Carvell and Johnston 1978).

Where the material is repeatedly applied in a selective manner such as a basal stem treatment, the resultant plant communities are much more species diverse. There will be more abundance of shrubs and woody plants, as well as herbaceous species (Carvell and Johnston 1978; Bramble and Byrnes 1975).

Effects on Animals

In general, animals require a broad diversity of habitat types. Many wildlife species thrive in this transitional zone, ecotone, between diverse vegetation types. Bramble and Byrnes (1974) have shown that wildlife usage on the rights-of-way treated with 2,4,5-T was greater than on adjacent undisturbed forests. Depending on the degree of disturbance from 2,4,5-T treatment, wildlife habitat may be altered for a short period, then recover, similar to conditions following fires. Further, openings and low plant cover created by spraying may be more favorable to certain wildlife species such as turkey and quail, but less favorable for large mammals. A report on 22 rights-of-way in New York State has shown that wildlife use is diverse and common on rights-of-way where 2,4,5-T had been used (Asplundh Environmental Services, 1977).

Soil

The application of 2,4,5-T for vegetation control has a minimal effect on soil (Asplundh Environmental Services 1977). Because of rapid vegetation and the lack of site disturbance, there are minimal amounts of erosion and compaction. Because of the selective nature of 2,4,5-T to vegetation, and the lack of residual activity, large areas of exposed soil do not occur (Carvell and Johnston 1978). Erosion problems on such rights-of-way tend to occur only in situations where constant vehicular or pedestrian traffic and construction activities maintain exposed soil conditions (Asplundh Environmental Services 1977).

Aquatic Environment

The aquatic environment receives minimal impact from herbicide usage in rights-of-way situations. Rights-of-way generally occupy very small parts of watersheds for particular streams, and water exposure is generally limited to that short span where the water course crosses the right-of-way. The major influence of right-of-way management on streams would arise through the removal of protective stream bank vegetation on those limited sites. In this case there may be small increases in water temperature on warm summer days. However, these temperature increases are only on the order of 3°C which do not adversely affect fish (Carvell and Johnston 1978). Because of restrictions on the label regarding 2,4,5-T and its use around water, rights-of-way managers do not treat riparian vegetation. Research in forest applications where major portions of watersheds have been treated have indicated little occurrence of 2,4,5-T in downstream water (Norris 1967, Patric 1971). Since an even smaller portion of watersheds is treated in rights-of-way, it would appear that the occurrence of the herbicide in downstream water would be essentially zero. The removal of woody vegetation from streambanks can result in increased erosion since deep-rooted species are not present. Silting of the stream channel can be an undesirable consequence (Carvell and Johnston 1978).

CHEMICAL ALTERNATIVES

There is available to the right-of-way manager a variety of other herbicides for controlling vegetation. The nature of this list would depend on right-of-way objectives, particular situations and policies on the part of the industry, and characteristics related to each individual herbicide. Each herbicide has unique characteristics, causes different responses in individual species, and also has quite different ecologic impact on specific sites. While individual responses are important, the collective response of the species complex can be most important in assessing impacts and benefits of the use of any method.

One important criteria in the selection of any herbicide treatment is the degree of control of the many target species on any site or efficacy. Table 6 presents a relative comparison of the responses to 2,4,5-T with other established herbicides for hardwood and deciduous woody-plant species of particular importance in the Eastern Region and the Pacific Northwest. This information is compiled from Agricultural Handbook No. 493, Response of Selected Woody Plants in the United States to Herbicides (Bovey 1977).

Table 7 is a summary of the information in table 6 for deciduous woody species showing the relative responses to different herbicides applied as basal and foliar sprays. These numbers do not connotate satisfactory control, only the relative degree of response. It is readily apparent that 2,4,5-T is much more effective than 2,4-D, dichlorprop, or silvex when used at normal use rates. AMS is effective on more species than 2,4,5-T when applied as a ground foliar spray, but is also nonselective for grasses and other vegetation. Dicamba appears to be better than 2,4,5-T as a basal spray. Dicamba alone is less effective than 2,4,5-T (lb for lb) on oak, maple, sassafrass, locust, elm, gum, and sumac (Starke 1978). Dicamba activity is enhanced when used in combination with other herbicides. Picloram greatly exceeds the efficacy of 2,4,5-T either as a basal spray or foliar application, but may be more readily transported in runoff water and has some soil residual activity.

Table 6--Comparative responses to 2,4,5-T with other selected herbicides by hardwood and deciduous woody plant species and method of application[a/]

Species	2,4-D		AMS		Dicamba		Dichlorprop		Picloram		Silvex	
	BS	FS	BS	FS	BS	FS	BS	FS	BS	FS	BS	FS
Alder												
common	+	=	+	=	=	-	=	-	=	-	+	-
red	=	=	=	=	-	-	=	-	-	-	-	=
Ash												
green	+	+	-	-		+	+	+			+	+
white	+	+	-	-	-	-	+	+	-	-	+	+
Aspen, quaking	+	=	+	+	=	+	+	=	=	+		
Basswood	+	+	-	-		-		+		-		
Beech, American	=	+	=	-		-		=		-		
Birch	=	+	=	=		=		=		=		=
yellow	+	+	+	+		=		+		=		
Boxelder	=	=	-		=		=	+	=	=	=	
Buckeye	+	+	+	-		-	+	+				-
Catalpa	+	+	+	+		-		+		-		+
Cedar												
Eastern red	+	=	-	-	-	-	-	=	-	-		
Northern white	+	=	-	-		-	+	-		-		
Cherry	+	+	=	-	=	-	=	+	=	-		+
Chinkapin												
allegheny		+	+	+		=						
golden		=		+						=		
Coffeetree, Kentucky		+	+	-	-							
Cottonwood		+		=		+		+			+	=
plains	=	+		=		=	=	=		=		=
Dogwood	=	=	=	=		=				=		
Elm												
American	+	=	+	-	=	=	+	=	=	-	+	=
slippery red	+	=	+	=		=		-				=
winged	+	+	+	=	=	+	+	+	=	-	+	+

Continued.

Table 6--Comparative responses to 2,4,5-T with other selected herbicides by hardwood and deciduous woody plant species and method of application a/ (Continued)

Species	2,4-D		AMS		Dicamba		Dichlorprop		Picloram		Silvex	
	BS	FS	BS	FS	BS	FS	BS	FS	BS	FS	BS	FS
Fir, balsam	=	=	-	-						-		
Gum												
black	+	+	=	-	-	-	+	+	-	-	+	+
sweet	+		=	=		=	+	+	=	=	=	=
Hackberry	=	+	=	+		+	=	+		=	=	=
Hawthorn	=	-	=	-	=	=	-	=	-	-	=	=
Hemlock	-	=	-	-	-	-	-	-	-	-		=
Hickory	+	+	=	=	+	+	+	+	=	=	=	=
Honeylocust	+	+	+	+		+	+	+		=		+
Hophornbeam, Eastern	=	=	=	=		-		=		-		
Hornbeam, American	=	=	=	=						=		
Juniper	=	+	-	-	-	-	-	=	-	-	=	=
Larch	=	=	+	+								
Locust, black	=	=	+	+	-	-	+	=	-	-	=	=
Madrone, Pacific	=	=		+								
Magnolia												
cucumbertree	=	+	-	-								
sweetbay	=	+	+	=		+	-	+		-		+
Maple												
bigleaf		=									-	-
red	+	+	=	-	-	=	+	+	-	-		
silver	+	+	=	-						-		
sugar		+		-								
vine					+	+	+	+	=	-	=	+
Mulberry, red	+	+	=	+	-	-	+	+	-	-	-	-

Continued.

Table 6--Comparative responses to 2,4,5-T with other selected herbicides by hardwood and deciduous woody plant species and method of application a/ (Continued)

Species	2,4-D		AMS		Dicamba		Dichlorprop		Picloram		Silvex	
	BS	FS	BS	FS	BS	FS	BS	FS	BS	FS	BS	FS
Oak												
blackjack	+	+	=	-	=	+	+	+	=	+	=	=
black	+	+	=	=	=	=	+	+	=	=	=	=
blue	=	+	=			-	=	=	+		+	=
California black			+	+								=
chestnut	+	+	=	-	=	-	+	+	=	=		+
live	+	+	-	=	+	+		+		-		=
Northern red	+	=	=	-	=	-	+	=	=	-	+	-
pin	+	=	=	-		=	+	+	=	-	+	+
post	+	+	=	-	=	=	+	=	=	+	=	=
sand shinnery	+	+	+	+		+		+		=		-
scarlet	=	+	=	=	-	=	=	+	-	-	-	=
swamp	+	+	-	-								
white	+	+	=	-	=	+	+	+	=	=	+	+
Osage orange	+	+	+	+		+	+	+	+	+		=
Pecan	+	=	+	=				=				=
Persimmon	+	=	-	=	-	-	+	+	-	-	=	+
Pine	=	=	-	-	-	-	=	=	-	-	-	=
shortleaf		-								-		=
Plum, wild	+	-	=	=	=		+	=	=	-	=	=
Poison ivy	+	+	=	=		=		+		=		+
Poison oak	+	+	=	+			+			=		=
Pacific			+	+					=	-		-
Poplar, balsam	-	=	-	-					-	-		-
Prickly-ash	+	=	-	-		=		=		=		=
Red bud	+	+	+	-	-	-	+	+	-	-		=
Rose		+		+				+				+
Saltcedar	=	=	=		+	-	+	=	=		+	=
Sassasfras	=	=	=	=	-	+	+	+	-	-	-	+
Sourwood	+	+	+	+	=	+	+	+	=	-		+

Continued.

Table 6--Comparative responses to 2,4,5-T with other selected herbicides by hardwood and deciduous woody plant species and method of application a/ (Continued)

Species	2,4-D		AMS		Dicamba		Dichlorprop		Picloram		Silvex	
	BS	FS	BS	FS	BS	FS	BS	FS	BS	FS	BS	FS
Spruce	+	=	+	+		=		+		–		+
Sumac	+	=	+	+	=	=	–	=	=	=		=
Sycamore, American	+	+	+	=	=	–	=	+	=	–	=	=
Tree-of-Heaven	+	=	+	+	=	=	+	=	=	=		+
Walnut	=	=	=	=		=		=		=		=
Willow	=	–	=	=	=						=	=
black	=	=	=	=		+		=		=		=

a/ BS-basal spray; FS-foliar spray; "+" - 2,4,5-T more effective than that herbicide applied in this manner; "=" - 2,4,5-T as effective as that herbicide applied in this manner; "–" - 2,4,5-T less effective than that herbicide applied in this manner.

Table 7--*Comparative responses to 2,4,5-T with other herbicides on deciduous woody species*[a/]

2,4,5-T effect	Basal spray	Foliar spray
	(number of species)	(number of species)
> 2,4-D	42	41
= 2,4-D	21	24
< 2,4-D	1	3
> AMS	22	19
= AMS	32	25
< AMS	11	24
> dicamba	4	17
= dicamba	19	19
< dicamba	10	19
> dichlorprop	30	35
= dichlorprop	9	19
< dichlorprop	3	3
> picloram	2	4
= picloram	23	22
< picloram	12	31
> silvex	13	20
= silvex	14	35
< silvex	5	8

a/ Deciduous woody species summarized from table 6 (hardwood species not included).

When looking at spectrums of plant control, it should be recognized that there is a continuous gradation of species in plant communities. Furthermore, there exists a gradation of response of a given species within a specific treatment. All members of a given species may not be controlled by a given herbicide even though the species may be considered "susceptible" to that treatment.

Use of non-2,4,5-T herbicide alternatives will result in lesser degrees of control, as illustrated in table 7. Consequently, the treatment cycle will generally be reduced from a four year average to three years. The most reasonable alternative herbicides and rates of application are described in more detail in the discussion of the economic impact of 2,4,5-T cancellation. These choices are based on many collective years of field experience by Asplundh Tree Expert Company, Chemical Department personnel.

There are many reasons why 2,4,5-T holds such a dominant position over other alternative herbicides in right-of-way usage. These reasons generally involve economics, efficacy, selectivity, and use familiarity. Current use patterns have grown out of extensive experience over the last 30 years. Some of the alternative herbicides are used in combination with 2,4,5-T to capitalize on advantages of each herbicide. Dicamba and picloram are both more expensive than 2,4,5-T and are more persistent in the environment. Consequently, neither is important as a treatment application alone. Combining these herbicides with 2,4,5-T reduces total herbicide cost, enhances control of many species as well as increasing the spectrum of susceptible species (particularly coniferous species), and reduces environmental residues. Picloram and dicamba may pose more hazard to adjacent sites than 2,4,5-T since these water-soluble herbicides may be more likely to be carried in runoff water. Trees growing adjacent to the right-of-way can be readily killed by absorption of herbicide from the treated soil. 2,4,5-T does not pose this problem. Dicamba alone is less effective than 2,4,5-T on many important and widespread woody plants that are weeds on rights-of-way including hickory, vine maple, blackjack and white oak, and sassafras (table 6).

Selectivity is a very important concept in rights-of-way management programs. The ballast area of railroad rights-of-way is the only major area where total vegetation control is the management objective. Selectivity is important for reasons of aesthetics and soil stabilization. Consequently, AMS is not a desirable alternative since it is a nonselective herbicide. In addition, AMS is highly corrosive to equipment, and high rates (60 lb/100 gallons water per acre) are necessary for brush control. Herbicides such as bromacil, tebuthiuron, hexazinone and glyphosate are nonselective herbicides and are not considered as 2,4,5-T alternatives of major importance. In addition, bromacil, tebuthiuron, and hexazinone are soil sterilant in nature which further reduces their potential viability as 2,4,5-T alternatives.

Glyphosate is a relatively untried herbicide for woody plant control in eastern U.S. Although it is essentially nonselective in terms of plant response it does not have residual soil activity. Its cost, currently around $60 for a 4-pound gallon, suggests that future use would likely be in combination with other herbicides such as 2,4,5-T. Glyphosate is most effective when applied late in the growing season.

Fosamine ammonium is currently being used in some locales for woody plant control. However, it must be applied late in the growing season before leaf coloration. Consequently, its use is to extend the spraying season and will not serve as a replacement to 2,4,5-T. This also apparently applies to glyphosate. It would be physically impossible to treat all the necessary acres in such a short time period.

MECHANICAL AND HAND LABOR ALTERNATIVES

Mechanical methods such as mowing, shearing, and rolling choppers, are currently being used in rights-of-way management. In some places and some situations, mechanical methods can be less costly than chemical applications. It seems logical to assume that right-of-way managers are currently using these methods where most economical. The fact that 2,4,5-T is currently used at the level it is, demonstrates that mechanical methods have severe operational limitations on many rights-of-way situations. Conditions such as rocky terrain, erosive soils, steep slopes, and winter weather limit use of mechanical methods. Many acres currently being treated with 2,4,5-T are physically impossible to treat mechanically.

In November, 1973, the Construction and Maintenance Division, Office of Highway Operations, Federal Highway Administration, conducted a poll of division offices regarding use and costs of vegetation management programs (Tidd 1974). From the relatively few states reporting costs of mechanical methods, principally mowing, and manual, the average costs were $23/acre, and $294/acre were average hand labor costs. The average cost of 2,4,5-T treatment was $23/acre. The states also reported that 2,4,5-T was less disruptive to the right-of-way, reduced sprouting, less hazardous on steep terrain, and made it possible to control large brush which would be difficult to mow. Kudzu and poison ivy were especially highlighted as weeds whose control was not possible by mechanical and manual methods. The states indicated that problems with manual methods included high costs, resprouts more difficult to control, operator hazard, and greatly increased frequency of treatment, often annually.

A survey of all Rural Electric Cooperatives was conducted by the National Rural Electric Cooperative Association in September, 1977 regarding their vegetation-management programs for rights-of-way and sub-stations. Based on respondents reporting per acre costs for mechanical and manual methods, mechanical costs for these electric cooperatives averaged $183/acre and manual costs averaged $657/acre.

For both surveys, manual methods are several times more expensive per treatment. Manual treatments tend to be repeated on a one to two year cycle. The relative operator hazard of manual brush control compared with chemical treatments is dealt with in the accident section of Chapter 5. It is highly unlikely that the necessary work force could be obtained to treat the total acres currently treated with 2,4,5-T.

DO NOTHING

The "Do Nothing" concept has little role in rights-of-way maintenance. The nature of the land use demands that materials, goods, services, and people be able to move safely and reliably. Consequently, the integrity of the right-of-way system simply must be maintained and will be maintained at some cost. In this type of land usage the costs, including any increased costs necessitated by alternative treatment types, will be passed along to the consumer.

ECONOMIC EFFECTS OF THE LOSS OF 2,4,5-T FOR VEGETATIVE MANAGEMENT ON RIGHTS-OF-WAY

ASSUMPTIONS

Certain assumptions were necessary in order to derive costs of vegetation management with and without 2,4,5-T. These assumptions were based on information from the Asplundh Tree Expert Company, the largest custom applicator of rights-of-way.

1. All acres currently treated with 2,4,5-T (alone or in mixture) will be treated with an alternative herbicide for vegetation management.

2. Average per-acre costs of selective treatment (both foliar and basal) and of stump spray after cutting are the same for all types of rights-of-way using these methods.

3. Only selective herbicides would be chosen in an alternative vegetation-management program because of the need to leave some vegetation for erosion control on rights-of-way. Aesthetics and wildlife management are also factors that limit the use of nonselective herbicides.

4. The level of control using any alternative will need to be the same as what is achieved currently using 2,4,5-T in order to maintain the integrity of the system supported by the right-of-way.

5. Currently, acres treated with 2,4,5-T once every four years would need treatment every three years, on the average, with the alternative herbicides to maintain the right-of-way system.

6. Cost figures and estimates of alternative choices provided by Asplundh Tree Expert Company are typical for all right-of-way areas under vegetation management currently using 2,4,5-T.

Results

The herbicide material cost per acre for 2,4,5-T treatment varies by type of application and right-of-way (ROW) (table 8). Because equipment used for broadcast foliar ground applications differs by ROW user, costs for this application method are presented by ROW type. The material cost per acre for 2,4,5-T varies from a low of $6.33 for broadcast foliar ground application used on highway ROW (primarily for herbaceous weed control rather than brush control) to a high of about $90 per acre for selective basal treatments and aerial applications. Material costs for other methods of application range from $35 to $50 per acre.

The alternative herbicides expected to be used if 2,4,5-T is canceled include Tordon 101, Banvel 4WS + 2,4-D, Weedone 170 and Banvel 520 (table 9). Herbicide material costs for the alternatives range from $7.69 per acre for broadcast foliar ground applications for highway ROW to about $85 for selective basal treatments and aerial applications. In general, the per acre costs for 2,4,5-T and the alternatives do not differ substantially. However, the alternatives are believed to be less efficacious.

The application cost varies from $107 per acre for aerial application for all ROW types to a low of $25 per acre for broadcast ground applications by highway ROW users (table 10). The application cost per acre is influenced by the type of equipment used, volume of spray applied, and whether the application is broadcast or selective. The high

Table 8--Herbicide treatment cost per acre for 2,4,5-T and 2,4,5-T vegetation-management program mixtures by type of treatment and right-of-way

Type of treatment	Herbicide[a]	Rate per 100 gals. of spray	Herbicide cost: Per gal. of product	Herbicide cost: Per 100 gal. of spray	Estimated use pattern	Weighted average cost per 100 gals	Quantity of spray per acre	Weighted average cost per acre
		Gals.	------Dollars---------		Percent	Dols.	Gals.	Dols.
Ground								
Broadcast foliar:								
Highway	2,4,5-T	1.0	19.95	19.95	15			
	2,4,5-T+2,4-D	1.0	15.10	15.10	85	15.83	40[b]	6.3
Electric	2,4,5-T	1.0	19.95	19.95	30			
	2,4,5-T+2,4-D	1.0	15.10	15.10	40			
	2,4,5-T+Tordon 101	0.5+0.5	9.98+10.61	20.59	15			
	Banvel 710	1.0	18.20	18.20	15	17.84	300	53.52
Railroad	2,4,5-T	2.0[c]	19.95[c]	39.90	15			
	2,4,5-T+2,4-D	2.5[c]	15.10[c]	37.75	85	38.07[c]	25	
	2,4,5-T	1.0	19.95	19.95	15			
	2,4,5-T+2,4-D	1.0	15.10	15.10	85	15.83	300	41.84[d]
Selective:								
Foliar	2,4,5-T	1.0	19.95	19.95	30			
	2,4,5-T+2,4-D	1.0	15.10	15.10	40			
	2,4,5-T+Tordon 101	0.5+0.5	20.59	20.59	15			
	Banvel 710	1.0	18.20	18.20	15	17.84	200	35.68
Basal	2,4,5-T	3.5	19.95	69.83	20			
	Tordon 155	1.0	55.60	55.60	50			
	2,4,5-T+2,4-D	4.0	15.10	60.40	30	59.89	80	87.91[e]
Stump spray	2,4,5-T	3.5	19.95	69.83	20			
after	Tordon 155	1.0	55.60	55.60	50			
cutting	2,4,5-T+2,4-D	4.0	15.10	60.40	30	59.89	45	49.45[f]
Aerial								
Broadcast foliar:	2,4,5-T +	2.0+2.5[g]	92.95	92.95	70			
	Tordon 101	1.5+2.0[g]	72.36	72.36	30	86.77	[f]	86.77

continued

Table 8--Herbicide treatment cost per acre for 2,4,5-T and 2,4,5-T vegetation-management program mixtures by type of treatment and right-of-way (continued)

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a/ Assume 4 lb/gal ae for 2,4,5-T alone or 2 lb/gal ae each for 2,4-D and 2,4,5-T combinations.

b/ Rate for herbaceous weed control rather than brush control.

c/ Based on rate of product in 25 gallons of water.

d/ Assumes that 60 percent of the use will be at 25 gallons per acre.

e/ Includes cost of 80 gallons of oil at $.50 per gallon.

f/ Includes cost of 45 gallons of oil at $.50 per gallon.

g/ Based on a combination of the rate of herbicide in 25 gallons, of water, 25 gallons of spray per acre, and rate of herbicde in 15 gallons of water, 15 gallons of spray per acre.

SOURCE: David Fritsch, Chemical Department, Asplundh Tree Expert Company, Willow Grove, Pennsylvania. Telephone Conversations with Harvey A. Holt, December 12-13, 1978.

Table 9--Herbicide costs per acre for alternatives vegetation-management program, if 2,4,5-T becomes unavailable, by type of treatment and right-of-way

Type of treatment	Herbicide	Rate per 100 gals. of spray	Herbicide cost: Per gal. of product	Herbicide cost: Per 100 gal. of spray	Estimated use pattern	Weighted average cost per 100 gals	Quantity of spray per acre	Weighted average cost per acre
		Gals.	------Dollars------		Percent	Dols.	Gals.	Dols.
Ground								
Broadcast foliar:								
Highway	Tordon 101	1.0	21.22	21.22	70			
	Banvel 4WS+2,4-D	0.25+0.05	35.15+8.87	13.22	25			
	Weedone 170	1.5	14.25	21.38	5	19.23	40 a/	7.69
Electric	Tordon 101	1.0	21.22	21.22	80			
	Banvel 4WS+2,4-D	0.25+0.5	35.15+8.87	13.22	15			
	Weedone 170	1.5	14.25	21.38	5	20.03	300	60.09
Railroad	Tordon 101	3.0 b/	21.22	63.66	100	63.66 b/	25	
	Tordon 101	1.0	21.22	21.22	70			
	Banvel 4WS+2,4-D	0.25+0.5	35.15+8.87	13.22	25			
	Weedone 170	1.5	14.25	21.38	5	19.23	300	61.26 c/
Selective Foliar:	Tordon 101	1.0	21.22	21.22	80			
	Banvel 4WS+2,4-D	0.25+0.5	35.15+8.87	13.22	15			
	Weedone 170	1.5	14.25	21.38	5	20.03	200	40.06
Basal	Weedone 170	4.0	14.25	57.00	80			
	Banvel 520	3.0	17.85	53.55	20	56.31	80	85.05 d/
Stump spray	Weedone 170	4.0	14.25	57.00	80			
	Banvel 520	3.0	17.85	53.55	20	56.31	45	47.84 e/
Aerial	Tordon 101 +	2.5+	21.22	84.01				
	Weedone 2,4-DP	2.0	15.48		85			
	Tordon 101 +	2.5+	21.22					
	Banvel 4WS	1.0	35.15	88.20	15	85.27	f/	85.27

a/ Rate for herbaceous weed control rather than brush control.

b/ Based on rate of product in 25 gallons of water.

c/ Assumes that 60 percent of the use will be at 25 gallons per acre.

d/ Includes cost of 80 gallons of oil at $.50 per gallon.

e/ Includes cost of 45 gallons of oil at $.50 per gallon.

f/ Based on Tordon 101 + Weedone 2,4-DP used at 25 gallons of spray per acre and Tordon 101 + Banvel 4WS used at 15 gallons of spray per acre.

SOURCE: David Fritsch, Chemical Department, Asplundh Tree Expert Company, Willow Grove, Pennsylvania. Telephone Conversations with Harvey A. Holt, December 12-13, 1978.

Table 10--Average per acre costs of application for herbicide treatment by right-of-way type and method of application

Right of way	Method of application				
	Broadcast		Selective		Stump
	Air	Ground	Foliar	Basal	spray
	Dollars				
Highway	-	25	46	87	48
Electric	107	40	46	87	48
Railroad	107	20	-	87	48
Pipeline	107	-	46	-	-

SOURCE: David Fritsch, Chemical Department, Asplundh Tree Expert Company, Willow Grove, Pennsylvania. Telephone Conversations with Harvey A. Holt, December 12-13, 1978.

cost for aerial application is because helicopters are used rather than fixed-wing aircraft.

The annual treatment cost for the current 2,4,5-T vegetation-management program is estimated at $96.7 million for all rights-of-way (table 11). Electric utilities accounted for $78.4 million followed by railroads which accounted for $11.5 million. Selective basal treatments for all rights-of-way were estimated at $41.1 million followed by aerial treatments at $40.0 million. Annual treatment cost for the alternative vegetation-management program on the acres currently treated with 2,4,5-T is estimated at $97.9 million--$1.2 million more than the 2,4,5-T management program (table 12).

Because the alternative herbicides are believed to provide a shorter period of control than 2,4,5-T, ROW users are expected to use a 3-year treatment cycle rather than the current 4-year treatment cycle with 2,4,5-T. It is estimated that for all rights-of-way about 228,000 additional acres would need to be treated annually if 2,4,5-T use is canceled (table 13). Electric utilities would need to treat 155,000 additional acres followed by railroads at 42,000 additional acres.

The total annual treatment costs (material plus application) on the additional acres treated because of a shift from a 4-year to 3-year treatment cycle is estimated at $32.6 million for all rights-of-way with electric utilities bearing $25.9 million of the cost (table 14). Selective basal and aerial treatment costs on the additional acreage are estimated at about $13 million each.

If 2,4,5-T use on all rights-of-way is canceled, use of alternative herbicides is expected to increase annual vegetation-management costs by $33.9 million (table 15). Electric utilities would have increased management costs of $25.2 million followed by railroads at $6.3 million. Annual vegetation-management costs are estimated to increase about $1.0 million for highway and pipeline ROW. For all rights-of-way, vegetation-management costs with alternatives would increase by 35 percent over the

Table 11—Total treatment costs from 2,4,5-T vegetation-management programs by method of application and type of right-of-way

Type of right-of-way	Unit	Method of application: Broadcast: Air	Broadcast: Ground	Selective: Foliar	Selective: Basal	Stump Spray	Treated annually with 2,4,5-T
Highway							
Acres[a/]	No.	0	58,447	5,614	733	3,373	68,167
Cost per acre[b/]	Dol.	-	31	82	175	97	
Total cost	$1,000	-	1,812	460	128	327	2,727
Electric							
Acres[a/]	No.	159,479	43,927	21,151	234,254	6,528	465,339
Cost per acre[b/]	Dol.	194	94	82	175	97	
Total cost	$1,000	30,939	4,129	1,734	40,994	633	78,429
Railroad							
Acres[a/]	No.	27,836	99,996	0	43	0	127,425
Cost per acre[b/]	Dol.	194	62	-	175	-	
Total cost	$1,000	5,313	6,200	-	8	-	11,521
Pipeline							
Acres[a/]	No.	19,391	0	2,635	0	0	22,026
Cost per acre[b/]	Dol.	194	-	82	-	-	
Total cost	$1,000	3,762	-	216	-	-	3,978
Total cost all rights-of-way	$1,000	40,014	12,141	2,410	41,130	960	96,655

a/ Table 5.

b/ Herbicide material cost from table 8 and application cost from table 10.

Table 12--Total treatment cost for alternative vegetation-management program, if 2,4,5-T becomes unavailable, by method of application and type of right-of-way

Type of right-of-way	Unit	Method of application: Broadcast: Air	Method of application: Broadcast: Ground	Method of application: Selective: Foliar	Method of application: Selective: Basal	Method of application: Stump Spray	Treated annually with 2,4,5-T or alternative[c/]
Highway							
Acres[a/]	No.	0	58,447	5,614	733	3,373	68,167
Cost per acre[b/]	Dol.	-	33	86	172	96	
Total cost	$1,000	-	1,929	483	126	324	2,862
Electric							
Acres[a/]	No.	159,479	43,927	21,151	234,254	6,528	465,339
Cost per acre[b/]	Dol.	192	100	86	172	96	
Total cost	$1,000	30,620	4,393	1,819	40,292	627	77,751
Railroad							
Acres[a/]	No.	27,386	99,996	0	43	0	127,425
Cost per acre[b/]	Dol.	192	81	-	172	-	
Total cost	$1,000	5,258	8,100	-	7	-	13,365
Pipeline							
Acres[a/]	No.	19,391	0	2,635	0	0	22,026
Cost per acre[b/]	Dol.	192	-	86	-	-	
Total cost	$1,000	3,723	-	227	-	-	3,950
Total cost all rights-of-way	$1,000	39,601	14,422	2,529	40,425	951	97,928

a/ Table 5.

b/ Herbicide material cost from table 9 and application cost from table 10.

c/ Acres currently treated with 2,4,5-T will be treated with alternative program, if 2,4,5-T becomes unavailable.

Table 13--Comparison of acres treated annually--four-year cycle and three-year cycle

Row type	Total acres treated[a]	Acres treated annually Four-year cycle	Acres treated annually Three-year cycle[b]	Added acres to be treated annually[c]
Highway	272,668	68,167	90,889	22,722
Electric	1,861,356	465,339	620,452	155,113
Railroad	509,700	127,425	169,900	42,475
Pipeline	88,104	22,026	29,368	7,342
Total, all ROW	2,731,828	682,957	910,609	227,652

a/ Derived from number of acres reported treated annually (table 5), every four years (e.g., 68,167 x 4).

b/ Total acres treated divided by 3.

c/ Difference between acres treated annually in a four-year cycle and in a three-year cycle.

Table 14—Additional acres treated annually because of a shift from a 4-year to a 3-year treatment cycle and total treatment costs, by right-of-way application method and total

Type of right-of-way	Unit	Method of application					Added acres needing treatment annually
		Broadcast		Selective			
		Air	Ground	Foliar	Basal	Stump Spray	
Highways							
Acres	No.	0	19,482	1,872	244	1,124	22,722
Cost per acre	Dol.	-	33	86	172	96	
Total cost	$1,000	-	643	161	42	108	954
Electric							
Acres	No.	53,160	14,642	7,050	78,085	2,176	155,113
Cost per acre	Dol.	192	100	86	172	96	
Total cost	$1,000	10,207	1,464	606	13,431	209	25,917
Railroad							
Acres	No.	9,129	33,332	0	14	0	42,475
Cost per acre	Dol.	192	81	-	172	-	
Total cost	$1,000	1,753	2,700	-	2	-	4,455
Pipeline							
Acres	No.	6,464	0	878	0	0	7,342
Cost per acre	Dol.	194	-	86	-	-	
Total cost	$1,000	1,241	-	76	-	-	1,317
Total cost all rights-of-way	$1,000	13,201	4,807	843	13,475	317	32,643

a/ Table 13, distribution of acreage by method of application estimated by assessment team.

b/ Herbicide material cost from table 9 and application cost from table 10.

SOURCE: David Fritsch, Chemical Department, Asplundh Tree Expert Company, Willow Grove, Pennsylvania, Telephone conversations with Harvey A. Holt, December 12-13, 1978.

Table 15--Estimated increase in annual vegetation-management program costs on rights-of-way, if 2,4,5-T becomes unavailable

Type of right-of-way	2,4,5-T treatment costs[a/]	Alternative treatment costs: On acres currently treated with 2,4,5-T[b/]	Alternative treatment costs: On additional acres treated annually[c/]	Alternative treatment costs: Total	Increased cost of alternative treatment[d/]	Increase in treatment cost
	----------Thousands of Dollars----------					--Percent--
Highways	2,727	2,862	954	3,816	1,089	40
Electric	78,429	77,751	25,917	103,668	25,239	32
Railroad	11,521	13,365	4,455	17,820	6,299	55
Pipeline	3,978	3,950	1,317	5,267	1,289	32
Total	96,655	97,928	32,643	130,576	33,916	35

a/ From table 11.

b/ From table 12.

c/ From table 14.

d/ Total alternative treatment cost minus 2,4,5-T treatment cost.

current 2,4,5-T vegetation-management program, ranging from a high of 55 percent for railroads to a low of 32 percent for electric and pipeline ROW. [1/]

Limitations

Certain problem areas and limitations became evident during this analysis. Included are the following:

1. The lack of a historical data base on the use of 2,4,5-T and other herbicides on rights-of-way limited the comprehensiveness of this analysis and the estimation of the complete impact of using alternative herbicides. Without historical data much of the analysis is based on limited surveys and professional judgment.

2. Some species of woody plants are not controlled by an alternative herbicide (table 7) (Bovey 1977). Added use of manual methods may be necessary to maintain current level of control. Use of manual methods on certain woody species intensifies management problems because of sprouting which rapidly increases density of manually cut plants.

[1/] The rights-of-way survey by Asplundh Environmental Services discussed in a previous section also addressed the question of economic benefits of 2,4,5-T use and non-use. Rights-of-way managers, overall, estimated their cost increase to be 42 percent of current expenditures if 2,4,5-T were not available and all currently registered herbicides were available. Rights-of-way contractors, given the same conditions, estimated, on the average, that alternative methods would increase costs 46 percent over current expenditures (Asplundh Environmental Services, 1978). Similarly, Senechal and Besley (1975) reported that if 2,4,5-T were restricted for rights-of-way use, and all other phenoxy herbicides were available, costs would increase 42 percent the first year and 65 percent as the treatment cycle was shortened.

3. Length of time in a treatment cycle varies by geographic region. Currently, a 3-year cycle is needed in the Southeast and a 5-year cycle in the Northeast. Impacts in this analysis were derived using an average of four years for 2,4,5-T and an average of 3 years for the alternatives. Actual impacts in the Southeast may be higher per acre and those of the Northeast lower per acre than what was presented in this analysis.

4. Regional distribution of acres currently treated with 2,4,5-T could not be determined.

5. Prices for various herbicides included in the analysis imply specific quantity discounts to right-of-way owners. Individual rights-of-way owners, managers, and commercial applicators may pay more or less for their herbicides.

CHAPTER 4: THE BIOLOGIC AND ECONOMIC ASSESSMENT OF 2,4,5-T USE IN THE PRODUCTION OF RICE IN THE UNITED STATES

SUMMARY

Rice is grown on 2.5 million acres annually, located mainly in four southern states (Arkansas, Louisiana, Texas, and Mississippi) and California. Small acreages are also located in Missouri and several other southern states. Where rice is grown, the crop is intensively managed and contributes significantly to the rural economy.

The broadleaf-aquatic weed complex in rice in the lower Mississippi Valley is controlled by 2,4,5-T. The principal problem weeds that are effectively controlled by 2,4,5-T in the Arkansas, Mississippi, northern Louisiana, and Missouri rice-producing areas are hemp sesbania, northern jointvetch, morningglory, ducksalad, and redstem. Presently, 2,4,5-T is applied annually to 292,000 acres of rice by aircraft and to 8,000 acres of rice levees by ground sprayers--a total of 300,000 acres in the 4-state area; 28 percent of the 1,080,000 total acres in this 4-state 2,4,5-T use area is treated each year. Since the most common use rate is 1 lb/A acid equivalent, 300,000 pounds of 2,4,5-T are applied annually to rice in the U.S., all in the Mississippi Valley.

Although alternate herbicide treatments control the broadleaf-aquatic weed complex less effectively than 2,4,5-T, the first choice herbicide substitutes would be the combination use of (1) silvex, 2,4-D, and propanil, and (2) propanil and 2,4-D. Either of these combinations could be substituted for 2,4,5-T on all of the 300,000 acres presently treated with 2,4,5-T. The pattern of use for the first combination would be applications of silvex and 2,4-D where they could be applied safely from standpoints of rice and nontarget crops, such as cotton and soybeans; propanil would be used on the remainder of the 2,4,5-T treated acreage. The pattern of use for the second combination would be applications of 2,4-D where it could be used safely from standpoints of

rice and nontarget crops, mainly cotton; propanil would be employed on the balance of the 2,4,5-T treated acreage.

Silvex controls the broadleaf-aquatic weed complex almost as effectively as 2,4,5-T; acreage treated with this herbicide would not encounter losses from increased weed infestations. However, 2,4-D and propanil do not control the weed complex as effectively as 2,4,5-T. Rice receiving these treatments would encounter losses from increased weed competition. 2,4-D controls hemp sesbania and morningglory as well as 2,4,5-T, but it fails to control northern jointvetch, ducksalad, and redstem as effectively as 2,4,5-T. Rice receiving propanil treatments would experience losses because it does not control northern jointvetch, ducksalad, morningglory, or redstem as effectively as 2,4,5-T; however, it controls hemp sesbania as well as 2,4,5-T.

MCPA, molinate, bifenox, bentazon, and oxadiazon, which are other herbicides registered for use in rice, do not control weeds as effectively as 2,4,5-T. They are not effective substitutes for 2,4,5-T in weed-control programs for rice. Cultural weed-control practices, such as seedbed preparation, seeding method, water management, summer fallowing land, and crop rotations are relatively ineffective for control of the broadleaf-aquatic weed complex susceptible to 2,4,5-T.

The lack of an effective herbicide such as 2,4,5-T for control of the broadleaf-aquatic weed complex in rice would lower production returns to rice growers. Based on average yield and quality losses for the 1975-77 period, returns to rice growers would be reduced $4.2 million annually during the first 3-year cropping cycle if 2,4,5-T were not available and the best alternate herbicide treatments (silvex, 2,4-D and propanil) were substituted for 2,4,5-T. During the second 3-year cropping cycle, rice growers would encounter even greater losses because weed infestations would increase; losses each year would be $6.7 million if the best alternate herbicide treatments were substituted for 2,4,5-T. If the second-best alternate treatments (propanil and 2,4-D) were substituted for 2,4,5-T, rice farmers would encounter losses of

$5.4 and $8.9 million annually during the first and second 3-year cropping cycles, respectively.

Total losses during the 6-year period after 2,4,5-T became unavailable would be $25.2 million if the best alternate treatments (silvex, 2,4-D and propanil) were substituted for 2,4,5-T. If 2,4,5-T and silvex are not available for use in weed-control programs, rice farmers would substitute propanil and 2,4-D, the second-best herbicide treatments, for 2,4,5-T. With this program the producers' loss would be a total of $33 million during the 6-year period immediately following unavailability of 2,4,5-T and silvex.

INTRODUCTION

Rice is the only agricultural commodity for human consumption in the United States which may be directly sprayed with 2,4,5-T during its production. This chapter describes weed-management practices and the use of 2,4,5-T for weed control in rice, use of alternative weed-control practices, estimates of present and potential use of 2,4,5-T for weed management in rice, and the potential impact of canceling the registration of 2,4,5-T on rice productivity and production costs.

This chapter is organized into three major parts:

The weed problem and available methods of control -- Assesses the overall losses caused by weeds in the U.S., identifies the specific weeds that are troublesome in rice, and describes weed control systems that are used by rice farmers.

Potential solutions for the problem -- Identifies herbicides and weed-control practices that are essential to an effective weed management system, emphasizes the importance of an integrated approach to weed management, and discusses new experimental approaches to weed control in rice.

Rice production and weed control -- Rice production management goals are defined as related to biology and ecology of plant communities in rice fields, weed impact on commodity yield and quality, and weed management strategies. Methods for controlling the weed problem in rice are discussed in depth; these include chemical alternates such as 2,4,5-T, propanil, 2,4-D, silvex, other herbicides, and combination uses; cultural-mechanical-hand labor alternates such as summer-fallowing, seedbed preparation, crop rotations, seeding methods, water management, cultivation, and handweeding; and a do-nothing approach. Each method subdivision includes patterns of use, efficacy, potential levels of use, changes in production costs, effects on yield and quality of the commodity, availability, direct and indirect effects on the environment which include influences on man, animals, vegetation, aquatic life, soil, water, atmosphere, and other aspects.

METHODOLOGY AND ASSUMPTIONS

The analysis of the economic implications of the use of 2,4,5-T to control weeds in rice assumes the following.

1. The analysis compared the economic effect of two scenarios; i.e., (1) availability of 2,4,5-T for use on rice versus unavailability of 2,4,5-T; (2) availability of 2,4,5-T for use on rice versus unavailability of 2,4,5-T and silvex.

2. The analysis was limited to the rice-growing areas of Arkansas, Mississippi, Louisiana, and Missouri (fig. 1) that need 2,4,5-T for effective weed management, which accounts for 11 percent of the 1975-77 average U.S. rice production. Rice-growing areas in California were not included because 2,4,5-T is seldom used for weed control. This is because cotton is not intercropped with rice and other materials can be used.

Other materials also provide adequate weed control in Texas.

3. The 1975-77 average acres, production, and value of rice were assumed to be representative of acres, production, and value of rice that would occur in the 1978-83 analysis period, if 2,4,5-T were unavailable. The 1978-83 analysis period was selected so as to include two cycles of rice-soybean rotations (one year rice and two years soybeans). It was assumed that this period was adequate to demonstrate the short-term to mid-term effects of weeds in rice without 2,4,5-T.

4. Partial budgets, considering only materials and cultural practices that changed, were used to estimate cost differences of 2,4,5-T and alternative weed-control programs. The partial budgets were developed by research and Agricultural Extension Service personnel in the respective production areas.

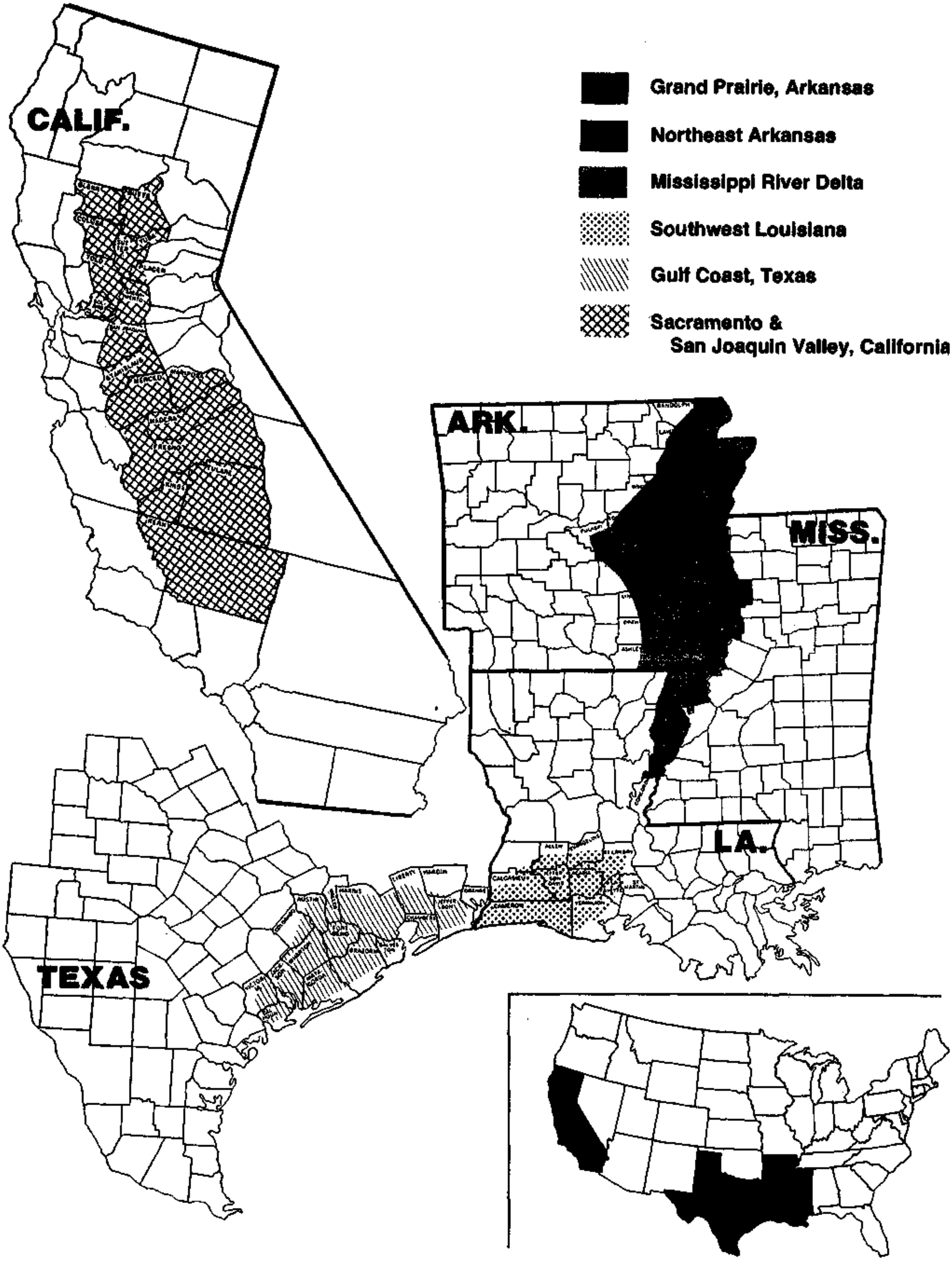

Figure 1. Major U.S. rice areas (Mullins et al. 1978).

5. Quality effects of weed-associated foreign matter and yield-reducing effects of weeds in rice were considered in estimating economic losses associated with the lack of 2,4,5-T.

6. The analysis assumes that no new herbicides that control the weed complex susceptible to 2,4,5-T, will be registered for use in controlling weeds in rice during the time period considered in the analysis.

7. State estimates indicate that 300,000 pounds are used annually (table 1). 2,4,5-T is applied at an average rate of 1 lb/A (active ingredient) one time per season (table 2). About 292,000 acres are treated aerially and about 8,000 acres of levees are treated by ground applicators for control of weeds (table 1). In the tables and discussions only the aerial applications are considered because (1) levee spraying is a new management practice, (2) other herbicide substitutes, such as propanil, silvex, 2,4-D, and MCPA control weeds ineffectively and probably would not be used by farmers to manage weeds on levees, (3) rice yields are naturally low on levees and weed infestations on these sites would have less impact on yield than in the flooded paddy, and (4) data are not available to assess the impact of weed infestations on levees. Therefore, we did not consider levee applications in the economic analysis.

In the 2,4,5-T use areas of Arkansas, Mississippi, northern Louisiana, and Missouri, about 1.1 million acres were grown in 1975-77 (table 3). This includes all of the harvested rice in Arkansas, Mississippi, and Missouri and 62,000 acres in northern Louisiana. 2,4,5-T is not used for weed control in rice in the southwest rice-growing area of Louisiana.

8. Silvex contains TCDD similiar to 2,4,5-T (Helling et al. 1973). It controls most of the weeds that infest rice as effectively as 2,4,5-T (table 4). Because it injures soybeans and cotton more than 2,4,5-T, it cannot be used as extensively as 2,4,5-T

Table 1--Estimated rice acreage and percentage treated with specific herbicides, major rice states, 1975-1977

State	Total rice Acreage[a]	Herbicide[b]: Propanil	Molinate	2,4,5-T[c]		2,4-D	MCPA	Silvex	Bifenox	Bentazon	Oxadiazon[d]
	1,000 acres	1,000 acres treated									
Arkansas	855	846	342	177	(172)	129	0	2	5	e/	0
Texas	519	509	311	0		26	52	0	100	e/	0
Louisiana	567	454	113	18	(17)	170	0	0	2	e/	0
Mississippi	142	140	71	101	(99)	7	0	0	2	0	0
Missouri	16	15	4	4	(d)	0	0	0	0	0	0
California	411	12	329	e/		e/	358	0	0	0	0
Total	2,510	1,976	1,170	300	(292)	332	410	2	109	e/	0
	Percent	Percent treated									
Arkansas	100	99	40	21		15	0	f/	f/	f/	0
Texas	100	98	60	0		5	10	0	19	f/	0
Louisiana	100	80	20	3		30	0	0	f/	f/	0
Mississippi	100	99	50	71		5	0	0	1	f/	0
Missouri	100	95	25	25		0	0	0	0	0	0
California	100	3	80	f/		f/	87	0	0	0	0
Total[g]	100	79	47	12		13	16	f/	4	f/	0

a/ Table 5.

b/ Data derived from official state records when available, from surveys, and from estimates made by

continued

Table 1--Estimated rice acreage and percentage treated with specific herbicides, major rice states, 1975-1977 (continued)

professional workers in given areas. Personal communications from John B. Baker, LSU, Baton Rouge, LA, June 23, 1978; Ted Miller and Don Bowman, MSU, Stoneville, MS, June 23, 1978; Harold Kerr and Joe Scott, Delta Center, U. Missouri, Portageville, MO, June 19, 1978; Ford Eastin, Texas A&M University, Beaumont, TX, June 21, 1978; Don Seaman, U of CA, Biggs, CA, June 20, 1978; Ford Baldwin, Cooperative Ext. Serv., Little Rock, AR, June 1978.

c/ Includes aerial and ground (levee spraying) applications -- 292,000 and 8,000 acres, respectively, for aerial and ground (levee) applications, this would be the levees on 50,000 acres of rice. Values in parenthesis are acres treated aerially. Spraying of 2,4,5-T on levees will not be considered in further discussions. In Louisiana, 2,4,5-T is used is the northern Mississippi River Delta rice-growing area (62,000 acres), but not in the southwestern rice-producing area. The U.S. Department of Agriculture estimates that 400,000-600,000 lbs of 2,4,5-T are used on rice each year; these estimates are probably high (U.S. Dept. of Agri. 1978).

d/ This herbicide was not registered in 1977, but was in 1978.

e/ Less than 1,000 acres treated.

f/ Less than 1%.

g/ Percentages calculated from acreage treated with each herbicide.

SOURCE: USDA-SEA-AR, Stuttgart, AR.

Table 2--Estimated cost of using 2,4,5-T by aerial application in rice areas, 1975-1977[a]

		2,4,5-T				2,4,5-T + 2,4-D	
Item	Unit	Arkansas	Mississippi	Louisiana	Missouri	Arkansas	Total
Herbicide quantity per acre[b]	lb	1.0	1.0	1.0	1.0	1.5[c]	
Cost per pound[d]	dol	5.50	5.50	5.50	5.50	4.45[e]	
Herbicide cost per acre	dol	5.50	5.50	5.50	5.50	6.70	
Application cost per acre[f]	dol	4.00	5.00	5.00	5.00	4.00	
Total herbicide cost/acre	dol	9.50	10.50	10.50	10.50	10.70	
Treated[g]	acres	112,000	99,000	17,000	4,000	60,000	292,000
Total area cost	dol	1,064,000	1,040,000	178,000	42,000	642,000	2,966,000

a/ 292,000 acres applied aerially (table 1).

b/ Herbicide rate based on active ingredients.

c/ 0.75 lb/A of each herbicide used.

d/ Arkansas Cooperative Extension Service (1978e)

e/ Composite cost of 2,4,5-T and 2,4-D when estimated prices were $5.50 and $3.40 per pound.

f/ Arkansas Cooperative Extension Service (1978e) and Mullins et al. 1978.

g/ Acreage (8,000 acres) treated by ground applicators (levees) ommitted.

SOURCE: USDA-SEA-AR, Stuttgart, AR.

Table 3--Rice acreage, per acre yield, production, and value in 2,4,5-T use area, 1975-1977

State	Acres harvested[a/]	Production[a/,b/]	Value of production[a/,c/]
	1,000 acres	1,000 cwt	1,000 dollars
Arkansas	855	38,604	323,000
Mississippi	142	5,718	46,000
Louisiana	62	2,358	18,000
Missouri	16	658	6,000
Total	1,075	47,338	393,000

a/ Data from table 5 and from the Rice Journal, 1978 for Louisiana.

b/ Average yield per acre = 44 cwt (47,338,000 ÷ 1,075,000).

c/ Average value per acre = $366 (393,000,000 ÷ 1,075,000).

SOURCE: USDA-SEA-AR, Stuttgart, AR.

Table 4--Control of common rice field weeds by selected herbicides[a/]

Weed	Herbicide								
	Propanil	Molinate	2,4,5-T	2,4-D	MCPA	Silvex	Bifenox	Bentazon	Oxadiazon
Alligatorweed (*Alternanthera philoxeroides*)	2	2	5	6	5	5	4	2	2
Arrowhead (*Sagittaria* spp.)	2	2	6	6	6	6	2	2	2
Barnyardgrass (*Echinochloa* spp.)	9	9	0	0	0	0	6	0	8
Beakrush (*Rhynchospora corniculata*)	6	3	8	8	8	8	5	6	5
Broadleaf signalgrass (*Brachiaria platyphylla*)	8	6	0	0	0	0	8	0	8
Bulrush, roughseed (*S. mucronatus* L.)	6	9	8	9	9	8	3	8	2
Bulrush, river (*S. fluviatilis* (Torr.))	2	0	2	2	2	7	3	8	2
Burhead (*Echinodorus cordifolius*)	2	0	8	9	9	8	3	6	3
Cattail (*Typha* spp.)	2	2	6	6	6	6	2	6	2
Cocklebur (*Xanthium* spp.)	4	2	9	9	9	9	5	9	5
Dayflower[a/] (*Commelina diffusa*)	5	5	9	9	9	9	8	9	8
Ducksalad (*Heteranthera* spp.)	5	0	6	9	6	6	8	5	8
Eclipta (*Eclipta alba*)	8	8	9	9	9	9	8	6	8
False pimpernel (*Lindernia* spp.)	7	0	9	9	9	9	8	7	8
Fimbristylis (*Fimbristylis* spp.)	8	4	8	8	8	8	8	7	8
Gooseweed (*Sphenoclea zeylanica*)	5	2	8	6	6	7	8	7	8

continued

Table 4--Control of common rice field weeds by selected herbicides[a] (continued)

Weed	Herbicide								
	Propanil	Molinate	2,4,5-T	2,4-D	MCPA	Silvex	Bifenox	Bentazon	Oxadiazon
Hemp sesbania (*Sesbania exaltata*)	9	2	9	9	6	9	6	4	6
Horned pondweed (*Zannichellia palustris*)	3	0	6	8	8	6	8	5	8
Jointvetch, northern (*A. virginica*)	6	2	9	5	4	8	5	4	5
Jointvetch, Indian (*A. indica*)	6	2	9	5	4	8	5	4	5
Knotgrass (*Paspalum* spp.)	4	2	0	0	0	0	4	0	4
Mexicanweed (*Caperonia castaneaefolia*)	3	3	8	6	6	7	8	5	8
Morningglory (*Ipomoea* spp.)	2	0	9	9	9	9	5	3	6
Naiad (*Najas* spp.)	0	0	0	0	0	0	6	2	6
Panicum grass (annuals) (*Panicum* spp.)	8	8	0	0	0	0	8	0	8
Pondweed (*Potamogeton* spp.)	2	2	6	6	6	6	4	2	4
Red rice (*Oryza sativa* L.)	0	7	0	0	0	0	0	0	0
Redstem (*Ammannia* spp.)	5	2	9	9	9	8	8	8	9
Smartweed (*Polygonum* spp.)	5	4	7	6	6	6	6	8	6
Spikerush (annuals) (*Eleocharis* spp.)	8	7	8	8	7	6	6	8	8
Sprangletop[b] (*Leptochloa* spp.)	5	0	0	0	0	0	8	0	7
Umbrellaplant (annuals) (*Cyperus* spp.)	7	6	7	7	7	7	8	8	8

continued

Table 4--Control of common rice field weeds by selected herbicides[a/] (continued)

Weed	Herbicide								
	Propanil	Molinate	2,4,5-T	2,4-D	MCPA	Silvex	Bifenox	Bentazon	Oxadiazon
Umbrellaplant (perennials) (*Cyperus* spp.)	6	5	6	6	6	6	6	8	6
Waterhyssop (*Bacopa rotundifolia*)	8	2	9	9	9	9	8	8	8
Waterprimrose (*Jussiaea* spp.)	2	2	7	6	5	6	7	6	7

a/ Data adapted from Smith et al 1977; Arkansas Agriculture Extension Service (1978a,b, and f). Susceptibility of weeds based on data taken from greenhouse and field experiments and from observations made in ricefields from general applications. Scale: 0 = no control; 10 = 100% control. Reviewed by John B. Baker, LSU, Baton Rouge, LA, June 23, 1978; Ted Miller and Don Bowman, MSU, Stoneville, MS, June 23, 1978; Harold Kerr and Joe Scott, Delta Center, U of Missouri, Portageville, MO, June 19, 1978; Ford Eastin, Texas A&M University, Beaumont, TX, June 21, 1978; Don Seaman, U of California, Biggs, CA, June 20, 1978; Ford Baldwin, Cooperative Ext. Serv., Little Rock, AR, June 1978.

b/ Tank mixture of propanil + molinate gives a control rating of 8.

SOURCE: USDA-SEA-AR, Stuttgart, AR.

in the rice areas of the Mississippi River Valley where sprays from target ricefields may drift and damage nearby soybeans and cotton. MCPA is considered not to be a substitute for 2,4,5-T because it fails to control common leguminous weeds such as hemp sesbania and northern jointvetch (table 4). Recently registered herbicides such as bifenox, bentazon, and oxadiazon cannot substitute for 2,4,5-T because they fail to control many of the weeds controlled by 2,4,5-T (table 4). Bifenox is registered under a Section 24C label in Arkansas, Louisiana, Mississippi, and Texas. Bentazon is registered under a Section 24C label in Arkansas, Mississippi, and Texas. Oxadiazon is registered under a Section 24C label in Arkansas, Louisiana, and Texas (Arkansas Cooperative Extension Service, 1978e).

9. Although ground applicators could be used for general or entire-field applications of phenoxy herbicides such as 2,4-D, use of such equipment will damage rice growth and rice levees, which makes required water management practices very difficult (Gerlow 1973). Also, ricefields would have to be drained to make ground applications; this would disrupt optimum production inputs. In addition 2,4-D damages rice if not applied at precise stages of rice growth. Therefore, use of ground spray equipment at this time is highly questionable and is not considered a viable alternate to 2,4,5-T.

RICE PRODUCTION IN THE UNITED STATES

MAJOR RICE-PRODUCING AREAS OF THE U.S.

The major rice-producing areas of the United States are located in four southern states (Arkansas, Louisiana, Texas, and Mississippi) and California; a small acreage is grown in southern Missouri (fig. 1 and tables 5 and 6). Arkansas, Louisiana, Texas, Mississippi, and Missouri produced about 84 percent and California about 15 percent of the 1975-77 production. About 1 percent of the rice is produced in other states.

Table 5--Acres, production, and value of rice, United States, Arkansas, Louisiana, Texas, California, Mississippi, and Missouri, 1975-1977 a/

Area and year	Acres Planted	Acres Harvested	Yield per acre	Production	Value per CWT b/	Value per acre	Value of production
	1,000 acres	1,000 acres	Pounds	1,000 CWT	Dollars	Dollars	1,000 Dollars
United States:							
1975	2,818	2,802	4,567	127,972	8.35	381	1,068,566
1976	2,489	2,480	4,663	115,648	7.02	327	811,849
1977	2,261	2,249	4,412	99,223	9.43 b/	416	935,673
1975-77 Avg. -	2,523	2,510	4,547	114,281	8.21	373	938,696
Arkansas:							
1975	885	882	4,540	40,053	8.54	388	352,053
1976	850	847	4,770	40,362	7.25	346	292,624
1977	840	837	4,230	35,396	9.43	399	333,784
1975-77 Avg. -	858	855	4,515	38,604	8.36	377	322,820
Louisiana:							
1975	660	658	3,810	25,064	8.38	319	210,036
1976	570	568	3,910	22,203	6.53	255	144,985
1977	480	475	3,670	17,445	9.43	346	164,506
1975-77 Avg. -	570	567	3,804	21,571	8.03	305	173,176

continued

Table 5--Acres, production, and value of rice, United States, Arkansas, Louisiana, Texas, California, Mississippi, and Missouri, 1975-1977 a/ (continued)

Area and year	Acres: Planted	Acres: Harvested	Yield per acre	Production	Value per CWT b/	Value per acre	Value of production
	------1,000 acres---		Pounds	1,000 CWT	-------Dollars--------		1,000 Dollars
Texas:							
1975	550	548	4,560	24,996	8.81	402	220,215
1976	510	508	4,810	24,430	7.21	347	176,140
1977	502	501	4,670	23,400	9.43	440	220,662
1975-77 Avg. -	521	519	4,677	24,275	8.47	396	205,672
California:							
1975	530	525	5,800	30,436	7.50	435	228,270
1976	400	399	5,520	22,017	6.50	359	143,111
1977	310	308	5,810	17,913	9.43	548	168,920
1975-77 Avg. -	413	411	5,710	23,455	7.68	438	180,100
Mississippi:							
1975	175	171	3,900	6,665	8.42	328	56,119
1976	145	144	4,200	6,048	6.79	285	41,066
1977	112	111	4,000	4,440	9.43	377	41,869
1975-77 Avg. -	144	142	4,027	5,718	8.11	327	46,351

continued

Table 5—Acres, production, and value of rice, United States, Arkansas, Louisiana, Texas, California, Mississippi, and Missouri, 1975-1977 a/ (continued)

Area and year	Acres: Planted	Acres: Harvested	Yield per acre	Production	Value per CWT b/	Value per acre	Value of production
	------1,000 acres---		Pounds	1,000 CWT	-------Dollars---------		1,000 Dollars
Missouri:							
1975	18	18	4,210	758	8.54	360	6,473
1976	14	14	4,200	588	7.25	304	4,263
1977	17	17	3,700	629	9.43	349	5,931
1975-77 Avg. -	16	16	4,113	658	8.44	347	5,556

a/ Preliminary data in many cases for 1977. Data from USDA-ESCS 1977 and 1978, Mullins et al. 1978.

b/ Season average price for U.S. and States for 1975 and 1976. Preliminary season average price for U.S. for 1977. Season average price for States for 1977 not available until approximately January, 1979.

SOURCE: USDA-SEA-AR Stuttgart, AR and Natural Resource Economics Division, USDA-ESCS, Corvallis, OR.

Table 6--Rice harvested, yield per acre, production, and value, selected states, 1975-77 a/ (Summary of table 5).

State	Acres harvested	Yield per acre	Production	Value
	1,000 acres	Pounds	1,000 cwt	1,000 dollars
Arkansas	855	4,515	38,604	323,000
Louisiana	567	3,804	21,571	173,000
Texas	519	4,677	24,275	206,000
Mississippi	142	4,027	5,718	46,000
Missouri	16	4,113	658	6,000
California	411	5,710	23,455	180,000
U.S. Total b/	2,510	26,846	114,281	934,000

a/ Average for 1975-77. See table 5 for detailed data.

b/ Totals may not sum or average because of rounding numbers.

In Arkansas, the rice areas are located in three separate geographical regions (Gerlow 1973). The Grand Prairie area is in the east-central part, including most of Arkansas, Lonoke, and Prairie Counties and a small part of Monroe County. The northeastern area bounded by Crowley's Ridge and the White, Black, and Mississippi Rivers, and includes parts of 15 counties. The southeastern area is composed primarily of five counties located in the Arkansas-Mississippi River Delta.

In Louisiana, the rice area lies in two separate regions. The older and larger southwestern area is located in nine parishes. The northern area is primarily in the Mississippi River Delta in 10 northeastern parishes. The Mississippi rice area is located in 15 west-central Mississippi River Delta counties. The Missouri rice area is located in the south-central boot heel area where two counties produce 90 percent of the rice. The Texas rice area lies primarily along the Gulf Coast in 20 southeastern counties.

The major rice-growing area in California is found in eight counties in the northern part of the Sacramento Valley. A small acreage of rice is also grown in eight counties in the San Joaquin Valley.

CONSUMPTION AND MARKETING OF RICE IN THE U.S.

The average value of the 1975-77 rice crop was approximately $934 million annually (table 5). In most states where rice is produced, the crop represents a major source of agricultural income and is highly important to large sectors of the rural economy.

Annual per capita consumption of rice averages about 10 pounds in the U.S. (USDA-ESCS 1978). Although the amount consumed continues to increase, production has always exceeded domestic consumption and large quantities are exported. During the 1975-77 period, approximately 60 percent of total U.S. rice production was exported (USDA-ESCS 1978). About 64 percent of this quantity was for dollar sales and the remainder was exported under various Government programs--mainly P.L. 480 (USDA-ESCS 1978).

The quantity of rice which moves within domestic channels including Puerto Rico, is exported for dollars or under P.L. 480 varies among states (table 7). About 48 percent of Arkansas and Mississippi rice is marketed domestically, about 43 percent goes for dollar exports, and 9 percent is exported under P.L. 480. For Louisiana, 44 percent of the rice is marketed through domestic channels, 23 percent through dollar exports, and 33 percent through exports under P.L. 480. In Texas, the figures are 33 percent, 62 percent, and 5 percent, respectively.

These marketing patterns indicate that Arkansas and Mississippi (high 2,4,5-T use areas) (table 1) are selling about 91 percent of their rice in domestic and dollar export markets which demand high quality rice. Therefore, production changes, such as elimination of 2,4,5-T, which affect the quality of rice produced in these states can adversely affect their markets and prices.

RICE PRODUCTION AND WEED MANAGEMENT GOALS

The goal of the U.S. rice industry is to produce adequate supplies of grain for domestic and foreign markets (Gerlow 1973). In addition, marketing and distribution systems that presently exist are maintained by adequate supplies of high-quality rice grain. Arkansas, Mississippi, northern Louisiana, and Missouri produce much of the high-quality long grain rice consumed domestically (table 7). The high-quality rice produced in these areas is also exported to foreign countries for dollar sales and its value contributes to the foreign exchange of the U.S. If this area is unable to meet domestic demand for high-quality rice, other rice-producing states would shift some of their high-quality export rice into these markets. Such shifts would alter existing marketing channels and seriously deter marketing agencies now active in Arkansas, Mississippi, northern Louisiana, and Missouri. Exports of inferior-quality rice could mean losses in dollar sales. Furthermore,

Table 7--Shipments of milled rice, marketing years 1975-1976[a/]

Location and source	Aug. 1975-July 1976	Aug. 1976-July 1977	Average 1975-1976	Percent
	1,000 cwt			
Arkansas & Mississippi				
Marketed domestically	10,890	12,360	11,620	48
Dollar exports	8,950	11,740	10,340	43
PL-480 exports	2,800	1,610	2,200	9
Total	22,640	25,710	24,160	
Louisiana				
Marketed domestically	5,220	4,510	4,860	44
Dollar exports	1,540	3,680	2,610	23
PL-480 exports	2,550	4,790	3,670	33
Total	9,310	12,980	11,140	
Texas				
Marketed domestically	6,820	8,000	7,410	33
Dollar exports	11,660	15,810	13,740	62
PL-480 exports	730	1,360	1,040	5
Total	19,210	25,170	22,190	

a/ Data from The Rice Millers' Association, 1978b. No data from California available.

the rice carryover could increase and the U.S. industry would have more rice to move through Federal programs that use rice with lower quality. If 2,4,5-T were unavailable and propanil or 2,4-D were substituted, low-quality rice would be produced because grain would be contaminated with weed seed.

The objectives of weed management in a rice-production system are: (1) to prevent or minimize losses in yield due to weed competition; (2) to prevent or minimize quality losses and subsequent lower value of rough and milled rice; and (3) to permit highly efficient use of costly production inputs e.g. high-yielding varieties, fertilizers, insect and disease control, and irrigation water (Smith et al. 1977).

To implement an effective weed-management program in rice, the interdependence of cultural-mechanical-crop management practices and herbicides must be recognized (Smith et al. 1977). When either is used alone, effective weed control is often not obtained. When cultural-mechanical systems fail to control weeds in rice (and they are usually inadequate), herbicides are necessary to reduce losses from weeds.

When weed grasses develop in ricefields because of improperly managed or ineffective cultural-mechanical systems, timely applications of effective rates of propanil or molinate reduce losses from grass weeds (Smith et al. 1977). Likewise, when aquatic, broadleaf, and sedge weeds infest ricefields, timely treatments with phenoxy herbicides can reduce yield and quality losses to these weeds. Usually cultural-mechanical systems fail to give effective weed control in most ricefield environments.

By combining control methods into effective systems, most weeds in rice can be controlled (Smith et al. 1977). Consequently, high yields of good-quality rice can be produced with a minimum of labor and machinery. Effective weed control also permits the rice farmer to select seeding methods, varieties, irrigation, and fertilizer practices, insect and disease-control programs that favor rice growth and production.

Rice farmers are presently using 2,4,5-T on about 300,000 acres of rice in Arkansas, Mississippi, northern Louisiana, and Missouri (table 1). 2,4,5-T is a basic weed control input into an integrated weed-management program for rice in the 2,4,5-T use area (Smith et al. 1977). Although other herbicides are used in weed-control programs for rice, they are not as effective on as broad a spectrum of broadleaf weeds as 2,4,5-T (table 4). Propanil and 2,4-D control many of the same broadleaf, aquatic, and sedge weeds as 2,4,5-T, but they fail on other species (table 4). Therefore, no combination of use patterns for propanil and 2,4-D will match 2,4,5-T for efficacy.

Cotton is frequently grown nearby ricefields in the 2,4,5-T use area (Baldwin 1978). Because this crop is very susceptible to 2,4-D damage from spray drift (Smith et al. 1977), this herbicide cannot be used in much of the 2,4,5-T use area. When 2,4-D damages cotton, yields and quality are reduced with subsequent income loss to the farmer. Also, judicial, social, and political problems may develop as a result of the damaged cotton. Therefore, 2,4,5-T is needed to control weeds in rice and to prevent the necessity of using herbicides more toxic to nontarget crops than 2,4,5-T. This herbicide injures cotton less than 2,4-D (Smith et al. 1977).

Soybeans, which are rotated with rice in the 2,4,5-T use area, are highly susceptible to silvex (Smith et al. 1977). Thus, this herbicide cannot be used on a significant portion of the rice presently treated with 2,4,5-T because spray drift could injure the crop and reduce yields.

Although cultural-mechanical-crop management practices help reduce weed problems in rice, they give best control when integrated with herbicide treatments (Smith et al. 1977). Phenoxy herbicides such as 2,4,5-T are essential in an integrated weed-management program for rice. They control the broadleaf, aquatic, sedge weed complex that develops in ricefields treated with any combination of cultural-mechanical-crop management practices.

Weeds reduce the yield and quality of rice in the U.S. by an estimated 15 percent each year on approximately 2.5 million acres; the loss was valued at about $165 million annually in 1975-77 (Smith et al. 1977). The cost of using herbicides to prevent greater losses was about $60 million each year during the same period (table 8). Also, the cost of cultural practices (including rotations, land preparation, irrigation, and fertilization), prorated to control weeds was estimated at $70 million (Smith et al. 1977). Thus, the total estimated direct losses from weeds and expenditures for their control were $295 million annually for the 1975-77 period.

Losses would exceed 50 percent in many ricefields that are heavily infested with weeds if herbicides were not applied to control the weed complex (Smith et al. 1977).

Herbicide usage in rice has steadily increased as effective herbicides have been developed. About 81 percent of the commercial rice in the U.S. was treated with one or more herbicides in 1968, up from 78 percent in 1965 and 53 percent in 1962 (Smith et al. 1977). Since 1968, herbicide usage in rice has continued to increase to where an estimated 98 percent of the acreage is now treated each year with at least one application. Frequently, ricefields are treated two or three times each year with various herbicides. Custom aerial applicators apply herbicides to 87 percent or more of the rice acreage while farmers apply the remainder (Smith et al. 1977).

Effective weed-control systems combine preventive, cultural, mechanical, chemical, and biological methods (Smith et al. 1977). Nonchemical methods may include some or all of the following practices: planting weed-free seed, crop rotation, levelling land, seedbed preparation, selecting the proper seeding method, and managing water and fertilizers properly. Chemical methods involve the use of herbicide treatments that selectively control weeds in rice when applied correctly. The weed

Table 8--Expenditures per acre for herbicides and their application for weed control in rice, 1975-1977

State	Acres harvested[a/]	Cost/Acre[b/]	Total expenditures
	1,000 Acres	Dollars	1,000 Dollars
Arkansas	855	31	26,505
Louisiana	567	16	9,072
Texas	519	26	13,494
California	411	16	6,576
Mississippi	142	33	4,686
Missouri	16	33	528
Total			60,861

a/ Data from Table 5.

b/ Average 1975-1977. Herbicide costs extrapolated from estimated costs and returns per acre of rice in major producing areas, 1975 season, Texas Agr. Exp. Sta. Dep. of Economics 1975, Mullins et al. 1978.

SOURCE: USDA-SEA-AR, Stuttgart, AR.

management system that omits any one of those components is often inadequate. Therefore, combination treatments of several cultural and herbicide practices are essential to control weeds effectively in rice production. Several herbicide treatments applied in mixtures or in sequence may be required for effective weed control. 2,4,5-T is an important component of an effective weed-control program for rice (Arkansas Cooperative Extension Service 1978f; Smith et al. 1977). This herbicide controls broadleaf, aquatic, and sedge weeds that infest ricefields better than other herbicides (table 4) and it is less injurious to nontarget crops than other phenoxy herbicides (Smith et al. 1977).

Conditions favorable for growing rice are also favorable for the growth and reproduction of many terrestrial, aquatic, and semiaquatic weeds (Smith et al. 1977). Table 4 lists the principal grass, broadleaf, aquatic, and sedge species that cause major losses in U.S. rice production. Weeds in rice produce an abundance of viable seed and other propagules, and once these infest the land, they are difficult to remove and may remain viable in the soil for many years. The broadcast and drill seeding of rice reduce the opportunity for cultivation after emergence to remove weeds. Thus, the use of herbicides for controlling weeds is of prime importance in a weed-management program for rice.

Herbicides registered for use in rice and their activity on important weeds are presented in table 4. Generally, herbicides registered for use in rice may be classed into three groups: (1) those that control grass weeds, which are propanil and molinate; (2) those that control broadleaf and aquatics weeds, which include the phenoxy herbicides (2,4,5-T, 2,4-D, MCPA, and silvex) and bentazon; and (3) those that control grass, broadleaf, aquatic, and sedge weeds which are bifenox and oxadiazon. These latter two herbicides were registered for use in rice only recently, and their use in rice is still small (table 1); also, they must usually be combined with propanil to satisfactorily control an adequate spectrum of weeds (Arkansas Cooperative Extension Service 1978f). Copper compounds (copper sulfate and copper complexes) are used for control of green and blue-green filamentous algae in rice, but their efficacy is erratic (Smith et al. 1977). Endothall is used in California (State 24 C label) for control of submerged aquatic weeds in rice (Seaman 1978), but it is not effective on the emersed aquatic weed complex of rice in the southern rice-producing area (USDA-SEA-AR 1978).

Frequently, herbicides registered for use in rice are tank mixed to increase the number of weed species controlled and to combine the attributes of each. Examples are: (1) a mixture of a postemergence herbicide with a preemergence one; or (2) a mixture of a herbicide active on grass weeds and one active on broadleaf weeds. Commonly used mixtures include propanil + molinate, propanil + 2,4,5-T, propanil + silvex, propanil + bentazon, and propanil + oxadiazon (Arkansas Cooperative Extension Service 1978f, USDA-SEA-AR 1978).

POTENTIAL SOLUTIONS FOR THE PROBLEM

Effective weed-management systems for rice require the integrated use of cultural-mechanical-crop management practices and herbicides (Smith et al. 1977). Cultural-mechanical-crop management practices help reduce weed problems, but they alone are inadequate in controlling weeds and preventing losses in yield and quality. The wise use of crop rotation systems helps reduce problems with many weeds; e.g. red rice, perennial grasses, broadleaf, and aquatic weeds, and annual broadleaf and aquatic weeds that are susceptible to 2,4,5-T. Preplant land preparation, special seeding practices, and water management also help reduce weeds that are susceptible to 2,4,5-T. However, many weeds that develop after seeding the rice crop are controlled only by the use of 2,4,5-T and other herbicides. Weed control is a continuing operation. Failure to keep weeds continuously under control will lead to a buildup of weed populations that affect rice and crops rotated with rice. Thus, a well-developed and integrated control program cannot be turned on and off without serious consequences.

Several herbicides are registered for use in rice. They are propanil, molinate, 2,4,5-T, 2,4-D, MCPA, silvex, bifenox, bentazon, and oxadiazon (tables 1 and 4). Propanil and molinate are the most widely used herbicides; they are principally active for control of grass weeds. However, propanil controls certain broadleaf and aquatic weeds that are susceptible to 2,4,5-T (table 4). The phenoxy herbicides--2,4,5-T, 2,4-D, MCPA, and silvex--control many broadleaf, aquatic, and sedge weeds that infest rice. Bifenox, bentazon, oxadiazon, and endothall are herbicides that have only recently been registered for use in rice (Arkansas Cooperative Extension Service 1978f, Seaman 1978). They all have tolerances established on rice but are registered for use in rice in specific rice-growing States under the special needs category (provided by Section 24C of FIFRA). Bifenox has been used commercially since 1976, bentazon since 1977, oxadiazon was registered for the first time in 1978, and endothall is used only in California for control of submerged aquatic weeds. Hence, only a small percentage of the rice acreage is presently treated with these new herbicides (table 1). They control some weeds that are susceptible to 2,4,5-T but do not control as many species of broadleaf, aquatic, and sedge weeds as does 2,4,5-T (table 4). They are frequently used in tank mixtures with propanil to increase the weed control spectrum.

The phenoxy group of herbicides must be applied to rice at precise stages of growth to prevent crop injury; also, their sprays may drift from ricefields and injure nontarget crops, e.g. cotton, soybeans, lespedeza and vegetables (gardens) (Smith et al. 1977). Of this group, 2,4,5-T is the safest one to use in areas where cotton is grown. It can also be applied safely to rice during early tillering stages of growth whereas 2,4-D and MCPA injure rice when applied at this early stage of growth. In addition, 2,4,5-T controls some broadleaf and aquatic weeds more effectively than 2,4-D or MCPA (table 4). Weeds included in this group are northern and Indian jointvetch, gooseweed, Mexicanweed, smartweed, and waterprimrose. Although silvex (ester) controls weeds about equally to 2,4,5-T (table 4), it is more injurious than 2,4,5-T to nontarget crops such as soybeans and cotton (Smith et al. 1977).

Therefore, silvex cannot be used as frequently as 2,4,5-T in rice-growing areas of Arkansas, Mississippi, Louisiana, and Missouri.

Consequently, other registered herbicides for weeds are not as effective as 2,4,5-T. Propanil, 2,4-D, MCPA, silvex, bifenox, bentazon, and oxadiazon used alone and in combination as tank mixture or sequential treatments can reduce losses caused by some weeds that 2,4,5-T controls (table 4). However, even when used as combination treatments, they do not control weeds sufficiently to prevent yield and quality losses or they damage nontarget crops too severely to be substituted for 2,4,5-T.

Many new herbicide candidates for rice are being researched each year by public and private institutions. Herbicides that have advanced beyond primary evaluations include butachlor, thiobencarb, sodium and potassium azide, triclopyr, oxyfluorfen, and acifluorfen (Southern Weed Science Society Research Reports 1975, 1976, 1977, 1978). These herbicides, used alone and in combination with each other or with propanil or molinate, control some of the weeds that are susceptible to 2,4,5-T. However, not one of them is comparable to 2,4,5-T from the combined standpoints of efficacy and safety to rice and nontarget crops. Many of these herbicides will probably never be registered for use in rice because of efficacy, phytotoxicity, or environmental problems.

An endemic anthracnose disease of northern jointvetch incited by the fungus Colletotrichum gloeosporioides f. sp. aeschynomene was discovered in 1969 at Stuttgart, Arkansas (Daniel et al. 1973). Water-spore suspensions in 10 gpa controlled 95 to 100 percent of the northern jointvetch in field trials from 1971-1977. The fungus is very virulent on northern jointvetch, a weed susceptible to 2,4,5-T but not to most other herbicides (table 4). It does not affect rice, soybeans, cotton, or common field forage and vegetable crops, or other weeds. Future research and development will determine if the fungus can be produced in sufficient quantities for general use for control of northern jointvetch. Registration requirements are also yet to be determined for fungi.

It is essential that research and development continue to find new, safe, and effective herbicides for rice. The U.S. Department of Agriculture, the State Agricultural Experiment Stations, and private industry are all working cooperatively to find new herbicides and biocontrol agents that are more effective than present control methods.

In summary, 2,4,5-T is an essential tool in a weed-management system for rice. When 2,4,5-T is combined with other herbicide treatments and with cultural-mechanical-crop management weed control practices, losses in rice can be reduced to a minimum. With an effective weed-control program, production inputs, e.g. fertilizers, insect and disease control practices, and irrigation water can be managed efficiently with subsequent efficient rice production (Smith et al. 1977).

RICE PRODUCTION AND WEED CONTROL

Established management goals of the rice industry in the U.S. are to: (a) develop and implement technology needed to assure an adequate supply of high-quality rice to meet domestic and foreign market demands; and (b) improve the quality of the environment for man and animals (Shaw 1976, USDA-ARS 1976, Joint Task Force SAES and USDA 1977). Weed control technology is essential to achieving these goals. The use of safe and efficient principles and practices of weed control that are integrated with other production and protection technology is essential to assuring a high-yielding ricefield agroecosystem that maintains and improves the quality of the environment.

BIOLOGY AND ECOLOGY OF PLANT COMMUNITIES

The biology of weeds is the establishment, growth, and reproduction of weeds as well as the influence of the environment on these processes (Klingman & Ashton 1975). The ecology of weeds is primarily concerned with the effects of climatic, physiographic, and biotic factors. Climatic relationships include light, temperature, water, wind, and atmosphere. Physiographic is concerned with soil factors, e.g. pH, fertility, texture, structure, organic matter content, carbon dioxide, oxygen, and water drainage; and topograhic factors, e.g. altitude, slope, and exposure to the sun. Biotic influences include plant relationships, e.g. competition, diseases, toxins, stimulants, parasitism, and soil flora; and animal interactions, e.g. insects, grazing animals, soil fauna, and man.

Many of the most common weeds of ricefields have broad tolerance to ecological factors (Fryer and Matsunaka 1977). For example, barnyardgrass grows in almost all ricefield environments throughout the world; it is considered the most widely distributed weed of ricefields (Holm et al. 1977). Rarer species, e.g. willowleaf morningglory, are associated with rice cultured on heavy clay soils of the Mississippi River Delta areas. Dayflower, another weed of limited distribution, is associated principally with the double cropping culture of rice practiced in Texas; but it also grows in the prairie-production areas in Arkansas.

Weed species of rice include various kinds of grass, broadleaf, aquatic, and sedge plants (table 4). Community composition of weeds is dependent on cultural practices, crop rotation, water and soil management, weed-control practices, and climatic and soil conditions (Smith et al. 1977). In dry-seeded and water-seeded rice of the southern rice-producing area, barnyardgrass is the most prevalent weed (Smith et al 1977); most of the weed control inputs are for the control of this one species (table 1). However, morningglory, cocklebur, pigweed, prickly sida, and others that grow primarily in an upland environment are troublesome on levees in both dry-seeded and water-seeded rice.

There are some distinct differences between the weed communities of dry-seeded and water-seeded rice (Smith et al. 1977). Semiaquatic species, e.g. hemp sesbania, northern jointvetch, and dayflower germinate while the stand of dry-seeded rice is being established. By the time ricefields are flooded, usually 4-6 weeks after seeding, these established species grow well in the floodwater. In contrast, the aquatic weed complex germinates and grows well in the aquatic environment of water-seeded rice. These emersed species, which include ducksalad, redstem, waterhyssop, gooseweed, false pimpernel, spikerush, and annual umbrellasedges, germinate with the rice crop in the flooded soil. They usually compete with the rice during the early season when the rice crop is being established. Weed-control practices, by necessity, differ because of the weed species associated with particular rice cultures.

Weed communities in ricefields are constantly changing with changing weed control technology (Smith et al. 1977). In the south, morningglories were not troublesome in ricefields before the extensive use of propanil. This herbicide, which often does not control morningglories, reduces infestations of barnyardgrass and other annual grasses on ricefield levees. Although grass control by the use of propanil has improved rice stands and yields on levees, the lack of grass competition has enhanced morningglory infestations on the levees. Although morningglories do not compete with rice or reduce yields as severely as barnyardgrass, their seeds, which are difficult to separate from rice grain, are harvested with the rice and subsequently reduce the grade and value of the rice crop. Rice grain that contains morningglory seeds requires costly handling procedures to remove the weed seed. Because 2,4,5-T controls morningglory weeds growing on levees, the use of this herbicide is essential to a weed-control program in rice-growing areas of Arkansas, Mississippi, Louisiana, and Missouri.

Other weed species that have increased in recent years because they are tolerant to propanil and molinate, include dayflower, northern jointvetch, smartweed, alligatorweed, arrowhead, gooseweed, Mexicanweed, and sprangletop (Smith et al. 1977). Many of these broadleaf species are controlled by 2,4,5-T (table 4). As weeds become tolerant during various growth stages to propanil and molinate, need for 2,4,5-T or other herbicides to control them will increase.

Some weeds are associated with specific soil types. Willowleaf morningglory, a weed susceptible to 2,4,5-T but not to propanil or molinate, is primarily a problem in rice grown on the heavy clay soil of the Mississippi River Delta areas (Smith et al. 1977). Conversely, dayflower is a problem weed on the silt loam soil of the prairie rice-growing areas of Arkansas.

WEED IMPACT ON COMMODITY YIELD AND QUALITY

Both the density of weeds in rice and the duration of weed-rice competition affect rice yields. In numerous field experiments with various rice varieties, yields decreased as weed density and duration of weed competition increased (tables 9 and 10).

Hemp sesbania populations of 5,000 to 43,000 plants per acre reduced yields from 10 to 40 percent when competition lasted all season (table 9). The same populations of northern jointvetch reduced yields from 4 to 19 percent when competition lasted all season. Hemp sesbania grows taller than northern jointvetch; hence, it shades the rice more and causes greater yield losses (Smith et al. 1977).

Broadleaf, aquatic, and grass weeds reduce yields when competition is during the early season (table 10). Ducksalad and barnyardgrass are much more competitive during the early season than are hemp sesbania and northern jointvetch. However, these latter two weeds reduced yields 6 to 8 percent when competition lasted for only 8 weeks. On the other hand, ducksalad reduced yields 15 percent when competition lasted for only 4 weeks. Effective herbicides must be applied early (before 4 weeks) in the growing season to prevent losses from ducksalad competition, and applied by midseason (8 weeks) to keep losses from competition of hemp sesbania and northern jointvetch to a minimum.

Natural ricefield infestations of hemp sesbania and northern jointvetch are not as uniform as those reported in table 10 (Smith et al. 1977). Natural ricefield infestations usually sparsely populate the entire

Table 9--Yield losses as influenced by density of hemp sesbania and northern jointvetch[a]

Weed plants/acre	Hemp sesbania	Northern jointvetch
	% Loss in Yield	
5,445	10	4
10,890	15	7
21,780	27	11
43,560	40	19

a/ Data adapted from Smith 1968.

SOURCE: USDA-SEA-AR, Stuttgart, AR.

Table 10--Yield losses due to weed competition[a]

	Length of competition			
Weed	4 Weeks	8 Weeks	12 Weeks	All season
	% Loss in Yield			
Hemp sesbania	2	6	9	19
Northern jointvetch	2	8	8	17
Ducksalad	15	27	-	21
Barnyardgrass	8	35	43	70
Sprangletop	-	-	-	35

a/ Data adapted from Smith 1968 and Smith 1975.

SOURCE: USDA-SEA-AR, Stuttgart, AR.

field or they grow in colonies in which not more than 25 percent of the land area is infested. In addition, a ricefield usually has a complex of both weeds. Thus, it is estimated that natural ricefield infestations of hemp sesbania and northern jointvetch range from 5 to 10 thousand plants per acre of each species. Therefore, full season competition of these two weeds may reduce rice yields an estimated 15 percent.

In 1974, hemp sesbania and northern jointvetch seeds were found in 33 percent of the rough rice samples on total production in the 2,4,5-T use areas of Arkansas, Mississippi, northern Louisiana, and Missouri (table 11). Discounts ranged from $0.11 per cwt for No. 2 grade to $2.78 per cwt for sample grade (table 12). These quality losses in the 2,4,5-T use areas of Arkansas, Mississippi, Louisiana, and Missouri were valued at $70 million annually during 1975-1977 and occur on ricefields that are not treated with 2,4,5-T or other herbicides for control of these species (Arkansas Cooperative Extension Service 1975).

Several species of morningglory infest rice in the 2,4,5-T use area, but not in rice fields treated with 2,4,5-T. Because most species grow primarily on levees, they cause only minor reductions in grain yield (an estimated loss of 1%). However, 46 percent of the rice grain in the 2,4,5-T use areas of Arkansas, Mississippi, Louisiana, and Missouri, is infested with morningglory seeds (table 11). For example, 15 percent of the grain contained enough seeds to lower the grade to U.S. No. 4. Morningglory seed reduced the grade and subsequent value of rough rice an estimated $12 million annually during 1975-1977.

MANAGEMENT STRATEGIES

Current weed-control technology for rice includes the integrated use of cultural, chemical, mechanical, ecological, and biological systems of control (Smith et al. 1977). These primary weed-control methods are supplemented by (a) the use of genetically improved and well adapted rice varieties, (b) improved crop management practices -- including

Table 11--Rice grain graded down because of weed seed in the 2,4,5-T use area, 1975-77[a/]

U.S. grade	Percent rough rice containing indicated weed seed: Hemp sesbania and Northern jointvetch	Percent rough rice containing indicated weed seed: Morningglory
2	1	4
3	7	12
4	11	15
5	6	6
6	6	6
Sample	2	3
Total	33	46

a/ Data based on a rice mill survey conducted by the Arkansas Cooperative Extension Service (1975) on 50% of the rice grown in Arkansas in 1974.

SOURCE: USDA-SEA-AR, Stuttgart, AR.

Table 12--Discounts of rough rice from weed seed in the crop, 1975-77[a/]

U.S. grade #	Discount
	Dol/cwt
1	0
2	0.11
3	0.22
4	0.33
5	0.78
6	1.33
Sample[b/]	2.78

a/ Data based on information collected by the Arkansas Cooperative Extension Service (1976) from the Rice Industry.

b/ A composite of all grades above grade 6.

SOURCE: USDA-SEA-AR, Stuttgart, AR.

optimum time of seeding, optimum plant populations per acre, and optimum tillage practices, (c) better plant nutrition, (d) improved farm equipment and mechanized practices for weed control, (e) improved irrigation management, (f) weed-free crop seed and other principles and practices that reduce weed competition and losses, (g) plant pathogens and insects to control weeds, (h) field sanitation, (i) crop rotations, (j) and preventive methods (Shaw 1976).

These rice production and protection practices, and others, are integrated with high-yielding agroecosystems compatible with a quality environment (USDA-ARS 1976; Shaw 1976). The control of diverse weed species and populations requires an integrated systems approach that includes nonchemical and chemical methods. The chemical methods of control require a broad spectrum of herbicides, mixtures of herbicides, herbicide rotations, sequential herbicide treatments, and the use of diverse and increasingly innovative and complex application techniques and equipment.

Cultural-mechanical-crop management practices are important components of an effective weed control system for rice (Smith et al. 1977). Although rice farmers are presently implementing such technology effectively, they also must use advanced herbicide techniques to obtain effective weed management in ricefields. Effective herbicide technology includes the judicious use of propanil, molinate, 2,4,5-T, 2,4-D, MCPA, silvex, bifenox, and bentazon as well as some new or minor use herbicide, e.g., oxadiazon, endothall, copper complexes, and copper sulfate (Smith et al. 1977).

Effective herbicide strategies include the sequential use of propanil or molinate for control of grass weeds and 2,4,5-T or other phenoxy herbicides for control of broadleaf, aquatic and sedge weeds (Smith et al. 1977). When these combinations of herbicide treatments are used with effective cultural-mechanical-crop management practices, weed competition and subsequent losses of rice yield and quality can be eliminated or reduced to a minimum.

2,4,5-T

Patterns Of Use

Current Patterns Of Use

2,4,5-T is used each year for control of aquatics, broadleaf and sedge weeds in rice-growing areas of Arkansas, Mississippi, Louisiana, and Missouri. Approximately 300,000 acres of rice in these four states are treated with 2,4,5-T (table 1). The acreage treated with 2,4,5-T ranges from 3 percent in Louisiana to 71 percent in Mississippi. The average use rate of 1 lb/A would result in about 300,000 pounds of active 2,4,5-T being used each year for weed control in rice. About 97 percent of the 2,4,5-T is aerially applied with fixed-wing aircraft or helicopters (Smith et al. 1977). However, in the last 5 years, ground applicators (4 wheel drive light-weight machines) have been used to spray levees at midseason (Arkansas Cooperative Extension Service, 1978e).

Use by States

Arkansas: 2,4,5-T is used in all rice-growing areas of Arkansas (Arkansas State Plant Board 1967-77). In the Mississippi River Delta area, cotton is grown nearby or adjacent to rice. Phenoxy herbicides such as 2,4-D and silvex cannot be used safely in these areas because cotton or soybeans are very sensitive to it (Smith et al. 1977). Although MCPA is safer to use than 2,4-D (but not as safe as 2,4,5-T), it does not control some of the principal broadleaf weeds, e.g. hemp sesbania and jointvetch, as effectively as 2,4,5-T (Smith et al. 1977).

2,4,5-T is also used in the prairie areas of Arkansas because northern and Indian jointvetch are prevalent. These two species are controlled better by 2,4,5-T than by other herbicide treatments (table 4). In this area where cotton is infrequently planted, 2,4,5-T is tank-mixed with 2,4-D to increase the number of aquatics, broadleaf, and sedge species controlled (Arkansas State Plant Board, 1967-77).

Mississippi: 2,4,5-T is used in all rice-growing areas of Mississippi (Miller 1978, Peoples 1978). Like the Mississippi River Delta area of Arkansas, cotton is grown near rice. 2,4,5-T is the safest phenoxy herbicide to use in this area and is the principal one used (table 1).

Louisiana: 2,4,5-T is used in the northeastern rice-growing area of Louisiana where cotton is intercropped with rice (Wilson 1978). However, 2,4,5-T is not used in the southwestern rice-growing area; here, 2,4-D is used because it controls the weed complex effectively and can be used without damaging nontarget crops (Baker 1978).

Missouri: 2,4,5-T is used in all rice-growing areas of Missouri because cotton is frequently intercropped with rice (Scott 1978, Kerr 1978).

Texas: 2,4,5-T is not used in the rice-growing areas of Texas because MCPA and 2,4-D control the aquatic and broadleaf weeds effectively and are relatively safe on nontarget crops (Eastin 1978).

California: Because cotton is not intercropped with rice in the California rice-growing area, 2,4,5-T is seldom used for weed control. MCPA is the principal phenoxy herbicide used for control of the aquatic-broadleaf weed complex (Seaman 1978).

Formulations, Rates and Volumes of Spray Material

Water soluble liquid amines of 2,4,5-T are used to control weeds in rice. Those used include diethanol amine, triethanol amine, dimethyl amine, triethyl amine and isopropyl amine (Smith et al. 1977). Ester formulations of 2,4,5-T are not used for weed control in rice (Baldwin 1978).

2,4,5-T amine salts are applied at an average rate of 1 lb/A, but the range is 0.5 to 1.5 lb/A of acid equivalent (Arkansas Cooperative Extension Service 1978f). The rate depends on weed species, stage of growth of the rice, air and water temperatures, use with other herbicides, and other factors (Smith et al. 1977).

2,4,5-T is applied with low gallonage sprayers mounted on fixed-wing or helicopter aircraft (Smith et al. 1977). Volumes applied range from 3 to 10 gpa (Smith et al. 1977) Arkansas Cooperative Extension Service 1978f), but 3 gpa is the most commonly used volume for applying 2,4,5-T. State regulations require that 2,4,5-T not be applied at less than 2 gpa (Arkansas State Plant Board 1978). State regulations also require that 2,4,5-T be applied with drift control agents, such as particulating, foam, or inversion agents, or be applied in an aircraft system designed to reduce spray drift.

Application Equipment and Characteristics of Spray

Fixed-wing and helicopter aircraft sprayers are usually equipped with booms and nozzles. Other distribution systems include rotary brushes or screens, disks, hollow propellers, bifluid and foam nozzles, and venturi type; however, these systems are infrequently used (Smith et al. 1977).

Booms are made of corrosion-resistant material such as aluminum (Smith et al. 1977). To minimize drift of spray, the boom is placed as far below the wing as practical, usually about 1 foot, and is extended within about 3 feet of the wingtip. If the boom extends to the wingtip, the spray may be whirled upward in the wingtip vortices to cause excessive spray drift. State regulations require that the length of the boom shall not exceed 70 percent of the wing span (Arkansas State Plant Board 1978).

Nozzles for fixed-wing aircraft sprayers are made of corrosion-resistant materials such as aluminum, brass, or nylon (Smith et al. 1977). Each is equipped with a quick-cutoff diaphragm, screen, and jet. Spray droplet size is greatly affected by the angle at which the nozzles discharge the spray into the airstream. Smaller droplets occur when the nozzles are directed against or across the airstream than when they are directed with it. For 2,4,5-T spraying to ricefields the nozzles are directed with the airstream (Smith et al. 1977). State regulations require that nozzles shall be aimed back parallel to, or not to exceed an angle of 45° from the boom on fixed-wing aircraft or from the line of flight on helicopters (Arkansas State Plant Board 1978). Droplet size is also affected by pump pressure and nozzle orifice diameter (Smith et al. 1977). Most rice-growing states have regulations that specify the maximum operating pressure for aerial spraying of 2,4,5-T; this usually does not exceed 20 psi. Orifice size is geared to deliver 3 gpa; most frequently used orifices range from D-2 to D-4 (Eichler 1978a). A compromise is usually made between small droplets, which give thorough coverage but have a tendency to drift, and large ones, which settle fast but do not give adequate coverage (Smith et al. 1977). Sprays usually give adequate weed control if droplets range from 100 to 300 μm in diameter.

Spray pattern or distribution is important (Smith et al. 1977). Proper placement and spacing of nozzles along the boom help to distribute the spray evenly. Usually the spray pattern is improved if more nozzles are placed on the right side of the plane than on the left. The air is swirled from the right to left by the counterclockwise rotation of the propeller (facing the propeller). Spraying the proper swath width for the particular aircraft also improves spray distribution. The wingspan and the flying height of the airplane govern the swath width. For 2,4,5-T spraying, the swath is usually about equal to the wingspan of the airplane. The number of nozzles on the boom ranges from 20 to 40. The swath width usually ranges from 30 to 50 feet. Proper flying height improves spray pattern and reduces spray drift. Spray distribution is best when fixed-wing airplanes fly 10 to 15 feet above the crop, but spray drift is less when they fly lower. Fixed wing aircraft usually release 2,4,5-T from 5 to 10 feet above the crop; this gives adequate distribution and minimum drift. Helicopters release 2,4,5-T from 2 to 5 feet above the rice crop. State regulations require that the flying height of fixed-wing aircraft and helicopters release the spray not more than 10 feet above the crop (Arkansas State Plant Board 1978).

During the last 5 years, ground applications have been used to apply 2,4,5-T to levees for control of weeds (Arkansas Cooperative Extension Service 1978e). A light-weight, 4-wheel drive machine equipped with tank, pump, boom, and nozzles straddles the levee and sprays about a 5- to 6-foot swath. The spray is released just above the rice canopy in a volume of 15 to 20 gpa. Only a small percentage of the rice acreage in the 2,4,5-T use area is treated by ground applicators (table 1). General spray applications to entire ricefields are not suitable with these ground applicators because they damage the levees (Arkansas Cooperative Extension Service 1978e). If all the rice in the 2,4,5-T use area (1.1 million acres--table 3) were treated for levee weed control, only about 5 percent of the land or 50,000 acres would be treated by ground equipment (table 13). The 292,000 acres treated aerially with 2,4,5-T do not require ground applications to levees. Therefore, the total potential acreage requiring weed control inputs on levees is estimated to be less than 25,000 acres. Probably no more than 8,000 acres of levees are presently being treated by ground applicators. This represents the levees on about 50,000 acres of rice (USDA-SEA-AR 1978). Conventional pumps and nozzles are used to make ground applications to levees.

Stage of Rice Growth at Time of Treatment and Atmospheric Conditions

The stage of growth greatly influences the response of rice plants to 2,4,5-T (table 14). Very young rice (from emergence up to 3 weeks after emergence) may be injured severely or even killed by 2,4,5-T at rates required to control weeds. Rice treated from 3 weeks after emergence until the internodes are 0.5 inches long, is tolerant to 2,4,5-T (Smith et al. 1977, Arkansas Cooperative Extension Service 1978f). The most tolerant stage can be positively identified when the basal internode begins to elongate from 0.25 to 0.5 inches long. Rice may be injured by 2,4,5-T when the internode is longer than 0.5 inch and during the panicle formation and heading stages. Applications during the booting stage (panicle initiation to panicle emergence) reduce grain yields as much as 20 percent, increase height as much as 12 percent, and reduce bushel weight of grain as much as 2 percent (Smith et al. 1977). Rice is usually 20-30 inches tall when the internodes are 0.25 - 0.5 inch long; its canopy covers the water surface at the time of application when rice stands are normal (Smith et al. 1977). Therefore, rice and

Table 13--Land area in levees on a 40-acre ricefield with various slopes a/

Slope of land[b]	Land in levees[c]	
Percent	Acres	Percent
0.5	6	15.0
0.4	5	12.5
0.25	3	7.5
0.15	2	5

a/ Adapted from Hall et al 1963.

b/ Land suitable for rice has slopes of .01 to 0.5% (USDA 1973). Vertical distance between levees is 0.1 to 0.2 ft.; levees are constructed at lower vertical distance on flatter land (Huey 1977).

c/ Approximately 5 ft. of levee is unflooded.

SOURCE: USDA-SEA-AR, Stuttgart, AR.

Table 14--Growth development of selected rice varieties[a]

Variety	Days from emergence to maturity[a]	Days from emergence to midseason[b],[c]	Days from midseason to draining[d]	Days from midseason to maturity[c]
Labelle	100	45	41	55
Belle Patna	102	47	41	55
Lebonnet	105	50	41	55
Bluebelle	107	52	41	55
Saturn	114	60	40	54
Nato	118	65	39	53
Starbonnet	128	70	44	58

a/ Average seeding date for Arkansas in May 3; 10 days allowed from seeding to emergence. Data taken from USDA-ARS 1973.

b/ Midseason is when internodes are 0.25 to 0.5 inch long. This is the time when most of the 2,4,5-T is applied for weed control (Smith et al. 1977).

c/ Data adapted from Huey 1977.

d/ Rice is drained after panicles droop, begin to brown, and lower grains are in the milk stage. This is usually about 14 days before maturity. (Huey 1977). Days from time 2,4,5-T is applied until time floodwater is drained from the ricefield when rice is almost mature.

SOURCE: USDA-SEA-AR, Stuttgart, AR.

weeds intercept most of the spray before it reaches the floodwater. Rice at 3 weeks after emergence is 6 to 10 inches tall and does not canopy the floodwater or soil. When applications are made at this early stage, significant amounts of the spray reaches the floodwater or soil. However, when 2,4,5-T is applied early, the floodwater is usually drained before spraying to expose small weeds to the spray. Hence, the soil receives most of the 2,4,5-T. Weeds covered with water are not controlled by 2,4,5-T applications.

2,4,5-T is usually applied during the early morning (5-8 a.m.) or late afternoon (6-9 p.m.) when temperatures have cooled and wind velocities have decreased. Usually temperatures range from 70 to 90°F and wind velocities are less than 5 mph. State regulations do not permit spraying of 2,4,5-T when temperatures exceed 90°F and wind velocity exceeds 5 mph. (Arkansas State Plant Board 1978).

Reasonable (Potential) Levels Of Use

Troublesome broadleaf and aquatic weeds, including hemp sesbania, nothern jointvetch, ducksalad, morningglory, and redstem infest an estimated 860,000 acres of rice in Arkansas, Mississippi, northern Louisiana, and southern Missouri; this is an estimated 80 percent of the acreage in these four rice-producing areas (table 15). Other broadleaf, aquatic, and sedge weeds infest the same and additional acreage that the above five weeds contaminate. In these same rice-producing areas, only 292,000 acres are treated aerially each year with 2,4,5-T (table 1). Therefore, at least 568,000 acres of rice contain broadleaf, aquatic, and sedge weeds that can be controlled with 2,4,5-T (tables 1 & 15). Although some of these acres receive alternate weed-control practices, including applications of propanil, 2,4-D, silvex, and others (bifenox and bentazon), the weed complex susceptible to 2,4,5-T is severe enough to cause losses in yield and quality. Therefore, many of these acres would receive 2,4,5-T applications if adequate supplies were available and if farmers were not reluctant to use it because of damage to nontarget crops and consumer and environmental group protests.

An estimated 284,000 acres of untreated rice could be economically treated with 2,4,5-T in an effective weed-management system (table 15).

Table 15--Estimated potential use levels of 2,4,5-T in Arkansas, Mississippi, northern Louisiana, and Missouri (2,4,5-T use area)

Weed	Acres infested[a/]	Potential acres for treatment with 2,4,5-T[b/]
	----------1,000 acres----------	
Hemp sesbania	572	172
Northern jointvetch	518	155
Ducksalad	648	194
Morningglory	464	139
Redstem	324	98
Acres infested with one or more weeds	860	284

a/ Data from Table 17.

b/ Does not include 300,000 acres treated with 2,4,5-T. Estimates developed by the Arkansas Cooperative Extension Service (1978e) Baldwin (1978) and USDA-SEA-AR (1978).

SOURCE: USDA-SEA-AR, Stuttgart, AR.

Therefore, the acreage potential for treatment with 2,4,5-T is 576,000 acres or almost twice the amount presently treated. This expanded use would be worth about $14 million to rice farmers and the rice industry (table 16).

Costs for Use

The cost of using 2,4,5-T varies slightly with the rice-producing area (table 5). In Arkansas, there are two distinct use areas--the prairie and the Arkansas-Mississippi River Delta. In the prairie areas, where cotton is grown infrequently, 2,4,5-T is used alone or mixed with 2,4-D (Arkansas State Plant Board 1967-1977). The cost of using 2,4,5-T alone is $9.50 per acre on 112,000 acres for a total cost of more than $1 million. The cost of using the 2,4,5-T/2,4-D mixture is $10.70 per acre in Arkansas.

The per-acre cost of using 2,4,5-T in the Mississippi, Louisiana, and Missouri rice-producing areas is about the same (table 2). The cost of herbicide plus applications is about $10.50 per acre in these three states.

Effect of Use on Commodity Yield and Quality

2,4,5-T is applied aerially to 292,000 acres of rice in Arkansas, Mississippi, Louisiana, and Missouri (table 1). The principal weed species infesting these areas are hemp sesbania, northern jointvetch, ducksalad, morningglory, and redstem (table 15); these five species are controlled or reduced with 2,4,5-T applications (table 4). Other less prevalent weeds that are controlled by 2,4,5-T, include beakrush, burhead, cocklebur, dayflower, eclipta, false pimpernel, fimbristylis, Indian jointvetch, Mexicanweed, smartweed, spikerush, umbrellaplant, waterhyssop, and waterprimrose (table 4). Although these weeds cause losses in yield and grade of rough rice, they usually occur as weed complexes with the five species in table 15. Only infrequently do they occur alone with rice. When they occur as monocultures, frequently they infest only small areas of the field or infest only levees.

Table 16—Annual use and returns for 2,4,5-T and projected returns with alternative scenarios 1-3 years after 2,4,5-T becomes unavailable, rice-growing areas of Arkansas, Mississippi, Louisiana, and Missouri

Area & alternative treatment	Acres in area[a]	Treated acres[b]	Per acre treatment cost[c]	Total cost[d]	Per acre yield	Total production[e]	Value per cwt	Total value[f]	Total value less treatment costs	Loss with best alternative[g]
	---Thousands---		Dollars	Thousand Dollars	CWT	Thousand CWT	Dollars	---------Thousand Dollars---------		
Arkansas:										
2,4,5-T	855	172	9.50	1,634	45.2[a]	7,774.4	8.36[k]	64,994	63,360	
Silvex, 2,4-D & Propanil	855	172	N.A.	1,685	N.A.	7,601.8	--	63,038	61,353	2,007
Silvex		60	9.50	570	45.2[a]	2,712.0	8.36[k]	22,672		
2,4-D		60	7.40	444	44.3[h]	2,658.0	8.28[l]	22,088		
Propanil		52	12.90	671	42.9[i]	2,231.9	8.19[m]	18,278		
2,4-D & propanil	855	172	N.A.	1,580	N.A.	7,541.2		62,225	60,645	2,715
2,4-D		116	7.40	858	44.3[h]	5,138.8	8.28[l]	42,549		
Propanil		56	12.90	772	42.9[i]	2,402.4	8.19[m]	19,676		
2,4-D	855	172	N.A.	858	N.A.	7,339.6	N.A.	60,221	59,363	
2,4-D		116	7.40	858	44.3[h]	5,138.8	8.28[l]	42,549		
No Treatment		56	0.00	0	39.3[j]	2,200.8	8.03[n]	17,672		
Propanil	855	172	12.90	2,219	42.9[i]	7,378.8	8.19[m]	60,432	58,213	
No Treatment	855	172	0.00	0	39.3[j]	6,759.6	8.03[n]	54,280	54,280	

continued

Table 16--Annual use and returns for 2,4,5-T and projected returns with alternative scenarios 1-3 years after 2,4,5-T becomes unavailable, rice-growing areas of Arkansas, Mississippi, Louisiana, and Missouri (Continued)

Area & alternative treatment	Acres in area[a/]	Treated acres[b/]	Per acre treatment cost[c/]	Total cost[d/]	Per acre yield	Total production[e/]	Value per cwt	Total value[f/]	Total value less treatment costs	Loss with best alternative[g/]
	---Thousands---		Dollars	Thousand Dollars	CWT	Thousand CWT	Dollars	---------Thousand Dollars---------		
Mississippi:										
2,4,5-T	142	99	9.50	941	40.3[a/]	3,989.7	8.11[k/]	32,356	31,415	
Silvex, 2,4-D & propanil	142	99	N.A.	1,175	N.A.	3,815.7		30,814	29,639	1,776
Silvex		30	9.50	285	40.3[a/]	1,209.0	8.11[k/]	9,805		
2,4-D		0	----	----	----	----	----	----		
Propanil		69	12.90	890	38.3[i/]	2,642.7	7.95[m/]	21,009		
2,4-D & propanil	142	99	N.A.	1,167	N.A.	3,815.7	N.A.	30,398	29,231	2,184
2,4-D		20	7.40	148	39.5[h/]	790.0	8.03[l/]	6,344		
Propanil		79	12.90	1,019	39.3[i/]	3,025.7	7.95[m/]	24,054		
2,4-D	142	99	N.A.	148	N.A.	3,562.9	N.A.	27,945	27,797	
2,4-D		20	7.40	148	39.5[h/]	790.0	8.03[l/]	6,344		
No Treatment		79	0.00	0	35.1[i/]	2,772.9	7.79[n/]	21,601		
Propanil	142	99	12.90	1,277	38.3[i/]	3,791.7	7.95[m/]	30,144	28,867	
No Treatment	142	99	0.00	0	35.1[j/]	3,474.9	7.79[n/]	27,069	27,069	
Louisiana:										
2,4,5-T	62	17	9.50	162	38.0[a/]	646.0	8.03[k/]	5,187	5,025	

continued

Table 16--Annual use and returns for 2,4,5-T and projected returns with alternative scenarios 1-3 years after 2,4,5-T becomes unavailable, rice-growing areas of Arkansas, Mississippi, Louisiana, and Missouri (Continued)

Area & alternative treatment	Acres in area[a/]	Treated acres[b/]	Per acre treatment cost[c/]	Total cost[d/]	Per acre yield	Total production[e/]	Value per cwt	Total value[f/]	Total value less treatment costs	Loss with best alternative[g/]
	---Thousands---		Dollars	Thousand Dollars	CWT	Thousand CWT	Dollars	---Thousand Dollars---		
Silvex, 2,4-D & propanil	62	17	N.A.	203	N.A.	623.2	N.A.	4,935	4,732	293
Silvex		5	9.50	48	38.0[a/]	190.0	8.03[k/]	1,526		
2,4-D		0	---	---	---	---	---	---		
Propanil		12	12.90	155	36.1[i/]	433.2	7.87[m/]	3,409		
2,4-D & propanil	62	17	N.A.	203	N.A.	617.0	N.A.	4,864	4,661	364
2,4-D		3	7.40	22	37.2[h/]	111.6	7.95[l/]	887		
Propanil		14	12.90	181	36.1[i/]	505.4	7.87[m/]	3,997		
2,4-D	62	17	N.A.	22	N.A.	575.0	N.A.	4,460	4,438	
2,4-D		3	7.40	22	37.2[h/]	111.6	7.95[l/]	887		
No Treatment		14	0.00	0	33.1[j/]	463.4	7.71[n/]	3,573		
Propanil	62	17	12.90	219	36.1[i/]	613.7	7.87[m/]	4,830	4,611	
No Treatment	62	17	0.00	0	33.1[j/]	562.7	7.71[n/]	4,338	4,338	
<u>Missouri:</u>										
2,4,5-T	16	4	9.50	38	41.1[a/]	164.4	8.44[k/]	1,388	1,350	
Silvex, 2,4-D & propanil	16	4	N.A.	49	N.A.	158.1	N.A.	1,315	1,266	84

continued

Table 16—Annual use and returns for 2,4,5-T and projected returns with alternative scenarios 1-3 years after 2,4,5-T becomes unavailable, rice-growing areas of Arkansas, Mississippi, Louisiana, and Missouri (Continued)

Area & alternative treatment	Acres in area[a]	Treated acres[b]	Per acre treatment cost[c]	Total cost[d]	Per acre yield	Total production[e]	Value per cwt	Total value[f]	Total value less treatment costs	Loss with best alternative[g]
	---Thousands---		Dollars	Thousand Dollars	CWT	Thousand CWT	Dollars	---------Thousand Dollars---------		
Silvex		1	9.50	10	41.1[a]	41.1	8.44[k]	347		
2,4-D		0	----	----	----	----	----	----		
Propanil		3	12.90	39	39.0[i]	117.0	8.28[m]	968		
2,4-D & propanil	16	4	N.A.	46	N.A.	157.3	N.A.	1,305	1,259	91
2,4-D		1	7.40	7	40.3[h]	40.3	8.36[l]	337		
Propanil		3	12.90	39	39.0[i]	117.0	8.27[m]	968		
2,4-D	16	4	N.A.	7	N.A.	147.7	N.A.	1,207	1,200	
2,4-D		1	7.40	7	40.3[h]	40.3	8.36[l]	337		
No Treatment		3	0.00	0	35.8[j]	107.4	8.10[n]	870		
Propanil	16	4	12.90	52	39.0[i]	156.0	8.27[m]	1,290	1,238	
No Treatment	16	4	0.00	0	35.8[j]	143.2	8.10[n]	1,160	1,160	
Totals, 4 States:										
2,4,5-T	1,075	292	9.40	2,775	43.1	2,574.5	8.26	103,925	101,150	
Silvex, 2,4-D & propanil	1,075	292	10.65	3,112	41.9	12,234.8	8.18	100,102	96,990	4,160
Silvex		96	9.40	913	--	4,152.1	--	34,350		
2,4-D		60	7.40	444	--	2,658.0	--	22,088		
Propanil		136	12.90	1,755	--	5,424.7	--	43,664		

continued

Table 16--Annual use and returns for 2,4,5-T and projected returns with alternative scenarios 1-3 years after 2,4,5-T becomes unavailable, rice-growing areas of Arkansas, Mississippi, Louisiana, and Missouri (Continued)

Area & alternative treatment	Acres in area[a/]	Treated acres[b/]	Per acre treatment cost[c/]	Total cost[d/]	Per acre yield	Total production[e/]	Value per cwt	Total value[f/]	Total value less treatment costs	Loss with best alternative[g/]
	---Thousands---		Dollars	Thousand Dollars	CWT	Thousand CWT	Dollars	---Thousand Dollars---		
2,4-D & propanil	1,075	292	10.26	2,996	41.5	12,131.2	8.14	98,792	95,796	5,354
2,4-D		140	7.40	1,035	--	6,080.7	--	50,117		
Propanil		152	12.90	1,961	--	6,050.5	--	48,675		
2,4-D	1,075	292	N.A.	1,035	39.8	11,625.2	8.07	93,833	92,798	
2,4-D		140	7.40	1,035	--	6,080.7	--	50,117		
No Treatment		152	0.00	0	--	5,544.5	--	43,716		
Propanil	1,075	292	12.90	3,767	40.9	11,940.2	8.10	96,696	92,929	
No Treatment	1,075	292	0.00	0	37.5	10,940.4	7.94	86,847	86,847	

a/ Data taken from Tables 1 and 6; average for 1975-1977.

b/ Data derived from official state records when available, from surveys, and from estimates made by professional workers in given areas. Personal communications between Roy Smith, USDA-SEA-AR, Stuttgart, AR and John B. Baker, LSU, Baton Rouge, LA, June 23, 1978; Ted Miller and Don Bowman, MSU, Stoneville, MS, June 23, 1978; Harold Kerr and Joe Scott, Delta Center, U. Missouri, Portageville, MO, June 29, 1978; Ford Eastin, Texas A&M University, Beaumont, TX, June 21, 1978; Don Seaman, U.of CA, Biggs, CA, June 20, 1978; Baldwin (1978). When silvex is substituted for 2,4,5-T, we estimate that in Arkansas 35, 35, and 30 percent of the 2,4,5-T acreage will be treated with silvex, 2,4-D and propanil, respectively. We estimate that in Mississippi, Louisiana, and Missouri 30 and 70 percent of the 2,4,5-T treated acreage will be sprayed with silvex and propanil, respectively; if silvex is available no 2,4-D will be used in Mississippi, Louisiana, and Missouri.

continued

Table 16--Annual use and returns for 2,4,5-T and projected returns with alternative scenarios 1-3 years after 2,4,5-T becomes unavailable, rice-growing areas of Arkansas, Mississippi, Louisiana, and Missouri (Continued)

c/ Data taken from table 22.

d/ Treated acres times per acre treatment cost.

e/ Treated acres times per acre yield.

f/ Total production times value per cwt.

g/ Total value less treatment costs for 2,4,5-T minus total value less treatment costs for alternative.

h/ Based on 2 percent yield loss estimated in biological assessment.

i/ Based on 5 percent yield loss estimated on biological assessment.

j/ Based on 13 percent yield loss estimated in biological assessment.

k/ Data taken from table 5.

l/ Based on 1 percent quality loss estimated in biological assessment.

m/ Based on 2 percent quality loss estimate in biological assessment.

n/ Based on 4 percent quality loss estimate in biological assessment.

SOURCE: Natural Resource Economics Division, Economics, Statistics, and Cooperatives Service, U.S. Department of Agriculture, Corvallis, Oregon.

Yield and quality losses have been estimated for hemp sesbania, northern jointvetch, ducksalad, morningglory, and redstem. These five weeds cause yield and quality losses that range from 1 to 10 percent and 0 to 4 percent, respectively (table 17).

Hemp sesbania and northern jointvetch cause yield and quality losses of 7 to 8 percent and 4 percent, respectively (table 17). Rarely do these two weeds infest entire ricefields in uniformly heavy infestations (USDA-SEA-AR 1978). They infest parts of fields in heavy stands or grow in sparse stands over entire fields. These plants produce numerous black seeds that are harvested with the rice during combining (table 11). Weed seeds, harvested with the rough rice, must be removed during the processing and milling operations. Although the seeds can be removed by special handling procedures, the grade and value is lowered because of the extra cost required for removing the seed (Howell 1977). Frequently, infestations of black seed lower the grade from U.S No. 1 to No. 4 which is a discount of $0.33 per cwt (table 12). Also, because weed plants are vegetatively green at harvest, they impede harvest operations, increase combine losses, and raise the moisture of rice (Smith et al. 1977).

Ducksalad and redstem are aquatic weeds that frequently grow in ricefields together with other less frequently occurring aquatic weeds (Smith et al. 1977). It is estimated that redstem occurs about one-half as frequently as ducksalad (table 15). Both weeds germinate as soon as ricefields are flooded. Ducksalad, a short, high-density weed, causes competition and significant yield losses during the first 4 to 8 weeks of the growing season (Smith et al. 1977). Even when ducksalad infestation reduces yield significantly, it does not reduce quality or grade of the rough rice. The plant produces tiny seeds that are not harvested with the grain during the combining of rice. Also, the plant usually dies naturally before rice matures. However, redstem, a taller less-thickly-populated weed than ducksalad, competes with rice during the late growing season and produces seed pods that interfere with combining and are harvested with the rough rice. Therefore, yield and quality of rough rice are reduced.

Table 17--Rice infested with and yield and quality losses from selected weeds in the 2,4,5-T use area when rice received no control inputs a/

Weed	Acres infested b/	Loss with no weed control inputs	
		Yield c/	Quality d/
	1,000 acres	Percent	
Hemp sesbania	572	8	4
Northern jointvetch	518	7	4
Ducksalad	648	10	0
Morningglory	464	1	4
Redstem	324	3	2
Acres infested with one or more weeds e/	860		
Percent loss from one or more weeds f/		13	4

a/ 2,4,5-T use area includes Arkansas, Mississippi, Missouri, and northern Louisiana (1,080,000 acres) (table 3).

b/ Based on 1976 survey by Arkansas Cooperative Extension Service (1977) and on estimates by Arkansas Cooperative Extension Service (1978e) and technical personnel.

c/ Based on data in Tables 9 & 10 for hemp sesbania, northern jointvetch, and ducksalad; based on estimates by the Arkansas Cooperative Extension Service (1978e) and Baldwin (1978) for morningglory and redstem.

d/ Grade reduction from US no.1 to no.4 causes a loss of $0.33 per cwt (table 12). Avg. yield and crop value/A in 2,4,5-T use areas = 44 cwt and $366, respectively (table 3) [(44)(0.33) = $14.50 ÷ 366 = 4%].

e/ An estimated 80% of the total acres in the 2,4,5-T use area infested with all or some of the 5 weeds [(1,080,000)(0.80)].

f/ Total yield loss from one or more weeds is estimated at 13%; total quality loss from one or more weeds is estimated at 4%.

SOURCE: USDA-SEA-AR, Stuttgart, AR.

Most species of morningglory grow on levees because they do not tolerate flooding (table 18, Smith et al. 1977). Three species grow mainly on ricefield levees. However, willowleaf morningglory tolerates floodwater; consequently it grows in flooded areas of the field. Morningglories cause only small yield losses. Because morningglories produce numerous large black weed that are harvested with the rough rice, they reduce the grade of rough rice significantly (table 11). Because these black seeds must be removed from the rough rice by costly handling operations, the grade of grain containing morningglory seed is reduced.

Because the five weed species listed in tables 17, 19, and 20 frequently grow in ricefields with other species, the loss in yield and quality would not be additive. Therefore, these five species, in addition to other broadleaf, aquatic, and sedge species usually associated with the five, cause an average estimated 13 percent reduction in yield and 4 percent loss in grade if controls are not used (table 17).

In the four states where 2,4,5-T is used, losses in yield range from $40 to $48 per acre; losses in quality range for $12 to $15 per acre (USDA-SEA-AR 1978). These losses would occur if 2,4,5-T were not available for use in weed-management programs. Without effective control programs, infestations of hemp sesbania, northern jointvetch, ducksalad, morningglory, and redstem would increase during the first 3-year cropping cycle and reductions in yield and quality woudl be prevalent (table 19). If 2,4,5-T were not available for use in the four State area and substitutes were not used, net losses of treatment costs would exceed $14 million annually (table 16).

As time progressed, losses would increase if inputs were not used to control weeds. During the second cropping cycle (4 to 6 years), yield losses and quality losses would average 16 and 5 percent, respectively (table 20).

Table 18—Effect of floodwater on growth of morningglory species grown in the greenhouse, 1975[a/]

Species of morningglory	Moist soil	Flooded at seeding (2/25)	Flooded at emergence (2/28)	Flooded 10 days after emergence (3/10)	Flooded 17 days after emergence (3/17)	Flooded 24 days after emergence (3/24)
	(gr.wt, g)	(% control — using moist soil as base)				
Tall, Ipomoea purpurea	24.2	100	60	0	0	2
Ivyleaf, I. hederacea	36.1	100	62	29	22	45
Small white, I. obscura	36.7	100	66	70	79	71
Willowleaf, I. Wrightii	16.2	100	0	0	0	0
Smallflower, Jacquemontia tannifolia	4.5	100	100	98	22	0
Small moonflower, Calonyction muricatum	74.0	100	65	42	32	26
			Leaf stage and height (inches) at indicated time of flooding			
Tall	NA[b/]	NA	1/4-1/2	2 lf, 4-5	5 lf, 10-12	5 lf, 24-28
Ivyleaf	NA	NA	do.	2 lf, 5-6	6 lf, 24-28	8-10 lf, 32-36
Small white	NA	NA	do.	2 lf, 3-4	5 lf, 8-10	6 lf, 16-18
Willowleaf	NA	NA	do.	2 lf, 2-3	4 lf, 10-12	8 lf, 24-26
Smallflower	NA	NA	do.	1 lf, 1-2	2 lf, 2-3	3 lf, 4-6
Small moonflower	NA	NA	2	2 lf, 9-10	4 lf, 20-24	6 lf, 34-36

a/ Morningglories seeded 3/4" deep in sterilized Crowley silt loam in no. 10 pots Feb. 25, 1975; emerged Feb. 28. Pots flushed to germinate weeds. Pots were flooded at indicated times to a depth of 1". Weed harvested for green weight 4/7. Stage and height (in.) of morningglory when flooded after emergence follow:

b/ Not applicable.

SOURCE: Unpublished, R. J. Smith, Jr. USDA-SEA-AR, Stuttgart, AR.

Table 19--Yield and quality losses in rice from selected weeds and weed control practices during the first 3 years after banning 2,4,5-T a/

Weed	None b/ Yield loss	None b/ Quality loss	2,4,5-T c/ Yield loss	2,4,5-T c/ Quality loss	Propanil d/ Yield loss	Propanil d/ Quality loss	2,4-D e/ Yield loss	2,4-D e/ Quality loss	Silvex f/ Yield loss	Silvex f/ Quality loss	Molinate g/ Yield loss	Molinate g/ Quality loss
	Percent loss											
Hemp sesbania	8	4	0	0	0	0	0	0	0	0	8	4
Northern jointvetch	7	4	0	0	5	3	5	2	0	0	7	4
Ducksalad	10	0	0	0	5	0	2	0	0	0	10	0
Morningglory	1	4	0	0	1	4	0	0	0	0	1	4
Redstem	3	2	0	0	2	2	1	1	0	0	3	2
Average h/	13	4	0	0	5	2	2	1	0	0	13	4

a/ All estimates by the Arkansas Cooperative Extension Service (1978e), Baldwin (1978), and USDA-SEA-AR (1978). Rice grown on land one year out of three; soybeans grown two years.

b/ Data from table 17. Do nothing.

c/ 2,4,5-T gives sufficient control to prevent losses on the 292,000 acres treated.

d/ Propanil can be used in the entire 2,4,5-T use area. It controls hemp sesbania as well as 2,4,5-T; it is partially effective on northern jointvetch, ducksalad, and redstem; it is ineffective on morningglory.

e/ Efficacy on treated acres — 2,4-D can be used on about 50% of the 2,4,5-T use acreage in Arkansas and on only about 20% of the 2,4,5-T use acreage in Mississippi, Louisiana, and Missouri. It controls hemp sesbania, ducksalad, morningglory, and redstem as well as 2,4,5-T, but cannot be applied early to prevent competition and losses from ducksalad and redstem; it is only partially effective on northern jointvetch (table 4).

f/ Use in 2,4,5-T area — Silvex can be used on about 50% of the 2,4,5-T use acreage in Arkansas, Mississippi, Louisiana, and Missouri. It controls all weeds about as well as 2,4,5-T, but its spray drift is more injurious than 2,4,5-T to cotton and soybeans (table 4; Smith et al, 1977, p. 15). Also, effective formulations of silvex are low volatility esters which are more active and more volatile in high temperature (95°F) ricefield environments than amine salts of 2,4,5-T (Smith et al 1977 p. 15).

g/ Although molinate can be used in all 2,4,5-T use areas, it is ineffective on the broadleaf weeds (table 4).

h/ Estimated average loss from one or more weeds; this value is not a numerical average.

SOURCE: USDA-SEA-AR, Stuttgart, AR.

Table 20—Yield and quality losses in rice from selected weeds and weed control practices during the 4 to 6 year period after banning 2,4,5-T a/

Weed	None b/		2,4,5-T c/		Propanil d/		2,4-D e/		Silvex f/	
	Yield loss	Quality loss	Yield loss	Quality loss	Yield loss	Quality loss	Yield loss	Quality loss	Yield loss	Quality loss
	Percent									
Hemp sesbania	12	5	0	0	0	0	0	0	0	0
Northern jointvetch	10	5	0	0	8	4	8	4	0	0
Ducksalad	12	0	0	0	8	0	4	0	0	0
Morningglory	2	6	0	0	2	6	0	0	0	0
Redstem	5	3	0	0	4	3	2	1	0	0
Average g/	16	5	0	0	8	3	4	2	0	0

a/ All estimates by USDA-SEA-AR (1978) and the Arkansas Cooperative Extension Service, (1978e) and Baldwin (1978). Rice grown on land one year out of three; soybeans grown two years.

b/ Do nothing; uncontrolled weed infestations build-up during the second 3-year cycle.

c/ 2,4,5-T gives sufficient control to prevent losses on 292,000 acres treated.

d/ Propanil controls hemp sesbania as well as 2,4,5-T; it is partially effective on northern jointvetch, ducksalad, and redstem; it is ineffective on morningglory (table 4).

e/ 2,4-D controls hemp sesbania, ducksalad, morningglory, and redstem as well as 2,4,5-T but cannot be applied early to prevent competition and losses from ducksalad and redstem (table 4).

f/ Silvex controls all weeds as effectively as 2,4,5-T but cannot be used as extensively as 2,4,5-T (see table 19, footnote f for details).

g/ Estimated average loss from one or more weeds; this value is not a numerical average.

SOURCE: USDA-SEA-AR, Stuttgart, AR.

Water Management in Ricefields Treated with 2,4,5-T

For control of all weed species during the early growing season (3 to 6 weeks after rice emergence) the floodwater is usually drained to expose weeds to the herbicide spray (Smith et al. 1977). Flooding may begin 1 day after 2,4,5-T application and usually is completed within 10 days. Thereafter, the water usually remains on the field until the rice is almost mature.

At midseason, (when rice internodes are 0.25 to 0.5 inch long), the floodwater is drained when short weed species, e.g. ducksalad, redstem, or waterhyssop infest the field (Smith et al. 1977). The soil may be muddy or dry, depending on how long the field was drained before application. If tall weeds, e.g. hemp sesbania, northern jointvetch, or gooseweed infest the field, the floodwater usually remains on the field for midseason application. However, the flood depth is shallow (about 2 inches deep) to expose as much weed growth as possible. After the midseason application, the floodwater remains on the field until the crop matures, (usually 40 to 45 days, table 14). Because the rate of development of rice varieties differs, 2,4,5-T is applied at different times after crop emergence (table 14). However, the period between 2,4,5-T applications at midseason and draining floodwater at maturity for all varieties is almost the same (40 to 45 days).

Source of Water For Rice Irrigation

Sources of water for ricefield irrigation include shallow and deep wells, reservoirs, rivers, bayous, lakes, and drainways (USDA-ARS 1978). In Arkansas, main sources of water include shallow (70 to 150 feet) and deep (600 to 800 feet) wells, reservoirs, and bayous. In northeast Louisiana and Mississippi, most of the irrigation water comes from shallow wells (70 to 150 feet) and bayous.

For successful rice production, it is important that the available water be of suitable quality. Rice irrigation water should be free of dissolved salts that are toxic to rice plants. Generally water is considered satisfactory for irrigating if it contains less than 400 pounds per acre-ft. of calcium carbonate equivalent and a conductivity measurement (EC x 10^6) of less than 900 (Huey 1977).

Chemical Alternatives

Patterns Of Use

Propanil

Propanil, applied to emerged rice and weeds, selectively kills barnyardgrass and many other grass, aquatic, broadleaf, and sedge weeds while rice is only slightly injured (table 4). About 79 percent of the rice in the U.S. is treated with propanil (table 1). Only a small acreage in California is treated with this herbicide because of restrictions on its use in the Sacramento Valley rice-producing area where spray drift from ricefields severely damages prune trees. However, propanil is used extensively in the southern rice-producing area, with about 95 percent of the rice acreage treated each year (table 1).

Propanil is usually applied aerially twice during the early growing season for control of grasses (Smith et al. 1977). Rates used range from 2 to 5 lb/A for each application--not to exceed a rate of 8 lb/A total per season. This is the maximum labeled amount that can be applied to the rice crop each year. Frequently, the maximum rate of 8 lb/A in two applications is required to control grass weeds (Gerlow 1973). Therefore, the control of the total weed population in the ricefield requires additional applications of other types of herbicides--the phenoxy herbicide group. Thus, a significant amount of rice acreage in the South is treated with phenoxy herbicides; the principal one used in Arkansas, Mississippi, northern Louisiana, and Missouri is 2,4,5-T (table 1).

If 2,4,5-T were not available to control weeds, propanil applications would need to exceed the maximum registered rate to obtain control of the grass and broadleaf weed complex. Such a practice could cause problems of rice injury and possible residues in the grain that exceed established tolerances for propanil.

Although propanil injures nontarget crops less than 2,4,5-T or other phenoxy herbicides, it can drift and injure crops such as cotton and soybeans (Smith et al. 1977). Precautions must be used when applying propanil to prevent damage to nontarget crops. Also, propanil injures rice when applied after midseason (when the internodes are more than 0.5 inches long). Therefore, timely applications are required to control weeds without causing severe damage to rice.

2,4-D

This herbicide is used each year on about 332,000 acres of rice in the U.S. (table 1). It is used in the southern rice-producing areas, but not in California. The acreage treated in the South ranges from 30 percent in Louisiana to little, if any, in Missouri. It is applied for control of many broadleaf, aquatic, and sedge weeds (table 4). It would be used more frequently if it were not so injurious to cotton (Smith et al. 1977, p. 15). Spray from aerial applications to ricefields frequently drifts to nearby cotton fields to cause significant damage. Most rice-growing states regulate the application of 2,4-D to ricefields.

Water soluble liquid amines and inorganic or organic salt powders are used to control weeds in rice (Smith et al. 1977). Rates of 2,4-D used for weed control in rice range from 0.5 to 1.5 lb/A of acid equivalent.

The rate depends on weed species, air and water temperatures, and other factors.

The stage of rice growth is very critical when 2,4-D is applied to rice (Smith et al. 1977). The rice must be in the early jointing stage (internodes 1/8 - 1/2 inch long); the time required for rice to reach the tolerant stage of growth varies with variety. Rice treated with 2,4-D during the early tillering stage (before the internodes begin elongating) grows tubular leaves ("onion leaf" symptoms) and malformed panicles. Also, rice treated with 2,4-D during the booting and panicle development stages may be injured severely. Rice treated during susceptible stages of growth may be reduced in yield by as much as 27 percent (Smith et al. 1977). It also can reduce plant height and bushel weight.

The floodwater is usually drained or lowered to expose weed growth to 2,4-D spray (Smith et al. 1977). Soon after application the floodwater is reapplied or increased to normal depths.

2,4-D is applied with low gallonage sprayers mounted on fixed-wing or helicopter aircraft in the same way 2,4,5-T is applied (Smith et al. 1977).

If 2,4,5-T were unavailable for use in rice, 2,4-D would be substituted on some of the rice where 2,4,5-T is now used (USDA-SEA-AR 1978). The amount of acreage treated with 2,4-D would vary somewhat with the rice-producing area. In Arkansas, 2,4-D could be used on all of the rice now treated with 2,4,5-T in the prairie-growing area; in other rice-growing areas of Arkansas 2,4-D could be substituted for 2,4,5-T on about half the acreage. However, in the Mississippi, Louisiana, and Missouri rice-producing areas, 2,4-D would be substituted for 2,4,5-T on only about 20 percent of the acreage. In the Mississippi River Delta areas where cotton is grown extensively, 2,4-D could not be used because of possible drift and damage to cotton.

One problem with the use of 2,4-D is that it cannot be applied during the early season; therefore, early competition of weeds such as ducksalad would have already occurred before this herbicide could be applied.

Silvex

This herbicide, which is applied aerially in the same way as 2,4-D, is used on less than 1 percent of the rice in the U.S. (table 1). It is used occasionally in the southern rice-producing area and not at all in California. It is applied for control of many broadleaf, aquatic, and sedge weeds (table 4). It has almost comparable activity to 2,4,5-T on most broadleaf, aquatic, and sedge weeds (table 4). This herbicide is very injurious to soybeans, a rotation crop with rice, and is more damaging to cotton than 2,4,5-T (Smith et al. 1977).

Emulsifiable ester formulations are used for weed control in rice (Smith et al. 1977). The amine and inorganic, salt formulations of silvex do not control the broadleaf, aquatic, and sedge weed complex of ricefields (USDA-SEA-AR 1978). Also, low-volatile ester formulations may vaporize in the hot (90°F or above) ricefield environment after application (Smith et al. 1977, Downey and Wells 1975). Vapor drift from ricefields to soybeans or cotton could damage these susceptible crops.

Rates, volumes and stages of rice growth for applying silvex are the same as for 2,4,5-T (Smith et al. 1977). Water management and other application and production practices for silvex and 2,4,5-T are the same.

If 2,4,5-T were not available for use in rice, silvex would be substituted on some of the rice where 2,4,5-T is now used (table 16) (USDA-SEA-AR 1978). The amount of acreage treated with silvex would be about the same in all 2,4,5-T use areas, which we estimate to be about 30-35 percent of the 2,4,5-T treated acreage. However, it would be used in a combined weed-control program with propanil and/or 2,4-D.

Propanil And/Or 2,4-D

If 2,4,5-T were unavailable for use in rice, propanil and/or 2,4-D would be viable substitutes for 2,4,5-T on most of the rice now being treated with 2,4,5-T (tables 16 and 21). The particular pattern of use would entail applications of 2,4-D on rice where it could be used safely. These rice-producing areas would include all of the prairie and about 50 percent of the acreage in other rice-producing areas of Arkansas. Also, 2,4-D could be used on about 20 percent of the rice now being treated with 2,4,5-T in Mississippi, Louisiana, and Missouri. Where 2,4-D could not be used safely, propanil alone would be used on the remainder of the acreage presently being treated with 2,4,5-T. Therefore, each herbicide (2,4-D and propanil) would be used on about 50 percent of the rice presently being treated with 2,4,5-T (tables 16 and 21). The substitution propanil treatment for 2,4,5-T would be in addition to earlier propanil treatments for grass control.

2,4-D would be used where applications could be made safely (from the standpoints of spray drift to cotton and safety to rice) because it controls many broadleaf, aquatic, and sedge weeds better than propanil (USDA-SEA-AR 1978). Propanil would be used during the early season when 2,4-D injures rice. It would also be used in all areas where cotton is grown near rice and where 2,4-D would be too hazardous or would be illegal.

Problems that would be encountered with the use of propanil and 2,4-D substituted for 2,4,5-T include: (a) the maximum registered rate of propanil may have to be exceeded to control the grass and broadleaf weed complex, (b) because early applications of 2,4-D injures rice, significant weed competition and losses would occur before the herbicide can be applied safely at midseason, and (c) propanil and 2,4-D do not control the weed complex as effectively as 2,4,5-T.

Silvex or 2,4-D with Propanil

If 2,4,5-T were unavailable for use in rice, the best substitute for 2,4,5-T would be silvex or 2,4-D with propanil on most of the

Table 21--Annual use and returns for 2,4,5-T and projected returns with alternative scenarios 4-6 years after 2,4,5-T becomes unavailable--rice growing areas of Arkansas, Mississippi, Louisiana and Missouri

Area & alternative treatment	Acres in area[a/]	Treated acres[b/]	Per acre treatment cost[c/]	Total cost[d/]	Per acre yield	Total production[e/]	Value per cwt	Total value[f/]	Total value less treatment costs	Loss with best alternative[g/]
	---Thousands---		Dollars	Thousand Dollars	CWT	Thousand CWT	Dollars	---------Thousand Dollars---------		
Arkansas:										
2,4,5-T	855	172	9.50	1,634	45.2[a/]	7,774.4	8.36[j/]	64,994	63,360	
Silvex, 2,4-D & propanil	855	172	N.A.	1,685	N.A.	7,479.2	N.A.	61,543	59,858	3,502
Silvex		60	9.50	570	45.2[a/]	2,712.0	8.36[j/]	22,672		
2,4-D		60	7.40	444	43.4[h/]	2,604.0	9.19[k/]	21,327		
Propanil		52	12.90	671	41.6[i/]	2,163.2	8.11[l/]	17,544		
2,4-D & propanil	855	172	N.A.	1,580	N.A.	7,364.0	N.A.	60,125	58,545	4,815
2,4-D		116	7.40	858	43.4[h/]	5,034.4	8.19[k/]	41,232		
Propanil		56	12.90	722	41.6[i/]	2,329.6	8.11[l/]	18,893		
Mississippi:										
2,4,5-T	142	99	9.50	941	40.3[a/]	3,989.7	8.11[j/]	32,356	31,415	
Silvex, 2,4-D & propanil	142	99	N.A.	1,175	N.A.	3,768.9	N.A.	29,951	28,776	2,639
Silvex		30	9.50	285	40.3[a/]	1,209.0	8.11[j/]	9,805		
2,4-D		0	----	----	----	----	----	----		
Propanil		69	12.90	890	37.1[i/]	2,559.9	7.87[l/]	20,146		

continued

Table 21--Annual use and returns for 2,4,5-T and projected returns with alternative scenarios 4-6 years after 2,4,5-T becomes unavailable—rice growing areas of Arkansas, Mississippi, Louisiana and Missouri (Continued)

Area & alternative treatment	Acres in area[a]	Treated acres[b]	Per acre treatment cost[c]	Total cost[d]	Per acre yield	Total production[e]	Value per cwt	Total value[f]	Total value less treatment costs	Loss with best alternative[g]
	—Thousands—		Dollars	Thousand Dollars	CWT	Thousand CWT	Dollars	———Thousand Dollars———		
2,4-D & propanil	142	99	N.A.	1,167	N.A.	3,704.9	N.A.	29,219	28,052	3,363
2,4-D		20	7.40	148	38.7[h]	774.0	7.95[k]	6,153		
Propanil		79	12.90	1,019	37.1[i]	2,930.9	7.87[l]	23,066		
Louisiana:										
2,4,5-T	62	17	9.50	162	38.0[a]	646.0	8.03[i]	5,187	5,025	
Silvex, 2,4-D & propanil	62	17	N.A.	203	N.A.	610.0	N.A.	4,798	4,595	430
Silvex		5	9.50	48	38.0[a]	190.0	8.03[k]	1,526		
2,4-D		0	----	----	----	----	----	----		
Propanil		12	12.90	155	35.0[i]	420.0	7.79[l]	3,272		
2,4-D & propanil	62	17	N.A.	203	N.A.	599.5	N.A.	4,679	4,476	549
2,4-D		3	7.40	22	36.5[h]	109.5	7.87[k]	862		
Propanil		14	12.90	181	35.0[i]	490.0	7.79[l]	3,817		
Missouri:										
2,4,5-T	16	4	9.50	38	41.1[a]	164.4	8.44[j]	1,388	1,350	
Silvex, 2,4-D & propanil	16	4	N.A.	49	N.A.	154.5	N.A.	1,276	1,227	123
Silvex		1	9.50	10	41.1[a]	41.1	8.44[j]	347		

continued

Table 21--Annual use and returns for 2,4,5-T and projected returns with alternative scenarios 4-6 years after 2,4,5-T becomes unavailable--rice growing areas of Arkansas, Mississippi, Louisiana and Missouri (Continued)

Area & alternative treatment	Acres in area[a/]	Treated acres[b/]	Per acre treatment cost[c/]	Total cost[d/]	Per acre yield	Total production[e/]	Value per cwt	Total value[f/]	Total value less treatment costs	Loss with best alternative[g/]
	---Thousands---		Dollars	Thousand Dollars	CWT	Thousand CWT	Dollars	---------Thousand Dollars---------		
2,4-D		0	----	----	----	----	----	----		
Propanil		3	12.90	39	37.8[i/]	113.4	8.19[l/]	929		
2,4-D & propanil	16	4	N.A.	46	N.A.	152.9	N.A.	1,256	1,210	140
2,4-D		1	7.40	7	39.5[h/]	39.5	8.27[k/]	327		
Propanil		3	12.90	39	37.8[i/]	113.5	8.19[l/]	929		
Totals, 4 states:										
2,4,5-T	1,075	292	9.50	2,775	43.1	12,574.5	8.26	103,925	101,150	
Silvex, 2,4-D & propanil	1,075	292	10.66	3,112	41.1	12,012.6	8.12	97,568	94,456	6,694
Silvex		96	9.50	913	----	4,152.1		34,350		
2,4-D		60	7.40	444	----	2,604.0		21,327		
Propanil		136	12.90	1,755	----	5,256.5		41,891		
2,4-D & propanil	1,075	292	10.26	2,996	40.5	11,821.3	8.06	95,279	92,283	8,867
2,4-D		140	7.40	1,035	42.6	5,957.4	8.15	48,574		
Propanil		152	12.90	1,961	38.6	5,863.9	7.96	46,705		

a/ Data taken from Tables 1 and 6; average for 1975-1977.

continued

Table 21--Annual use and returns for 2,4,5-T and projected returns with alternative scenarios 4-6 years after 2,4,5-T becomes unavailable--rice growing areas of Arkansas, Mississippi, Louisiana and Missouri (Continued)

b/ Data derived from official state records when available, from surveys, and from estimates made by professional workers in given areas. Personal communications between Roy Smith, USDA-SEA-AR, Stuttgart, AR and John B. Baker, LSU, Baton Rouge, LA, June 23, 1978; Ted Miller and Don Bowman, MSU, Stoneville, MS, June 23, 1978; Harold Kerr and Joe Scott, Delta Center, U. Missouri, Portageville, MO, June 19, 1978; Ford Eastin, Texas A&M University, Beaumont, TX, June 21, 1978; Don Seaman, U. of CA, Biggs, CA, June 20, 1978; Baldwin (1978). When silvex is substituted for 2,4,5-T, we estimate that in Arkansas 35, 35, and 30 percent of the 2,4,5-T treated acreage will be treated with silvex, 2,4-D, and propanil, respectively; we estimate that in Mississippi, Louisiana, and Missouri 30 and 70 percent of the 2,4,5-T treated acreage will be sprayed with silvex and propanil, respectively; if silvex is available no 2,4-D will be used in Mississippi, Louisiana, and Missouri.

c/ Data taken from Table 22.

d/ Treated acres times per acre treatment cost.

e/ Treated acres times per acre yield.

f/ Total production times value per cwt.

g Total value less treatment costs for 2,4,5-T minus total value less treatment costs for alternative.

h/ Based of 4 percent yield loss estimated in biological assessment.

i/ Based on 8 percent yield loss estimated in biological assessment.

j/ Data taken from Table 5.

k/ Based on 2 percent quality loss estimated in biological assessment.

l/ Based on 3 percent quality loss estimated in biological assessment.

SOURCE: Natural Resource Economics Division, Economics, Statistics, and Cooperatives Service, U.S. Department of Agriculture, Corvallis, Oregon.

rice now being treated with 2,4,5-T (table 16). The pattern of use would be applications of silvex (ester) on rice where it could be used safely. Silvex would be used on about 35 percent of the 2,4,5-T treated acreage in Arkansas, mainly in the Mississippi River Delta area where cotton is intercropped with rice; it would be used on about 30 percent of the 2,4,5-T treated acreage in Mississippi, Louisiana, and Missouri, especially where cotton is intercropped with rice. Also, silvex would be used in all of these areas where early-season applications are required to control early infestations of broadleaf, aquatic, and sedge weeds. About 35 percent of the rice in Arkansas would be treated with 2,4-D; it would be used principally in the prairie rice-producing areas where cotton is not grown and where soybeans, which are highly susceptible to silvex, is intercropped with rice. 2,4-D would not be used in the 2,4,5-T use areas of Mississippi, Louisiana, and Missouri because cotton, which is highly susceptible to 2,4-D, is grown near rice. Where silvex or 2,4-D could not be used, propanil would be used on the remainder of the acreage presently being treated with 2,4,5-T; we estimate that propanil would be used for broadleaf weed control on about 30 percent of the 2,4,5-T acreage in Arkansas and about 70 percent of the acreage in Mississippi, Louisiana, and Missouri.

Problems that would be encountered with the use of silvex, 2,4-D and propanil substituted for 2,4,5-T include: (a) only the ester formulations of silvex, which are somewhat volatile in the high temperature (90°F +) ricefield environment, control weeds of rice effectively, (b) silvex, which is significantly more injurious than 2,4,5-T to nontarget soybeans and cotton, would be used in fewer weed control situations than 2,4,5-T, and (c) the maximum registered rate of propanil may have to be amended to control the grass and broadleaf weed complex.

Other Herbicides

Molinate, which is used on about 47 percent of the rice in the U.S., is not a substitute for 2,4,5-T (tables 4 and 19). Molinate does not control the principal broadleaf and aquatic weeds that are troublesome in the 2,4,5-T use areas (table 19). It is ineffective on hemp sesbania, northern jointvetch, ducksalad, morningglory, and redstem.

MCPA, which is used principally in Texas and California (table 1), is less effective on many broadleaf weeds of rice (Smith et al. 1977). MCPA is not used in the 2,4,5-T use areas of Arkansas, Mississippi, northern Louisiana, and Missouri because it is relatively ineffective on hemp sesbania, northern jointvetch, and Indian jointvetch (table 4).

Bifenox, bentazon, and oxadiazon are three new herbicides that have only recently been registered for use in rice (Arkansas Cooperative Extension Service 1978e). However, they are now used on less than 2 percent of the rice in the 2,4,5-T use areas (table 1). Bifenox and oxadiazon are applied during the early season for control of barnyardgrass, sprangletop, and the aquatic-weed complex. Bentazon is applied during the early to midseason stages of growth for the control of redstem, dayflower, smartweed, and umbrellasedges. Oxadiazon and bentazon are frequently mixed with propanil for early postemergence control of weeds. The mixtures control more species of weeds than a single herbicide application.

The use of these three herbicides as substitutes for 2,4,5-T is limited because they do not control most of the broadleaf and aquatic weeds as effectively as 2,4,5-T (table 4). Bifenox and oxadiazon control ducksalad and redstem effectively, but they are only partially effective on hemp sesbania, northern jointvetch, and morningglory. Bentazon controls redstem effectively, gives partial control of ducksalad, and is ineffective on hemp sesbania, northern jointvetch, and morningglory.

Therefore, when these new herbicides are extensively used in rice, they would have only a slight impact on the use of 2,4,5-T for early and midseason control of broadleaf, aquatic, and sedge weeds in rice (USDA-SEA-AR 1978).

Potential Efficacy

Propanil

Propanil is used mainly to control grass weeds in rice. These include barnyardgrass, broadleaf signalgrass, and panicum grasses (table 4). Propanil also controls some broadleaf weeds as effectively as 2,4,5-T; these include eclipta, hemp sesbania, and waterhyssop. However, propanil is significantly less active than 2,4,5-T on many broadleaf, aquatic, and sedge weeds; these include arrowhead, beakrush, burhead, cattail, cocklebur, dayflower, gooseweed, northern and Indian jointvetch, Mexicanweed, morningglory, pondweed, redstem, smartweed, and waterprimrose.

2,4-D

This herbicide is used to control broadleaf, aquatic, and sedge weeds in rice (table 4). It is ineffective on grass weeds. 2,4-D gives excellent control of beakrush, roughseed bulrush, burhead, cocklebur, dayflower, ducksalad, eclipta, false pimpernel, fimbristylis, hemp sesbania, horned pondweed, morningglory, redstem, spikerush, and waterhyssop. It is less effective than 2,4,5-T on gooseweed, northern and Indian jointvetch, Mexicanweed, smartweed, and waterprimrose. 2,4-D is more effective than 2,4,5-T on alligatorweed, ducksalad, and horned pondweed. Therefore, 2,4-D is less effective than 2,4,5-T on 6 weed species, and is more effective on 3 species. They are about equally effective on the other weeds above.

On the 5 major broadleaf and aquatic weeds in the 2,4,5-T use area (tables 19 and 20), 2,4-D is less active than 2,4,5-T on northern jointvetch, more active on ducksalad, and about equal to 2,4,5-T on hemp sesbania, morningglory, and redstem. However, 2,4-D cannot be applied during the early season to control weeds such as ducksalad and redstem (Smith et al. 1977). Ducksalad competition reduces rice yields during the first few weeks after the crop emerges (table 10). Therefore, losses from ducksalad competition would occur before 2,4-D could be applied to the ricefield at midseason.

Propanil And 2,4-D

If both of these herbicides were substituted for 2,4,5-T, they would control weeds better than either used alone. In areas where 2,4-D could be used safely, 2,4-D would give comparable control to 2,4,5-T on hemp sesbania and morningglory; it would be less effective on northern jointvetch, ducksalad and redstem (table 19). In areas where 2,4-D could not be used, propanil would be substituted for 2,4,5-T (USDA-SEA-AR 1978). In these areas propanil controls hemp sesbania as effectively as 2,4,5-T; it gives partial control of northern jointvetch, ducksalad, and redstem; it does not control morningglory which causes more losses from dockage than any weed in the 2,4,5-T use areas of the Mississippi Valley (table 11).

Silvex, 2,4-D And Propanil

If all three of these herbicides were substituted for 2,4,5-T, they would control weeds better than any other alternative to 2,4,5-T. In areas where silvex could be used safely, it would give comparable control to 2,4,5-T on weeds, e.g., hemp sesbania, northern jointvetch, ducksalad, morningglory, and redstem (table 19). Silvex controls most of the weeds listed in table 4 almost as effectively as 2,4,5-T; however, gooseweed, northern jointvetch, Indian jointvetch, Mexicanweed, redstem, smartweed, spikerush, and waterprimrose are controlled slightly less effectively with silvex. The differentials in activity of these two herbicides on these weeds are only slight and would not contribute significantly to increased losses if silvex were substituted for 2,4,5-T.

In areas where 2,4-D could be used safely, it would give comparable control to 2,4,5-T on hemp sesbania and morningglory, but would be less effective on northern jointvetch, ducksalad, and redstem. In areas where silvex or 2,4-D could not be used safely, propanil would be used (USDA-SEA-AR 1978). In these areas propanil controls hemp sesbania as well as 2,4,5-T, it gives partial control of northern jointvetch, ducksalad, and redstem, and it does not control morningglory.

If 2,4,5-T were not available for use in rice, the best weed control would be obtained by combining the use of silvex, 2,4-D and propanil. By doing this, losses in yield and quality could be kept to a minimum. However, even with the use of silvex, 2,4-D and propanil, losses from weeds would be increased substantially when compared with 2,4,5-T (table 16).

Other Herbicides

Molinate does not control the troublesome broadleaf and aquatic weeds that infest rice (table 19). MCPA does not control troublesome leguminous broadleaf weeds (table 4). Bifenox, bentazon, and oxadiazon are only partially effective on the complexes of broadleaf, aquatic, and sedge weeds that infest rice. Therefore, none of these herbicides are effective substitutes for 2,4,5-T.

Effect on Rice Yield and Quality

Propanil

If propanil were substituted for 2,4,5-T on all the acres presently treated with 2,4,5-T, yield and quality losses would average 5 percent and 2 percent, respectively, more than they do now with the use of 2,4,5-T during the first 3-year period after banning 2,4,5-T (table 19). During the second 3-year period after banning 2,4,5-T, losses in yield and quality would average 8 percent and 3 percent, respectively (table 20). Because propanil controls hemp sesbania as effectively as 2,4,5-T, this weed would not cause any losses. Northern jointvetch, ducksalad, and redstem are only partially controlled with propanil; hence, these weeds would increase after 3 years and would cause even greater losses.

However, these losses would be less with the use of propanil than if no controls were used. Since morningglories are not controlled with propanil, they cause losses equal to no controls at all.

2,4-D

If 2,4-D were substituted for 2,4,5-T on all the rice where 2,4,5-T is presently used, yield and quality losses would average 2 percent and 1 percent, respectively more than they do now with 2,4,5-T during the first 3-year cropping cycle (table 19). During the second 3-year period, yield and quality losses would average 4 percent and 2 percent, respectively (table 20). The use of 2,4-D would prevent any losses from hemp sesbania and morningglory; however, losses would occur from northern jointvetch which is only partially controlled by 2,4-D and from ducksalad and redstem because 2,4-D cannot be applied safely to rice during the early growth stages. Because of drift hazards to cotton, and by regulatory restrictions, 2,4-D could be used on only half the present acreage treated with 2,4,5-T (USDA-SEA-AR 1978).

Silvex

Because silvex controls the principal broadleaf weeds of rice as effectively as 2,4,5-T, losses from hemp sesbania, northern jointvetch, ducksalad, and redstem would not occur on rice treated with silvex substituted for 2,4,5-T (tables 19 and 20).

Other Herbicides

Molinate fails to control the weeds listed in table 19. Therefore, losses from these weeds would be as great as if no controls were used. Because MCPA fails to control hemp sesbania and northern jointvetch, it would not be a substitute for 2,4,5-T. The new herbicides--bifenox, bentazon, and oxadiazon--would partially reduce the broadleaf-aquatic weed complex listed in table 19, but they would be substantially less effective than 2,4,5-T. Because these herbicides are so new and they are registered for use in only a few rice-producing areas, no estimates were developed as to their effectiveness in reducing losses in yield and quality of rice.

Costs

Propanil

One application of propanil costs $3.40 per acre more than one application of 2,4,5-T (table 22). Propanil applied at midseason (6-8 weeks after emergence of the crop) controls some broadleaf weeds, e.g. hemp sesbania, as effectively as 2,4,5-T. However, other weeds, e.g. northern jointvetch and morningglory are not controlled as effectively with propanil as with 2,4,5-T. If propanil were substituted for 2,4,5-T in all the rice presently treated with 2,4,5-T, rice farmers would have to spend about $1 million more for the herbicide (table 16). In addition to the extra cost for herbicides, rice farmers would encounter greater yield and quality losses because propanil gives less effective weed control than 2,4,5-T; these losses would amount to about $7.5 million annually (table 16). Therefore, the extra cost of propanil and greater losses in yield and quality, compared with 2,4,5-T, would cost rice farmers more than $8.5 million each year. Also, losses would increase with time because infestations of tolerant weeds would become more prevalent (tables 19 and 20).

2,4-D

An application of 2,4-D costs about $2 per acre less than 2,4,5-T (table 22). 2,4-D applied at midseason (rice internodes 1/8-1/2 inch long) controls many broadleaf weeds as effectively as 2,4,5-T; these include hemp sesbania and morningglory (table 19). However, 2,4-D does not control northern jointvetch, ducksalad, and redstem as effectively as 2,4,5-T. If 2,4-D were substituted for 2,4,5-T in areas where it could be used safely, it would be used on only about half of the rice now treated with 2,4,5-T alone (table 16). If no other herbicides were

Table 22--Estimated cost of using 2,4,5-T and alternate herbicides in rice areas, southern rice producing area, 1975-1977

		Herbicide								
			Propanil[a/]							
Item	Unit	2,4,5-T	One appl.	Two appl.	Molinate	2,4-D	Silvex	Bifenox	Bentazon	Oxadiazon
Quantity	lb	1.0	3.0	6.0	3.0	1.0	1.0	3.0	0.75	0.75
Cost per pound	dol	5.50	3.30	3.30	3.70	3.40	5.50	6.00	14.00	14.50
Herbicide cost/acre[b/]	dol	5.50	9.90	19.80	11.10	3.40	5.50	18.00	10.50	10.90
Application cost/acre[c/]	dol	4.00	3.00	3.00	2.75	4.00	4.00	3.00	3.00	3.00
Total herbicide cost	dol	9.50	12.90	21.80	13.85	7.40	9.50	21.00	13.50	13.90

a/ One application of 3 lb/A controls many broadleaf weeds; two applications at 3 lb/A each control weed grasses.

b/ Based on cost reported by the Arkansas Cooperative Extension Service (1978e, Baldwin (1978) and Mullins et al (1978).

c/ Based on cost reported by the Arkansas Cooperative Extension Service (1978c).

SOURCE: USDA-SEA-AR, Stuttgart, AR.

available, the other half of the acreage would receive no controls. Although rice farmers would spend about $1.7 million less for herbicides if 2,4-D were substituted for 2,4,5-T, their losses in production would be about $10.1 million more (table 16). Therefore, the rice industry would lose over $8.4 million net annually when the use of 2,4-D is compared with 2,4,5-T. Also, losses would increase with time because tolerant weed species would increase.

Propanil And 2,4-D

If propanil and 2,4-D were substituted for 2,4,5-T on all the rice now treated with 2,4,5-T, each herbicide would be used on about half of the acreage presently treated with 2,4,5-T (table 16). If they were used instead of 2,4,5-T rice farmers would spend only $221,000 more annually for herbicides. Because they are less effective than 2,4,5-T, rice production losses would be $5.2 million more each year than they are now with 2,4,5-T during the first 3-year cropping cycle (table 16). Therefore, when the cost of propanil and 2,4-D, and the production losses are compared with 2,4,5-T, the rice industry would lose more than $5.4 million annually. During the second 3-year cropping cycle, losses would be about $8.9 million compared with 2,4,5-T (table 21). Losses would increase with time because tolerant species such as northern jointvetch would build up.

Silvex, 2,4-D And Propanil

If silvex, 2,4-D, and propanil were substituted for 2,4,5-T on all the rice now treated with 2,4,5-T, silvex, 2,4-D, and propanil would be used on about 33, 20 and 47 percent of the rice, respectively (table 16). These three herbicides would be the best substitute treatment in the 2,4,5-T use areas. If they were used instead of 2,4,5-T rice farmers would spend about $337,000 more annually for herbicides. Because they are less effective than 2,4,5-T, rice production losses would be $3.8 million more each year than they are now with 2,4,5-T during the first 3-year cropping cycle (table 16). Therefore, when the cost of silvex, 2,4-D, and propanil, and the production losses are compared with 2,4,5-T, the rice industry would lose more than \$4.2 million annually. During the second 3-year cropping cycle, losses would be about \$6.7 million, compared with 2,4,5-T (table 21). Losses would increase with time because tolerant species such as northern jointvetch would increase.

Anticipated Availability of Other Herbicides

Adequate supplies of propanil and 2,4-D are available for weed control applications. Several chemical companies formulate each of these herbicides which makes for healthy competition and availability at a reasonable cost. Although one application of propanil at 3 lb/A costs about \$3 per acre more than one application of 2,4,5-T, 2,4-D costs about \$2 per acre less than 2,4,5-T (table 22). These costs almost balance and would not be a significant factor in affecting supply and demand. However, supplies of ester formulations of silvex are inadequate at the present time because less than 1 percent of the rice acreage is now treated with this herbicide (table 1). However, silvex inventories could be increased rapidly and supply would meet demand after a few years.

Environmental Effects

The use of chemical alternatives for 2,4,5-T may have an adverse environmental effect. Although propanil is low in phytotoxicity to nontarget crops, 2,4-D is very injurious to cotton and silvex damages soybeans severely (Smith et al. 1977). In the 2,4,5-T use areas cotton and soybeans are the major crops grown nearby ricefields (Smith et al. 1977). If the use of 2,4-D were increased in rice-producing areas where cotton is also grown, spray drift damage could increase to the point of adversely affecting cotton production. If the use of silvex were increased in rice-producing areas where soybeans are a major crop in the rotation, spray drift damage could increase to the level of reducing soybean yields and quality. Cotton and soybean farmers may retaliate and demand a ban on the use of 2,4-D or silvex for weed control in rice. In Arkansas over the past two decades, cotton farmers and other groups have tried on several occasions to obtain a ban on the use of 2,4-D for rice in cotton-growing areas; these movements have been associated with increased use of and injury from 2,4-D (Pay 1978a). Present State regulations prohibit the use of 2,4-D in rice-growing areas where cotton is intercropped with rice (Arkansas State Plant Board 1978). Every effort should be made to have available safe, effective herbicides for weed management in rice. Continuous minor losses to weeds, even when a full array of herbicides are available, suggest that any loss of weed control technology will result in increased weed infestations.

Cultural, Mechanical, and Hand Labor Alternatives

Management of cultural and mechanical weed control practices may be used effectively to control specific weeds (table 23, Smith et al. 1977).

Preventive methods of weed control are required to avoid weed problems before they begin in ricefields. Preventive methods include use of weed-free crop seed (table 23), use of irrigation water free of weed seed or other propagation parts, and use of clean equipment. Conformance to certified seed regulations and use of certified seed are related ways of avoiding weed seed contamination.

Practical cultural-mechanical weed control practices include summer fallowing, seedbed preparation, crop rotations, special seeding methods, management of irrigation water, and cultivation (Smith et al. 1977). Handweeding can also be used if weed infestations are sparse or isolated to small areas in the ricefield.

Table 23--Response of common ricefield weeds to selected cultural practices[a]

Weed	Hand Weeding[b]	Clean rice seed[b,c]	Seedbed prepa- ration	Water seeding	Dry seeding	Timely flood- ing[d]	Timely drain- ing[d]	Rice stand[e]	Summer fallow	Crop rota- tion
Alligatorweed	Poor	Poor	Good	Poor	Poor	Poor	Poor	Good	Good	Good
Arrowhead	Poor	Good	Good	Poor	Good	Poor	Fair	Good	Good	Good
Barnyardgrass	Poor	Good	Good	Good	Poor	Fair	Poor	Fair	Fair	Fair
Beakrush	Poor	Good	Good	Poor	Fair	Poor	Fair	Good	Good	Good
Broadleaf signalgrass	Poor	Good	Good	Good	Poor	Good	Poor	Fair	Fair	Fair
Bulrush	Poor	Poor	Good	Poor	Good	Poor	Good	Poor	Good	Good
Burhead	Poor	Poor	Good	Poor	Good	Poor	Good	Good	Good	Good
Cattail	Poor	Poor	Good	Poor	Good	Poor	Good	Poor	Good	Good
Cocklebur	Poor	Good	Good	Good	Poor	Good	Poor	Good	Poor	Poor
Common waterplantain	Poor	Poor	Good	Poor	Good	Poor	Good	Good	Good	Good
Dayflower	Poor	Good	Good	Poor	Poor	Fair	Poor	Good	Fair	Fair
Ducksalad	Poor	Poor	Poor	Poor	Fair	Poor	Good	Good	Poor	Poor
Eclipta	Poor	Poor	Poor	Good	Poor	Fair	Poor	Good	Fair	Fair
False pimpernel	Poor	Poor	Poor	Poor	Fair	Poor	Good	Good	Poor	Poor
Fimbristylis	Poor	Poor	Poor	Poor	Good	Poor	Good	Good	Poor	Poor
Gooseweed	Poor	Poor	Good	Poor	Good	Poor	Good	Good	Good	Fair

continued

Table 23--Response of common ricefield weeds to selected cultural practices[a] (continued)

Weed	Hand Weeding[b]	Clean rice seed[b,c]	Seedbed preparation	Water seeding	Dry seeding	Timely flooding[d]	Timely draining[d]	Rice stand[e]	Summer fallow	Crop rotation
Hemp sesbania	Good	Good	Good	Fair	Poor	Fair	Poor	Fair	Fair	Fair
Horned pondweed	Poor	Poor	Poor	Poor	Good	Poor	Fair	Good	Fair	Fair
Jointvetch	Good	Good	Good	Fair	Poor	Fair	Poor	Fair	Fair	Fair
Knotgrass	Poor	Poor	Good	Poor	Fair	Poor	Fair	Good	Good	Good
Mexicanweed	Good	Good	Good	Fair	Poor	Fair	Poor	Fair	Fair	Good
Morningglory	Poor	Good	Good	Good	Poor	Good	Poor	Good	Poor	Poor
Naiad	Poor	Poor	Fair	Poor	Good	Poor	Fair	Good	Fair	Fair
Panicum grasses:										
Annuals	Poor	Poor	Fair	Good	Poor	Fair	Poor	Good	Good	Good
Perennials	Poor	Poor	Good	Poor	Poor	Fair	Poor	Good	Good	Good
Pondweed	Poor	Poor	Good	Poor	Good	Poor	Fair	Good	Good	Good
Red Rice	Good	Good	Good	Fair	Poor	Poor	Poor	Fair	Good	Good
Redstem or purple ammannia	Poor	Poor	Poor	Poor	Fair	Poor	Good	Good	Poor	Poor
Smartweed	Poor	Good	Good	Poor	Fair	Poor	Poor	Good	Good	Good
Spikerush:										
Annuals	Poor	Poor	Fair	Poor	Fair	Poor	Good	Good	Good	Good
Perennials	Poor	Poor	Good	Good	Poor	Poor	Poor	Good	Good	Good
Sprangletop	Poor	Good	Fair	Poor	Poor	Poor	Poor	Good	Good	Good

continued

Table 23--Response of common ricefield weeds to selected cultural practices[a/] (continued)

Weed	Hand Weeding[b/]	Clean rice seed[b,c/]	Seedbed prepa-ration	Water seeding	Dry seeding	Timely flood-ing[d/]	Timely drain-ing[d/]	Rice stand[e/]	Summer fallow	Crop rota-tion
Umbrellaplant:										
Annuals	Poor	Poor	Fair	Poor	Fair	Poor	Good	Good	Good	Good
Perennials	Poor	Poor	Good	Fair	Poor	Fair	Poor	Good	Good	Good
Waterhyssop	Poor	Poor	Poor	Poor	Fair	Poor	Good	Good	Poor	Poor
Waterprimrose	Poor	Good	Good	Poor	Fair	Poor	Fair	Good	Good	Good

a/ From Smith et al, 1977. Ratings for classes of cultural practice: Good - practice can be used effectively in commercial rice to prevent or reduce weed infestations. Fair - practice can be used in commercial rice but usually gives only fair weed control. Poor - practice cannot be used economically in commercial rice or fails to control the weed.

b/ These practices are ineffectice if land is already contaminated with weed propagules.

c/ Seeding weed-free crop seed reduces problems with all weeds. A poor rating indicates that weed seeds do not usually contaminate seed rice. (Weed seeds are not harvested with the crop or can be removed easily with commercial cleaning equipment). A good rating indicates that the weed seeds are difficult to remove from the rice seed and special effort is required to remove the weed seeds.

d/ After crop emergence.

e A good rice stand of 12 to 20 plants per square foot helps reduce problems with many weeds.

SOURCE: USDA-SEA-AR, Stuttgart, AR.

Efficacy

Fallowing and Seedbed Preparation

Summer fallowing of riceland controls and reduces infestations of many broadleaf, aquatic, and sedge weeds that are controlled by 2,4,5-T (Smith et al. 1977). Weeds that this practice or 2,4,5-T reduce include: alligatorweed, arrowhead, beakrush, burhead, cattail, gooseweed, morningglory, pondweed, smartweed, spikerush, umbrellaplant, and waterprimrose (tables 4 and 23). Some broadleaf and aquatic weeds that are controlled by 2,4,5-T are not controlled well by fallowing; these include cocklebur, dayflower, ducksalad, eclipta, false pimpernel, fimbristylis, hemp sesbania, northern and Indian jointvetch, Mexicanweed, redstem, and waterhyssop. Because many of these weeds have hard seed that live in the soil for long periods (Smith et al. 1977), they are not reduced to practical levels by fallowing. Even if fallowing controlled weeds effectively, most farmers do not have capital or land reserves that would permit a large scale fallowing program. (Baldwin 1978). Consequently, 2,4,5-T or other herbicide applications are required to control these weeds in the rice crop.

Thorough seedbed preparation helps to control most weeds that infest ricefields. The goal is the elimination of all weed growth up to the time of planting. Repeated cultivations in the spring at 1- to 3-week intervals before seeding rice, reduce many weeds that are controlled by 2,4,5-T (Smith et al. 1977). These include alligatorweed, arrowhead, beakrush, cattail, gooseweed, hemp sesbania, northern and Indian jointvetch, Mexicanweed, morningglory, and others (tables 4 and 23). Although these weeds are reduced by preparing the seedbed well, many of them have seeds that contaminate the soil and remain viable for many years (Smith et al. 1977). The weed seed germinates after the rice crop is planted and must be controlled by other practices. Some troublesome weeds included in this category are hemp sesbania, northern jointvetch, and morningglory; these three can be controlled by 2,4,5-T.

Crop Rotation

Properly managed rotations combined with the use of herbicides are important for controlling many troublesome weeds of rice (table 23) (Smith et al. 1977). Keeping all crops in the rotation free of weeds reduces weeds in the rice crop. In the 2,4,5-T use areas of Arkansas, Mississippi, northern Louisiana, and Missouri, soybeans are frequently rotated with rice (Huey 1977). A common rotation is one year of rice and two years of soybeans. Rotating an upland row crop, e.g. soybeans, with rice is excellent for controlling perennial broadleaf weeds that are also controlled by 2,4,5-T; weeds controlled by this practice include alligatorweed, arrowhead, beakrush, burhead, cattail, smartweed, spikerush, umbrellaplant, and waterprimrose (table 23). However, many annual broadleaf and aquatic weeds that produce seed which remain viable for years in the soil, are not reduced by crop rotations. Seeds of these weeds germinate as soon as the land is returned to rice. 2,4,5-T is frequently required to control weeds of this category, e.g., hemp sesbania, northern jointvetch, morningglory, ducksalad, and redstem. Controlling weeds, e.g., hemp sesbania and northern jointvetch, in the rice crop helps lower infestations in rotation crops, e.g., soybeans; weed control technology in soybeans is inadequate to control these species (Baldwin 1978).

Seeding Method

Rice may be drill-seeded, broadcast-seeded in moist soil and disked or harrowed to cover, or water-seeded (Smith et al. 1977). The method of seeding influences subsequent weed growth and weed control. Water-seeding may be used selectively to control hemp sesbania, northern jointvetch, and morningglory (table 23). To be effective the water must be held at 4 inches for 3 to 4 weeks after seeding. Such management is frequently injurious to rice. It may be difficult to obtain an adequate rice stand, if the floodwater is kept on the field for long periods. Frequently the floodwater must be removed to favor rice growth. Consequently, during the drained period, weeds such as hemp sesbania, northern jointvetch, and morningglory germinate and grow. They must be controlled by 2,4,5-T or other herbicide applications. Even if the floodwater can be kept on the ricefield without damaging the rice, these weeds are not controlled on the levees. Therefore, levees must be treated with 2,4,5-T or other herbicide applications to control the above weeds. Water-seeding increases problems with aquatic species, e.g., ducksalad, redstem, gooseweed, waterhyssop, false pimpernel, and spikerush. When these weeds develop in water-seeded rice, they must be controlled with applications of 2,4,5-T or other herbicides.

Water Management

Timely flooding or draining reduce problems with many weeds that are also controlled by 2,4,5-T (tables 4 and 23, Smith et al. 1977). Applying floodwater to young morningglory weeds kills some species (table 18); however, plants growing on levees are not controlled by this practice. Also, willowleaf morningglory which grows in the paddy is not controlled by floodwater. These weeds must be controlled by 2,4,5-T or other herbicide applications.

Aquatic weeds that germinate and grow in flooded ricefields, can be reduced by timely draining (table 23) (Smith et al. 1977). Weeds that are reduced by this practice and by 2,4,5-T applications include the aquatic weed complex of ducksalad, false pimpernel, gooseweed, redstem, spikerush, umbrellaplant, and waterhyssop. Frequently, drying ricefields cannot be accomplished while the weeds are small and susceptible to desiccation because of rainy weather during the critical period. Also, drying sufficiently to kill the aquatic weed complex may desiccate and injure young rice. In addition, dried ricefields may become reinfested with grass weeds that must be controlled by applications of herbicides; drying ricefields also cause losses of nitrogen fertilizer. (Arkansas Cooperative Extension Service 1978e). Therefore, drying of ricefields to control weeds is not a dependable and predictable tool in a weed management system and can be costly. 2,4,5-T or other herbicide applications are frequently required to control weeds that cannot be controlled by drying methods.

Handweeding and Cultivation

Although handweeding is the main method of weed control in Asian countries (where rice is transplanted into rows), it is used only to remove scattered infestations in rice grown for seed in the U.S. (Smith et al. 1977, table 23). Mechanical cultivation methods, except for rotary hoeing, to remove weeds after the rice crop has been seeded are usually not practical. In drill-seeded (6-inch spacing) rice cultivation between rows to remove weeds is difficult because of levees, and in dry-broadcast or water-seeded rice cultivation is impossible.

Rotary hoeing soon after crop emergence controls small weeds in dry-seeded rice (Smith et al. 1977). It is the only practical method of cultivation after seeding, but it is seldom used because it is only effective on small weeds when the soil is neither too dry nor too wet. Also, levees interfere with this weed-control practice.

Consequently, 2,4,5-T or other herbicide applications are required to control weeds in ricefields that cannot be controlled by handweeding or cultivation.

Costs of Cultural Mechanical and Hand Labor Alternatives

Fallowing and Seedbed Preparation

Summer fallowing is an expensive and a relatively ineffective alternate to 2,4,5-T (Smith et al. 1977). If the land is fallowed, soybeans, grain sorghum, cotton, or lespedeza--important cash crops in the 2,4,5-T use area--are not produced. Per acre gross income in 1976 from these crops averaged $130 for soybeans, $110 for grain sorghum, $240 for cotton, and $130 for seed lespedeza (USDA-SRS 1977). Rice farmers cannot stand such massive losses of income on one-half to two-thirds of their tillable land.

Rice farmers are presently spending substantial amounts of money for seedbed preparation. In 1977 an estimated $40 per acre was spent on seedbed preparation; approximately one-half or $20 per acre of this cost is prorated to weed control (Mullins et al. 1978). Presently, farmers are doing an acceptable job in controlling weeds up to the time of seeding with seedbed preparation practices, especially the broadleaf-aquatic weed complex that is controlled by 2,4,5-T. Because weeds germinate after seeding the crop, additional inputs and costs for preplant seedbed preparation would not substitute for 2,4,5-T applications.

Seeding Method

Water-seeding rice for weed-control purposes is frequently not practical because farmers do not have sufficient water supplies to flood fields rapidly and the water frequently contains salts which prevent seeding rice into the water (Arkansas Cooperative Extension Service 1978e, Baldwin 1978). The practice of water-seeding to control weeds susceptible to 2,4,5-T requires an extra flooding and draining in the rice-production process (Huey 1976). This additional irrigation management costs about $7 per acre. Also, this practice requires about 40 pounds per acre of extra seed rice valued at $5 per acre (Huey 1977). Therefore, the direct effects of water-seeding for weed control cost rice farmers an extra $12 per acre. Because this practice intensifies problems with aquatic weeds, the farmer may have to make an extra application of propanil valued at $13 per acre to control aquatic weeds (table 22). The farmer may encounter yield and quality losses because propanil does not control aquatic weeds as effectively as 2,4,5-T; this loss is valued at $23 per acre (USDA-SEA-AR 1978). The direct cost of water-seeding and the indirect cost of applying extra herbicide and losses in yield and quality may cost the rice farmer as much as $48 per acre. Consequently, 2,4,5-T is needed for use in rice to prevent the need for water-seeding and the associated extra costs of production.

Water Management

Draining after permanent flooding to control the aquatic weed complex can be costly to the farmer. An extra draining and reflooding costs about $7 per acre (Huey 1976). Because nitrogen is usually applied by the time of permanent flooding, draining and reflooding decreases its efficiency as much as 50 percent (Huey 1976); if we assume a 20 percent loss, the additional nitrogen required costs about $2 per acre. During the drained-period, grass weeds may reinfest the ricefield and require an application of propanil valued at $13 per acre (table 22). Therefore, draining and flooding to control weeds that would normally be controlled by 2,4,5-T cost the rice farmer $22 per acre.

Flooding fields early to control such weeds as morningglory can be costly to the farmer. Frequently, early flooding injures rice growth with subsequent yield losses, especially on high pH soil (Huey 1977). Yield losses as high as 10 percent might be expected (Huey 1976); this loss is valued at $36 per acre. Therefore, 2,4,5-T is needed to control weeds and permit management of irrigation water in a way advantageous to the rice plant.

Handweeding and Cultivation

Handweeding for control of weeds reduced by 2,4,5-T is costly to rice farmers. Only a few weed species can be handweeded effectively (table 23, Smith et al. 1977). Handweeding sparse infestations of hemp sesbania and northern jointvetch requires 4 to 8 man hours per acre, valued at $12 to $24. Handweeding also causes some damage to the rice because walking through the field breaks down the rice plants (Arkansas Cooperative Extension Service 1978e).

Cultivation after seeding by rotary hoeing is so ineffective that this practice is not a viable alternate to 2,4,5-T (Smith et al. 1977).

Effect on Yield

Many of the cultural-mechanical-handweeding practices implemented specifically for weed control are injurious to rice (Smith et al. 1977, Huey 1977); such practices frequently reduce yield and quality of the crop. Fallowing land during the summer eliminates all crop production. The use of special seeding practices e.g., water-seeding may reduce rice stands and yields when practiced after temperatures become hot in late May and June. Early flooding or timely draining to control weeds may not favor rice growth; subsequently, yield and quality of the rice crop may be lowered. Walking through rice fields during mid-season to late-season growth stages to perform handweeding practices can break jointing rice plants with subsequent yield and quality reductions.

Anticipated Availability

The cultural-mechanical weed control practices are adequately available and are presently used extensively by rice farmers. However, they are only moderately effective for special weed-control problems and some are very costly to farmers (table 23, Smith et al. 1977). For example, fallowing, which does not permit crop production during one production cycle, is very costly to the farmer who usually cannot afford the loss of income from the land.

Hand labor to perform weed-control tasks in rice is generally not available to rice farmers. Presently only about 12 man hours, exclusive of labor for handweeding, are required to grow an acre of rice at a cost of $47 per acre; this includes labor for land preparation, irrigation, harvesting, and other practices (Mullins et al. 1978). Even if hand labor were available for weed-control tasks, the farmer could not afford to bear the cost. The use of hand labor to control weeds would double to quadruple the labor requirement for rice production; this would cost the farmer $100-$200 more per acre to produce rice and subsequently would limit or prohibit rice production because the cost of such practices would consume all of the profit.

If cultural-mechanical weed control inputs had to be increased because 2,4,5-T were unavailable, use of equipment and labor for machinery operations would increase. In 1977 rice farmers spent about $40 per acre for tractor and equipment fuel and repairs and for labor to operate the equipment (Mullins et al. 1978). The increased use of energy in times of short supply would be counter productive to the U.S. national policy of energy conservation. If weeds were not controlled with 2,4,5-T or other herbicides, it is estimated that farmers would have to spend 50 percent more than they do now for extra preplanting land preparation (Arkansas Cooperative Extension Service 1978e). Therefore, preplant operations (tractor and equipment fuel, repair, and labor) would cost the farmer a total of $60 per acre. Also, the farmer would need more laborers who are frequently unavailable to carry out these operations.

If hand labor were increased for weed control tasks because 2,4,5-T was unavailable, laborers would have to perform the difficult and mundane tasks of handweeding. Laborers for handweeding tasks are usually not available in sufficient quantities required for effective control of weeds that are controlled by 2,4,5-T (Arkansas Cooperative Extension Service 1978e). In addition, this would increase the cost of production and make rice growing unprofitable.

Because the use of cultural-mechanical-hand labor weed control practices instead of herbicides would lower rice yields and quality, rice supplies in the 2,4,5-T use areas of Arkansas, Mississippi, northern Louisiana, and Missouri would be reduced (Smith et al. 1977, Gerlow 1973). This would alter present processing and marketing channels with subsequent adverse effects on the rice industry (Gerlow 1973). Jobs and the economy in these rice-producing areas could be seriously altered.

Environmental Effects of Alternatives

The use of cultural, mechanical, and hand labor alternatives to 2,4,5-T would have only minor direct effects on the environment. Of the various management practices discussed, only summer fallowing and crop rotations would cause any direct effects on the environment.

As indicated above, summer fallowing is not a valid alternate to 2,4,5-T in a weed management program for rice (Arkansas Cooperative Extension Service, 1978e). Farmers cannot afford to let the land be idle during the summer. They must at least grow an alternate upland crop to produce needed income. Because fallowing land is an impractical alternate and would not be used by farmers as an alternate to 2,4,5-T, its effects on the environment will not be discussed.

Although cropping systems alone are ineffective in controlling most weeds controlled by 2,4,5-T (Smith et al. 1977), they could be used in combination with alternate herbicides, such as propanil, 2,4-D, and integration of both to reduce weeds if 2,4,5-T were unavailable. The practice of growing upland crops more frequently on land to reduce weeds controlled by 2,4,5-T may affect soil erosion and compaction, rice production, and sedimentation in the aquatic environment.

Terrestrial Environment

Cultural, mechanical, and hand labor alternatives to 2,4,5-T would have insignificant net effects on vegetation or animals inhabiting ricefields or crops rotated with rice except to increase the diversity of weed communities (USDA-SEA-AR 1978).

The more frequent use of upland crops such as soybeans, cotton, and grain sorghum could increase soil erosion (USDA-SEA-AR 1978). Land that grows upland crops in the 2,4,5-T use areas of Arkansas, Mississippi, Louisiana, and Missouri is not terraced or leveed. Consequently, water from heavy rains drains from upland fields faster than from leveed ricefields; the water running from the upland fields erodes the soil.

Also, frequent production of upland crops may contribute to soil compaction (USDA-SEA-AR 1978). Upland crops are usually grown in rows to permit cultivation. The use of heavy cultivation equipment several times during the growing season compacts the soil. Because rice is not cultivated, heavy cultivation equipment would not compact the soil after the crop is planted.

Cultural, mechanical, and hand labor practices would have insignificant effects on the environment as related to future management options and commodity production if managed so as to maintain a functional rice-cropping system. If a change in the cropping system was forced by elimination of needed herbicides, the environmental changes would be substantial.

Aquatic Environment

The use of cultural-mechanical weed control practices as alternatives to 2,4,5-T would have insignificant effects on water quality, animals, and downstream water users. However, the increased frequency of growing upland crops may increase sedimentation and turbidity in streams because of greater soil erosion (USDA-SEA-AR 1978). It is generally believed that cropping systems would not shift enough to alter the sedimentation problem. Presently less than 15 percent of the land in the 2,4,5-T use area is devoted to rice; upland crops are grown on the remainder (USDA-SRS 1977). Even if all the land were shifted from rice to upland crops, the change would have only minor impact on erosion and sedimentation.

Do Nothing

Effects on Yield and Quality

If no herbicide treatments were substituted for 2,4,5-T in the rice-growing areas of Arkansas, Mississippi, Louisiana, and Missouri, where this herbicide is being used, losses in yield and quality of the crop are estimated at 13 and 4 percent, respectively, during the first 3-year cropping cycle (table 19). On the 292,000 acres presently treated aerially with 2,4,5-T, the average yield and quality losses are estimated at about $43 and $13, respectively (USDA-SEA-AR 1978). If no controls are used, the total value of these losses are estimated at more than $14 million annually (table 16). During the second 3-year cropping cycle, yield and quality losses would average 16 and 5 percent, respectively (table 20).

Effects on Future Management Options and Commodity Production

If 2,4,5-T were canceled for use in rice in the Arkansas, Mississippi, northern Louisiana, and Missouri rice-producing areas, farmers would have ineffective weed control practices available for control of broadleaf, aquatic, and sedge weeds in rice (table 19). Although the use of cultural-mechanical-crop management weed-control practices would increase, they would be less effective than 2,4,5-T (tables 4 and 23). In addition, other herbicides, that are less effective on ricefield weeds, would have to be substituted for 2,4,5-T to reduce losses and permit rice farmers to continue in business (table 4). Many of these alternate herbicides are more costly than 2,4,5-T (table 22); thus, the farmer would spend more for weed control inputs than he does now, a move which would reduce profits directly. In the short term some of the newer herbicides are available only in limited quantities, and could not be supplied to farmers in sufficient amounts to carry out weed-control programs.

In summary, yield and quality losses and increased costs for weed control inputs would have adverse effects on the rice farmer, the rice industry, and agribusiness in rice-producing areas of Arkansas, Mississippi, northern Louisiana, and Missouri.

If 2,4,5-T were not used on the 292,000 acres presently treated aerially, the average per acre yield would be reduced from 44 to 38 cwt. (tables 3 and 19). In addition, the rough rice would be contaminated with large quantities of weed seed which would lower the grade of the rice (table 11). Rice farmers are receiving about $160 per acre net returns above variable and fixed costs (Arkansas Cooperative Extension Service 1978c). No control of broadleaf, aquatic, and sedge weeds would result in the loss of $56 per acre (USDA-SEA-AR 1978). Therefore, if weeds susceptible to 2,4,5-T were not controlled, net returns above variable and fixed cost would be only about $100 per acre. After 4 to 6 years, yield and quality losses would be even greater because resistant weeds would build up (tables 19 and 20).

The loss of $56 per acre might appear to be a relatively small percentage of the total income from the crop. This loss, however, is all absorbed by the farmer since the overhead for the production system is constant. In rice, as for other cropping systems, the farmers' income is the residue after milling, shipping, and sales costs have been deducted from retail income. Small changes in retail prices, therefore, have a disproportionately heavy impact on farm price and future cropping systems. Consequently, there is a high uncertainty factor in the farmers' income.

Significant change in profits from rice production would shift rice land to production of more profitable crops, e.g. soybeans, grain sorghum, and cotton. The reduced rice production in the Mississippi Valley areas would adversely affect rice supplies and the existing processing and marketing patterns (Gerlow 1973). Other rice-producing states would supply the market for high-quality rice now produced in the 2,4,5-T use areas. Such drastic changes in rice production would affect the entire agribusiness of rice-producing areas of Arkansas, Mississippi, northern Louisiana, and Missouri.

Marketing patterns in the 2,4,5-T use areas of Arkansas, Mississippi, northern Louisiana, and Missouri indicate that most of the production is high-quality rice that moves into domestic and foreign dollar markets (table 7, Gerlow 1973). If these areas are unable to meet demands for high-quality rice, other rice-producing states, e.g., Texas, would shift some of their high-quality export rice into these markets. Such shifts would alter existing marketing agencies now active in the 2,4,5-T use areas. Dollar rice markets could also be affected since the major asset of the U.S. rice industry is high-quality rice (Gerlow 1973). Exports of inferior-quality rice could mean losses in dollar sales and in foreign exchange for the U.S. The rice carryover could increase and the U.S. Government would have more rice to move through Federal programs that use lower quality rice.

ECONOMIC IMPACT FROM LOSS OF 2,4,5-T

To summarize the expected revenue losses from the lack of 2,4,5-T during the first two cropping cycle periods, it is necessary to express each year's loss in terms of value as of a base year. This is accomplished by discounting the estimated future revenue losses and reduced spray costs without 2,4,5-T back to a present value for 1978, using a rate of 7 percent. This is a reasonable procedure because a $1 loss in 1979 or any future year, is worth less to a rice producer than a $1 loss in 1978.

Reductions in the total value of rice (given current prices) from lower production and increased downgrading due to weed competition and weed associated foreign matter in the harvested rice are expected to be $3.6, $3.3, $3.1, $4.9, $4.5, and $4.2 million at the end of the first, second, third, fourth, fifth, and sixth year respectively, without 2,4,5-T if silvex, 2,4-D, and propanil are available (table 24) _ceteris paribus_. If silvex, which is similar to 2,4,5-T becomes unavailable, reductions in total value of rice would be expected to increase to $4.8, $4.5, $4.2, $6.6, $6.2, and $5.8 million respectively, during the first six years that both 2,4,5-T and silvex are unavailable _ceteris paribus_. Added to these losses would be the increased cost of the alternative, less-effective, weed-control programs (table 16). When the higher costs of alternative control programs are considered, the total impacts on net present income to rice producers from the use of the alternative weed control programs are, _ceteris paribus_ $3.9, $3.6, $3.4, $5.1, $4.8, and $4.5 million respectively during the first six years if silvex, 2,4-D, and propanil are available (table 24). Again, if silvex becomes unavailable, the total impact would be $5.0, $4.7, $4.4, $6.8, $6.3, and $5.9 million respectively, during the first six years. It is stressed

Table 24--Summary of short and mid-term losses in rice if 2,4,5-T is unavailable for weed control[a/]

Alternative and year	Reduced grower revenue discounted to 1978	Increased weed-control costs without 2,4,5-T discounted to 1978	Total impact discounted to 1978
	----------Thousands of dollars----------		
Silvex, 2,4-D, & Propanil:			
End of year 1..........	3,573[b/]	315[b/]	3,888
2..........	3,339	294	3,633
3..........	3,121	275	3,396
4..........	4,850[c/]	257[c/]	5,107
5..........	4,532	240	4,772
6..........	4,236	225	4,461
	23,651	1,606	25,257
2,4-D & Propanil:			
End of year 1..........	4,797[d/]	207[d/]	5,004
2..........	4,483	193	4,676
3..........	4,190	180	4,370
4..........	6,596[c/]	169[c/]	6,765
5..........	6,165	158	6,323
6..........	5,761	147	5,908
	31,992	1,054	33,046

a/ Two best alternative weed-control programs from tables 16 and 21 are shown for comparison purposes.

b/ Years 1 to 3 discounted from 4 state summary in table 16, i.e. reduced revenue, column 9=$103,925,000-100,102,000 $3,823,000 x 7% discount factor = $3,573; increase cost, column 5=$3,112-2,775=$337 x 7% discount factor = $315.

c/ Years 4 to 6 discounted from 4-state summary in table 21 similar to above.

d/ Years 1 to 3 discounted from 4-state summary in table 16 similar to above.

SOURCE: Natural Resource Economics Division, Economics, Statistics, and Cooperatives Service, U.S. Department of Agriculture, Corvallis, OR.

that these impact estimates assume <u>ceteris paribus</u> conditions in rice production and marketing.

Average gross return for rice in the four states using 2,4,5-T to control weeds in rice is estimated to be $347 per acre (table 25). This estimate is the weighted average value received by farmers during the 1975, 1976, and 1977 seasons. Average production costs in the four states with 2,4,5-T are $255 per acre. Thus, the average returns to land, overhead, risk, and management for rice in the four states is $92 per acre with 2,4,5-T. Average returns to land, overhead, risk, and management with 2,4,5-T are expected to decrease from $92 per acre per year to $78 per acre per year during the first rotation period (table 25). During the second rotation period (second three years), average returns are expected to decrease to $72 per acre per year.

Additional losses are expected if 2,4,5-T and silvex are both unavailable. Average returns to land, overhead, risk, and management without 2,4,5-T and silvex are expected to decrease from $92 per acre per year to $74 per acre per year during the first rotation period (table 26). During the second rotation period (second three years), average returns are expected to decrease to $62 per acre per year.

Expected changes in rice production in the four states due to a lack of 2,4,5-T for weed-control in rice are small compared to U.S. total rice production and range from .04 to .08 percent of U.S. rice production (table 27). However, in the 2,4,5-T use area these yield losses represent 0.7 to 1.6 percent of the total production (table 27).

If 2,4,5-T and other herbicides are unavailable for use in rice, farmers may substitute soybeans or other crops for rice because alternate crops may be more profitable than rice. Comparing the per-acre returns for rice without 2,4,5-T and silvex (tables 25 and 26) to the per-acre returns for soybeans (tables 28 and 29) suggests that rice farmers in Louisiana, Mississippi, and Missouri might shift rice to soybeans if 2,4,5-T and silvex become unavailable. Annual per-acre returns for rice and soybeans compare as follows:

Table 25--Average annual per-acre returns to land, overhead, risk, and management with and without 2,4,5-T on the 292,000 acres of rice needing a herbicide treatment, such as 2,4,5-T, in Arkansas, Mississippi, Louisiana, and Missouri, treated year, and first and second rotation in untreated period a/

No. years without 2,4,5-T	Gross returns with 2,4,5-T b/	Increased costs & loss of gross returns per acre c/	Gross returns without 2,4,5-T	1975-77 Production costs d/	Returns to land, overhead, risk, and management
	----------	----------	Dollars	----------	----------
Arkansas:					
0................	377	0	377	255	122
1-3...............	377	12	365	255	110
4-6...............	377	20	357	255	102
Mississippi:					
0................	327	0	327	254	73
1-3...............	327	18	309	254	55
4-6...............	327	27	300	254	46
Louisiana:					
0................	305	0	305	254	51
1-3...............	305	17	288	254	34
4-6...............	305	25	280	254	26
Missouri:					
0................	347	0	347	248	99
1-3...............	347	21	326	248	78
4-6...............	347	31	316	248	68
Average, 4 states:					
0................	347	0	347	255	92
1-3...............	347	14	333	255	78
4-6...............	347	23	327	255	72

continued

Table 25--Average annual per-acre returns to land, overhead, risk, and management with and without 2,4,5-T on the 292,000 acres of rice needing a herbicide treatment, such as 2,4,5-T, in Arkansas, Mississippi, Louisiana, and Missouri, treated year, and first and second rotation in untreated period a/ (Continued)

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a/ Returns to land, overhead, risk, and management were estimated assuming ceteris paribus conditions with respect to price and production levels.

b/ Average per acre gross returns for 1975-1977 (table 5).

c/ Calculated from tables 16 and 21. Loss with best alternate ÷ acres treated = increased costs and loss of gross return per acre, i.e. example for Arkansas from table 16 is: \$2,007,000 ÷ 172,000 = \$11.67 and from table 21 is \$3,502,000 ÷ 172,000 = \$20.36.

d/ Mullins, et al 1978.

SOURCE: Natural Resource Economics Division, Economics, Statistics, and Cooperatives Ser., U.S. Dept. of Agric., Corvallis, OR.

Table 26--Average annual per-acre returns to land, overhead, risk, and management with and without 2,4,5-T and silvex on the 292,000 acres of rice needing a herbicide treatment such as 2,4,5-T, in Arkansas, Mississippi, Louisiana, and Missouri, treated year, and first and second rotation in untreated period a/

No. years without 2,4,5-T	Gross returns with 2,4,5-T b/	Increased costs & loss of gross returns per acre	Gross returns without 2,4,5-T	1975-1977 Production costs c/	Returns to land, overhead, risk, and management
	dollars				
Arkansas:					
0................	377	0	377	255	122
1-3..............	377	16	361	255	106
4-6..............	377	28	349	255	94
Mississippi:					
0................	327	0	327	254	73
1-3..............	327	22	305	254	51
4-6..............	327	34	293	254	39
Louisiana:					
0................	305	0	305	254	51
1-3..............	305	21	284	254	30
4-6..............	305	32	273	254	19
Missouri:					
0................	347	0	347	248	99
1-3..............	347	23	234	248	76
4-6..............	347	35	312	248	64
Average, 4 States:					
0................	347	0	347	255	92
1-3..............	347	18	829	255	74
4-6..............	347	30	317	255	62

continued

Table 26--Average annual per-acre returns to land, overhead, risk, and management with and without 2,4,5-T and silvex on the 292,000 acres of rice needing a herbicide treatment such as 2,4,5-T, in Arkansas, Mississippi, Louisiana, and Missouri, treated year, and first and second rotation in untreated period a/ (Continued)

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a/ Returns to land, overhead, risk, and management were estimated assuming *ceteris paribus* conditions with respect to price and production levels.

b/ Average gross returns for 1974-1976.

c/ Mullins, et al 1978.

SOURCE: Natural Resource Economics Division, Economics, Statistics, and Cooperatives Service, U.S. Dept. of Agri., Corvallis, OR.

Table 27--Estimated annual rice production loss from the lack of 2,4,5-T and silvex, total for four states in Lower Mississippi region and percent of U.S. rice production a/

Alternatives and number of years without 2,4,5-T	Production loss each year	Percent of U.S. Rice production	Percent of 2,4,5-T use area b/
	Thousands CWT	Percent	Percent
Silvex, 2,4-D and propanil			
1 - 3	340.7	.036	0.720
4 - 6	561.7	.060	1,186
2,4-D and propanil			
1 - 3	443.3	.047	.936
4 - 6	753.2	.080	1.591

a/ Two best alternative weed-control programs are shown for comparison purposes.

b/ In the 2,4,5-T use area, an average 47,338 thousand cwt of rice was produced in 1975-77.

SOURCE: Natural Resource Economics Division, Economics, Statistics, and Cooperatives Service, U.S. Dept. of Agri., Corvallis, OR.

Table 28--Average annual per acre returns to land, overhead, risk, and management for soybeans in the rice-producing areas of Arkansas, Louisiana, Mississippi, and Missouri

Area	1975-77 gross returns a/	1975-77 Production costs b/	Returns to land, overhead, risk, and management
	Dollars		
Arkansas.............	125	72	53
Louisiana............	133	71	62
Mississippi..........	129	74	55
Missouri.............	144	74	70

a/ See table 29.

b/ Draft budgets obtained from Arkansas Cooperative Extension Service (1978d).

SOURCE: Natural Resource Economics Division, Economics, Statistics, and Cooperatives Service, U.S. Department of Agriculture, Corvallis, OR.

Table 29--Acres, production, and value of soybeans, United States, Arkansas, Louisiana, Mississippi, and Missouri, 1975-1977 a/

Area and year	Acres: Planted	Acres: Harvested	Yield per acre	Production	Value per bushel	Value per acre	Value of production
	---1,000 acres---			1,000 Bu	------Dollars------		1,000 dollars
United States:							
1975.........	54,732	53,761	28.8	1,546,120	4.60	132	7,000,340
1976.........	50,327	49,443	25.6	1,264,890	7.32	187	9,254,208
1977.........		57,911	29.6	1,716,334	5.79	172	9,937,574
Average.....		53,705	28.1	1,509,115	5.79	163	8,730,707
Arkansas:							
1975.........	4,750	4,700	24.5	115,150	4.50	110	507,600
1976.........	4,360	4,320	18.0	77,760	7.15	122	555,984
1977.........		4,600	22.0	101,200	6.30	139	637,560
Average.....		4,540	21.6	98,037	5.78	125	567,048
Louisiana:							
1975.........	2,000	1,920	24.5	47,040	4.70	115	205,296
1976.........	2,150	2,120	26.0	55,120	6.85	178	377,572
1977.........		2,680	23.5	62,980	5.80	115	307,284
Average.....		2,240	24.6	55,047	5.39	133	296,817
Mississippi:							
1975.........	3,230	3,120	22.5	70,200	4.65	105	319,176
1976.........	3,335	3,250	22.0	71,500	6.90	152	493,350
1977.........		3,650	20.5	74,825	6.35		475,139
Average.....		3,340	21.6	72,175	5.95	129	429,222

continued

Table 29—Acres, production, and value of soybeans, United States, Arkansas, Louisiana, Mississippi, and Missouri, 1975-1977 a/ (continued)

Area and year	Acres: Planted	Acres: Harvested	Yield per acre	Production	Value per bushel	Value per acre	Value of production
	----1,000 acres----			1,000 Bu	-------Dollars---------		1,000 dollars
Missouri:							
1975.........	4,550	4,470	26.0	116,220	4.55	118	518,632
1976.........	4,300	4,200	20.0	84,000	7.25	145	609,000
1977.........		4,800	30.0	144,000	5.65	107	813,600
Average.....		4,490	25.6	144,740	5.64	144	647,077

a/ Data for 1975 and 1976 taken from 1977 Agricultural Statistics. Harvested acres, yield, and production data for 1977 taken from USDA, ESCS, SRS, "Crop Production" report, released August 10, 1978. Price data for 1977 taken from USDA, ESCS, Crop Reporting Board, "Agricultural Prices - Annual Summary, 1977", June, 1978.

SOURCE: Natural Resource Economics Division, Economics, Statistics, and Cooperatives Service, U.S. Department of Agriculture, Corvallis, OR.

	Rice				
	Without 2,4,5-T		Without 2,4,5-T & silvex		
	1-3 years	4-6 years	1-3 years	4-6 years	Soybeans
	Dollars				
Arkansas	110	102	106	94	53
Louisiana	34	26	30	19	62
Mississippi	55	46	51	39	55
Missouri	78	68	76	64	70

Assuming ceteris peribus conditions with respect to price and production levels, soybeans, may be substitued for rice in Louisiana, Mississippi, and Missouri if 2,4,5-T and silvex become unavailable.

CHAPTER 5

THE BEHAVIOR AND IMPACT OF 2,4,5-T AND TCDD IN THE ENVIRONMENT

SUMMARY

Spray drift of herbicides is an acknowledged concern. Effects on plants off the target area has led to detailed research studies to define the variables and develop solutions. Several states have enacted regulations which are designed to reduce unintended effects due to drift while still permitting the use of herbicides. Equipment and methodology are available to reduce drift to a low level. Avoiding drift entirely, especially from aerial applications, is not currently possible. Proper attention to formulation and to atmospheric and application factors will maximize on target deposition and minimize off-site damage.

In soils, 2,4,5-T does not persist in significant amounts from one year to the next. Soil microorganisms play a leading role in their detoxification. Plants (weeds and crops) are main receptors of foliar-applied 2,4,5-T. Herbicide residues in or on vegetation may be as high as 300 ppm, but residues decline rapidly thereafter by plant metabolism, photodegradation, volatilization, and removal by rainfall. Deferred grazing on pastures and rangeland to allow for release of forage species also allows time for residues to disappear. Movement of 2,4,5-T can occur in surface runoff water if heavy rainfall occurs soon after treatment. However, loss of herbicide from treated areas by movement in runoff water is usually a very small percentage of the total herbicide applied. 2,4,5-T rapidly dissipates in streams by dilution and is difficult to detect some distance downstream from the point of application. In impounded water, 2,4,5-T disappears rapidly, especially if adapted microorganisms are present. The possibility of these herbicides contaminating groundwater supplies is very unlikely. Residues of 2,4,5-T rarely occur in meat, milk, and other agricultural products when label directions are followed in current patterns of use. 2,4,5-T does not accumulate in animal tissues and is rapidly excreted in man and animals should intake occur.

There is substantially less literature on TCDD than on 2,4,5-T, but there are sufficient data to make reasonable inference to the behavior of TCDD in the environment. TCDD has a short half-life (1 day) when it is on vegetation in the presence of a hydrogen donor. Photochemical degradation also occurs on soil (half-life about 50 hours). In the absence of light, TCDD has a half-life in soil of one year. TCDD is not mobile in soil, thus groundwater contamination is highly unlikely to occur from currently registered uses of 2,4,5-T. TCDD residues have not been measured in vegetation soil or water after the application of 2,4,5-T. Assuming specific levels of TCDD in 2,4,5-T and applying coefficients derived from controlled experiments for degradation, it is possible to calculate the level of TCDD which may be present in specific parts of the environment after application of 2,4,5-T. TCDD will bioaccumulate in organisms which have a substantive and continuing exposure to this chemical. In the natural environment, several processes operate to reduce or eliminate organism exposure. Environmental monitoring indicates substantial bioaccumulation of TCDD (sufficient to produce residues in excess of 10 ppt in the majority of the population) is not occurring in animals in or near areas treated with 2,4,5-T in current operational programs. TCDD can be produced by combustion of 2,4,5-T treated material (under special conditions) but because of the rapid decomposition of 2,4,5-T, burning of treated vegetation is not expected to produce levels of TCDD greater than those present immediately after the application of the herbicide.

Humans not involved in the application of 2,4,5-T could conceivably be exposed to 2,4,5-T or TCDD in air, food, or water. TCDD levels have usually not been measured but can be estimated from the level of 2,4,5-T. In areas of heavy use, 2,4,5-T concentrations in the air may average 0.1 mg/m^3 within a few hundred feet of sprayed areas. National surveys for 2,4,5-T in food and water fail to detect the herbicide in all but a small percentage of the samples.

Applicators will receive the most substantial exposure to 2,4,5-T because they are most likely to come in contact with the herbicide in its concentrated form on a regular basis. Analysis of the actual patterns of use of 2,4,5-T in the four commodity groups covered by this report shows worker exposure to spray material varies from 1 minute to 165 hours per year. The number of individuals involved in some phase of application is estimated to be about 15,424 with a weighted average exposure of 24 hours per year.

The selection of assumptions for exposure scenarios has a substantial impact on calculated margins of safety. The use of assumptions which more accurately reflect actual exposure situations than those used in the PD-1 generated a series of correction factors which were used to calculate adjusted exposure levels for four scenarios used in PD-1. These adjusted exposure levels were used with the no-adverse-effect levels cited by EPA in PD-1 to calculate adjusted margins of safety. The PD-1 and the adjusted margins of safety are compared below:

	Margin of safety			
	2,4,5-T		TCDD	
Exposure scenario	PD-1 a/	AT b/	PD-1	AT
2. Dermal exposure - backpack sprayer	3	5.6×10^3	43	4.1×10^4
3. Dermal exposure - tractor mounted boom	11	1.1×10^6	167	8.8×10^6
4. Dermal exposure - aerial application	312	3.9×10^7	6.0×10^3	3.0×10^8
5. Inhalation - aerial application	870	7.2×10^5	1.5×10^4	1.2×10^7

a/ Margin of safety calculated from PD-1.

b/ Adjusted margin of safety corrected by the Assessment Team using the factorial method.

Using data from 2 experiments involving dermal absorbtion of 2,4,5-T by humans, applicator exposure was also calculated on an absolute basis for several exposure situations. Human absorbtion of 2,4,5-T is estimated to range from less than 0.001 mg/kg/hr to a maximum of 0.076 mg/kg/hr when exposed skin is wet with spray for the entire application period. The addition of long-sleeved shirt and gloves would reduce exposure 91 percent. In a test of operational application by helicopter, tractor, and backpack sprayers, short-sleeved applicators were exposed to an average of 0.0003, 0.0012, and 0.0123 mg/kg/hr. Both the factorial and the absolute basis show that applicator exposure is substantially less than estimated in PD-1.

The herbicide 2,4,5-T is practically nontoxic to soil organisms and the soil microbial population is partially responsible for its breakdown. In acute or subacute exposure tests, 2,4,5-T is moderately toxic to some species of fish and only slightly toxic to lower aquatic organisms, birds, and wild animals under laboratory conditions. Herbicides containing 2,4,5-T are moderately toxic to laboratory mammals by acute or subacute oral and dermal intake and are only slightly toxic by inhalation. In the field, 2,4,5-T is not usually present at acute or subacute levels when used according to current label instructions.

2,4,5-T appears to cause the greatest effect on the environment through alteration of the density and species composition of the vegetative community. This alteration is usually the intended purpose of weed and brush-control projects and will occur regardless of the alternative technique used.

INTRODUCTION

The main environmental effect of 2,4,5-T is to produce changes in the density and species composition of vegetation by controlling broadleaf plants. These changes produce indirect environmental effects which were discussed as part of chapters 1, 2, 3, and 4 for specific commodities. This chapter deals with the movement, persistence, and fate of 2,4,5-T and TCDD in the environment and the exposure that this behavior produces for nontarget species. Special attention is given to analysis of the exposure applicators may receive from the current patterns of 2,4,5-T use.

The chapter has 7 major sections. The first section deals with spray drift both in a theoretical and a practical sense. A second section deals with the initial amounts deposited and the subsequent fate of 2,4,5-T in soil, vegetation, water, animals, and off-target sites. Data from research, residue monitoring and large scale surveys of 2,4,5-T in the environment are included. Processes of breakdown and disappearance of 2,4,5-T are also included for each environmental component. A third section reviews the state of knowledge of the environmental behavior of TCDD. Other sections give (1) data on the probable routes and amount of exposure of applicators and the general population to 2,4,5-T via air, food and water sources, (2) the consequences of exposure, and (3) the ecological effects of 2,4,5-T use.

PART 1: SPRAY DRIFT, SOME THEORETICAL AND PRACTICAL CONSIDERATIONS

Drift is defined as the airborne transport of spray droplets away from the point of release. Movement of herbicides may also occur by vaporization and subsequent air movement. Because the formulations of 2,4,5-T in common use today are usually nonvolatile amines or low-volatile esters, 2,4,5-T is not likely to occur at significant levels in the atmosphere following an application. Although research on spray drift has not received the attention it merits, a selected bibliography published in 1974 (Anonymous 1974) lists 195 pages of references.

An important point for the reader to bear in mind is that even small amounts of drift of 2,4,5-T can cause visible symptoms on off-site plants. Although chemicals that are not phytotoxic may contaminate an area without anyone suspecting their presence, the presence of phenoxy herbicides is always conspicuous. The response of sensitive species such as cotton, tomato, potato, peas, beans, and a number of common weeds indicate the presence of even small amounts of this herbicide.

THEORETICAL ASPECTS OF SPRAY DRIFT

The theory of spray drift is based on Stokes Law which describes the motion of a sphere through a fluid-like medium such as air. A modification of Stokes' equation (Hansen 1965) commonly used in drift studies is:

$$D = 1.49 \left(\frac{10^4 VH}{r^2}\right) \qquad (1)$$

where:
- D = drift in feet
- H = height above ground in feet
- V = crosswind velocity in mph
- r = droplet diameter in um

Using the modified equation, the drift of spray droplets in a 5 mph crosswind from a height of 100 feet would be as shown in table 1. The

Table 1--Theoretical drift of spray droplets released 100 feet above ground in a five mile per hour crosswind.

Droplet size, diameter	Theoretical drift,
μm	feet
50	298
100	74
200	19
400	4.6
600	2.0
800	1.2
1000	0.7
1500	0.3

drift distances resulting from other crosswind velocities or other release heights can be determined by applying an appropriate factor to the distances given or by calculation using the modified Stokes equation. Thus droplet size is the critical factor determining spray drift, since halving the droplet diameter results in a fourfold increase of drift distance.

A spray droplet is also subject to evaporation while falling. A very small droplet can evaporate completely before reaching the ground or a leaf surface. Assuming an air temperature of 86°F, relative humidity of 50 percent, and still air, the approximate lifetime and distance of fall for water droplets would be as shown in table 2 (Akesson and Yates 1978). The tabulation shows that water droplets less than 100 um diameter would probably never reach the ground or a leaf surface when applied from a height of 10 feet, an approximate minimum for aerial application.

The lifetimes and fall distances for herbicide spray droplets would vary from the figures given above. The kind of carrier (oil or water), vapor pressure of the carrier and the herbicide, and the kind of emulsion (oil in water or water in oil) would all influence droplet lifetime. Air turbulence causes major deviations from calculated fall-out rates.

The amine formulations of 2,4,5-T are essentially nonvolatile, even at high summer temperatures. Esters have a range of volatility that is correlated with the length and structure of the alcohol portion of the ester molecule. Ester formulations having an alcohol chain of five carbons or less are commonly classed as high-volatile esters. Low-volatile esters have longer alcohol moieties. The vapor pressures of various esters of 2,4-D in mm of Hg at a temperature of 187°C have been determined in order of decreasing vapor pressure to be: isopropyl, 17; butyl, 9.2; pentyl, 7.7; propylene glycol butyl ether, 3.9; butoxy ethanol, 3.9; 2-ethyl hexyl, 3.0; and isooctyl, 2.7. While the vapor pressures for equivalent esters of 2,4,5-T are not all known, it appears they are lower than for 2,4-D. The following values were reported for

Table 2--Lifetime and fall distance of water droplets in air[a,b]

Droplet size, diameter	Lifetime	Fall distance
μm	seconds	inches
200	56	1678
100	14	151
80	9.5	36
50	3.5	11
40	2.4	2
20	0.6	less than 1
10	0.2	less than 1
2	0.1	less than 1

a/ Akesson and Yates (1978)

b/ 86°F, 50% relative humidity, still air esters of 2,4,5-T: butyl, 4.5; pentyl, 3.9; 2-ethyl hexyl, 1.8 (Flint et al. 1968, Grover 1976). Low-volatile esters are more commonly used. The use of high-volatile esters is specifically prohibited in some states.

PRACTICAL ASPECTS OF SPRAY DRIFT

Drift during application is to some extent swath displacement, which is essentially a matter of moving the spray swath downwind. However, since fine particles move further downwind than larger ones, the swath is not only displaced, but is dispersed to some extent. It is easy to compensate for swath displacement by altering the path of the spray equipment. Reducing swath dispersion is more difficult.

Most of the application equipment in use today produce a range of droplet sizes. The greater the volume of spray solution found in small droplets (less than 100 um), the greater the drift. However, there is an upper range of droplet sizes beyond which biological effect of a herbicide is reduced. Thus, herbicide applications should have the goal of achieving a range of droplet sizes that minimizes drift without unduly sacrificing biological effectiveness. The factors that influence droplet size and drift will be discussed separately to permit an easier understanding of the principles involved.

MECHANICAL FACTORS

There are only five factors in conventional spray application equipment that can be varied to affect droplet size (Stewart and Gratkowski 1976). (1) Increasing air speed results in smaller droplets because of the greater shear forces imposed on the spray solution as it leaves the nozzle. (2) Pressure in the spray system also affects droplet size. Higher pressure increased turbulence in the nozzle, which in turn increases shear forces at the nozzle orifice, resulting in smaller droplets being formed. (3) Orifice diameter of nozzles is directly related to droplet size. A larger orifice will reduce shear forces caused by turbulence in the nozzle, and larger droplets will be produced. (4) The kind of nozzle also affects droplet size. Six types of hydraulic pressure nozzles are used for aerial spraying: hollow cone with whirl plate, hollow cone with offset entrance, fan, full cone, cylindrical jet, and flooding nozzles (Stewart and Gratkowski 1976). Nozzles producing narrow, cylindrical patterns form fewer small drops, thus they are better for reducing drift. Maximum reduction is possible by using cylindrical jet nozzles or hollow cone nozzles without the whirl plate that discharge the spray as a narrow, solid stream. (5) Nozzle orientation is a major factor affecting droplet size. The smallest range of droplet sizes and the lowest volume of spray solution in small droplets is obtained when nozzles are oriented parallel to the airstream and discharge downwind to the direction of air flow. As the angle of release relative to the airstream increases, shear forces increase and a greater number of small droplets are formed.

Equipment is available that will provide droplet sizes of 300-400 vmd (volume median diameter in um) with 70 to 90 percent recovery in a 500 foot width; 400-600 vmd with 85 to 95 percent recovery; 800-1000 vmd with 95 to 98 percent recovery; and 800 to 1000 vmd with 99 or more percent recovery (Akesson and Yates 1978).

ATMOSPHERIC FACTORS

Temperature and relative humidity influence drift through evaporation, which reduces droplet size and results in more drift. In practice, many states impose limitations to herbicide application based on these two factors. Limitations are also imposed in terms of maximum permissible windspeed at the time of application. A maximum windspeed of 5 mph is common, although up to 10 mph is permitted in areas where there is less hazard to sensitive vegetation.

A critical atmospheric factor is the temperature gradient with height, specifically the occurrence of warm air overhead, usually referred to as an inversion condition (Akesson and Yates 1978). An inversion limits vertical air circulation and acts to concentrate fumes and small particles in a cloud under the inversion ceiling, relatively close to the ground. The material thus entrapped may be transported long distances in amounts sufficient to cause damage to sensitive crops.

SPRAY SOLUTION FACTORS

Spray solutions can be modified to reduce the number of small droplets and thereby reduce drift. The principles involved are the increase of viscosity or surface tension, each of which tends to reduce the number of small droplets. The types of preparations available to reduce drift may be classified as invert emulsions, thickeners, particulating agents, and foaming agents (Gratkowski and Stewart 1973).

Invert emulsions are formulations in which water droplets are dispersed within a continuous oil phase. Mayonnaise is an invert emulsion with physical characteristics resembling invert spray mixtures. Viscosity of such emulsions depends on the ratio of oil to water. Because viscosity can be increased, the spray drops can be increased to very large sizes if desired. Another advantage is that the oil that surrounds each water droplet vaporizes more slowly than water and less droplet volume is lost during fall. However, some small droplets are still produced so drift is not eliminated. Thick invert emulsions are applied with special equipment designed to throw the material in large chunks.

Thickening agents are water-soluble polymers that increase the viscosity of spray solutions. They increase droplet size, but do not eliminate all small droplets. A more recently developed thickening agent is a polyvinyl polymer. In addition to increasing droplet size, it also seems to reduce the formation of small droplets.

Particulating agents are granular polymers. Each granule swells to a limited size, and is essentially a separate entity when sprayed. Droplet sizes can be more accurately controlled by this means than with thickeners. Specialized equipment is needed for effective application of solutions to which particulating agents have been added. Despite some advantages, use of particulating agents has never become widespread, and it does not appear that use will increase.

Foaming agents have been developed to improve control, but their use has not been widely adopted. Nozzles were developed specifically for dispensing foams. Research has shown that the decreased drift obtained is attributable more to the nozzle than the foam itself (Bouse et al. 1976).

Although many variables affect spray drift, it is clear that elimination of small droplets, especially those less than 100 um in diameter, is the fundamental solution to the drift problem. However, the biological effectiveness of the phenoxy herbicides decreases as droplet size increases and droplet density decreases. For example, McKinlay et al. (1972) found that increasing droplet size from 100 to 200 um with volume kept constant, required three times as much active ingredient, and when size was increased to 400 um, six times as much herbicide was needed to give equivalent biological effects. There are two factors that tend to make smaller droplets more effective. First, the leaf area contacted by a given volume of spray solution is greater when droplets are smaller. That may enhance absorption. Secondly, high herbicide concentrations localized in larger droplets may so damage the underlying cells that translocation to other tissues is reduced. In practice the lower effectiveness of larger droplets can be offset by increasing herbicide concentration of the spray solution or by increasing the total volume. Both increase costs.

Drift can be reduced when using conventional application equipment by taking advantage of the best combination of nozzle type and orientation, orifice size, pressure, and spray mixture. In addition, modern engineering developments permit reduction of droplets below 100 um diameter to near zero. The microfoil boom, for example, has nozzles placed in a boom shaped like an airfoil which minimizes turbulence at the point where droplets are formed. Primary droplets from microfoil nozzles are about twice the size of the orifice. Smaller satellite droplets are formed from thin filaments of spray between the primary droplets, but proper nozzle orientation will result in the capture of small droplets by large droplets in the smooth air behind each nozzle. When equipped with 0.013- and 0.028-inch nozzles, droplets of 800 and 1,700 um, respectively, are produced with a variation of only ± 200 um. Integrity of the droplet size range cannot be maintained at air speeds greater than 60 mph. Accordingly, the microfoil boom is used only on helicopters.

The microfoil boom is expensive to buy and is subject to clogging and other problems if not properly maintained. Nevertheless, it provides the best drift control available at this time. Other application systems are in the process of development (Stewart and Gratkowski 1976).

REDUCTION OF DRIFT THROUGH REGULATION

Many states have regulations designed to promote proper use, thereby reducing drift. In Arkansas (McKinlay et al. 1972), for example, sale of high-volatile esters of 2,4,5-T are prohibited except by written permission of the Director of the State Plant Board. Moreover, manufacturers must have a permit to sell any quantity more than one quart in size; invoices for such sales must be mailed to the State Plant Board within seven days of the sale. Sales of more than one quart may be made only to dealers or custom or private applicators who hold a current permit. Arkansas is divided into two zones. Zone 1 includes the cotton-growing area of the State, Zone 2 includes the remainder of the State. In Zone 1, 2,4,5-T may not be applied either aerially or by ground within 1/4 mile of susceptible crops at any time unless prior authorization is received. Moreover, low-volatile esters of 2,4,5-T may not be aerially applied between April 15 and October 1 within one mile of susceptible crops. In Zone 2, 2,4,5-T may not be aerially applied within 1/4 mile of susceptible crops at any time unless prior authorization is received. Both aerial and ground applications of 2,4,5-T may be made under restricted conditions of wind velocity, temperature, height of spray release pressure, spray volume, nozzle design and orientation, and proximity to dwellings.

In Oregon and Washington, the temperature, wind velocity, humidity, width of buffer strips, and other conditions are specified for 2,4,5-T spraying on forests.

In California, applications of 2,4,5-T are regulated by the Department of Food and Agriculture. Forest and rangeland use requires a plan of operation for the defined treatment area, a spill contingency plan, and a plan for sampling streams for possible contamination before a permit to conduct the spraying is granted. Written notice must be published in a newspaper that has general circulation within the proposed treatment area, and public comment received within 25 days after publication must be reviewed and evaluated. Property owners within 1/4 mile of the proposed treatment area must be notified by the permittee.

In Texas, wind speed, spray pressure or droplet size, and release height are regulated. Aerial applications of 2,4,5-T may not be made nearer than 4 miles upwind from a susceptible crop when windspeed is 7 to 10 mph.

The regulations in effect for Arkansas, Oregon, Washington, California, and Texas are representative of the type of regulatory control exercised by most states. Drift is widely recognized as a serious but largely correctable problem amenable to regulatory control. The important point is that applications of 2,4,5-T cannot be made by just anyone in any way he chooses, but must be made in compliance with recognized safety standards.

PART 2: THE BEHAVIOR AND FATE OF 2,4,5-T IN THE ENVIRONMENT

INITIAL DEPOSIT

In nearly all parts of the environment the highest levels of chemical residue occur immediately after application. The data in this section can be used to estimate exposure levels for all types of animals which feed in or enter areas shortly after application.

VEGETATION

Vegetation is the primary receptor of 2,4,5-T sprays. The amount of herbicide intercepted by vegetation varies with the rate and nature of the application and the type and density of the vegetation. Data from Altom and Stritzke (1972) show 33 percent of the herbicide application penetrated the overstory. Bouse and Lehman (1967) reported 19 to 22 percent penetration. These data suggest up to 80 percent of the spray is intercepted by overstory vegetation.

Norris et al. (1977) looked at the initial distribution of 2,4,5-T low-volatile esters in oil applied by helicopter to a mixed hardwood brush community in northwest Oregon. They found marked contrast in the concentration of herbicide shortly after application among various species which indicates the nature of the intercepting surface is also important (table 3). This particular area was re-treated 1 year later, and the results (table 3) show an increase in the initial herbicide concentrations in live blackberries (Rubus sp.), grass, and vine maple which reflects a general decrease in vegetation densities from the year before. The initial concentration on Douglas-fir (Pseudotsuga menziesii) is the same in both years because the individual trees sampled were growing in the open, and the density did not change from one year to the next. Plumb et al. (1977) reported initial herbicide concentrations of 95 and 92 ppm 2,4-D and 2,4,5-T respectively, in chamise (Adenostoma fasiculatum) immediately after a simulated aerial application of 3 lb/A each 2,4-D and 2,4,5-T in southern California (table 3).

Table 3--Phenoxy herbicide residues in vegetation

Herbicide	Location	Plant species	Application	Residue level ppm (days after application)	Reference
2,4-D	So. Calif.	Chamise	3 lb/A ae PGBE ester in water, simulated aerial application, May	95(0) 70(14) 69(29) 20(69) 16(146) 3.8 (379)	Plumb et al. 1977
2,4-D	Texas	Grass	1 lb/A ae 2,4-D amine in water, simulated aerial application, June	80(0) 70(7) 45(14) 30(28) 6(56) 1(112)	Morton et al. 1967
2,4-D	Sweden	Poplar	Glass house application, 2,4-D butoxyethyl ester in diesel oil	2300(1) 2500(3) 1800(9) 1300(37) 870 (365)	Eliasson 1973
2,4,5-T	Texas	Grass	1 lb/A ae PGBE ester in water, simulated aerial application	73(0) 2.1(42) 0.02(182)	Bovey & Baur 1972
2,4,5-T	Germany	Raspberry (fruits)	5.4 lb/A formulation not known, in water, foliage application from ground, June & July	16(0) 11.2(5) 3.4(15) 1.5(30) (by interpolation Table 2)	Olberg et al. 1974
2,4,5-T	Texas	Live oak (stem tips)	2 lb/A ae 2,4,5-T isooctyl ester in water, simulated aerial application, June	9.6(30) 0.7 (180)	Baur et al. 1969
2,4,5-T	Texas	Grass	2 lb/A ae 2,4,5-T isooctyl ester in water, simulated aerial application, June	7.0(30) 0.2(180)	Baur et al. 1969
2,4,5-T	Texas	Grass	0.5 lb/A ae 2,4,5-T butoxyethanol ester in water, simulated aerial application, June	48(0) 35(7) 10(14) 9(28) 7(56)	Morton et al. 1967
2,4,5-T	Texas	Grass	2 lb/A ae 2,4,5-T Butoxyethanol ester in water, simulated aerial application, June	205(0) 150(7) 50(14) 60(28) 25(56)	Morton et al. 1967
2,4,5-T	Oregon	Douglas-fir	2 lb/A ae, isooctyl ester in oil, helicopter application in early spring-first annual application	52(0) 11.1(30) 0.35(90) 0.47(180) 0.22(360) 0.0(720)	Norris et al. 1977
			Second annual application	52(0) 14.2(30) 0.10(90) 0.04(180) 0.0(360)	

(continued)

Table 3--Phenoxy herbicide residues in vegetation (continued)

Herbicide	Location	Plant species	Application	Residue level ppm (days after application)	Reference
2,4,5-T	Oregon	Vine maple	First annual application	10.6(0) 0.48(30) 0.28(90) 0.16(180) 0.48(360) 0.02(720)	ibid.
			Second annual application	23.2(0) 10(30) 0.10(90) 0.10(180) 0.02(360)	
2,4,5-T	Oregon	Grass	First annual application	114(0) 3.4(30) 0.58(09) 0.14(180) 0.12(360) 0.0(720)	ibid.
			Second annual application	140(0) 9.3(30) 0.21(90) 0.12(180) 0.0(360)	
2,4,5-T	Oregon	Blackberry (vines & foliage)	First annual application	45(0) 0.59(30) 0.05(90) 0.02(180) 0.03(360) 0.0(720)	ibid.
			Second annual application	165(0) 2.9(30) 0.01(90) 0.0(180) 0.0(360)	
2,4,5-T	So. Calif.	Chamise	3 lb/A ae, PGBE ester in water, simulated aerial application, May	92(0) 44(14) 32(29) 14(69) 2.9(146)	Plumb et al. 1977

Grass is an important component of both forests and range. Grass communities have potential for high herbicide concentrations because they are a relatively low-growing type of vegetation with a large surface-to-mass ratio. Bovey and Baur (1972) detected from 27 to 140 ppm 2,4,5-T on the day of application of 0.5 lb/A and 53 to 144 ppm from 1 lb/A applications in native or tame pasture grasses. Similar amounts using similar rates per acre of 2,4,5-T have been reported in other studies (Bovey et al. 1974, Bovey et al. 1975, Scifres et al. 1970, Morton et al. 1967).

Olberg et al. (1974), investigating 2,4,5-T residues in wild raspberry fruits (species not identified), reported that initial herbicide concentrations ranged from 0.7 to 3.3 ppm 1 hour after treatment with 5.4 lb 2,4,5-T per acre in tests conducted in 1972. Apparently similar applications in 1973 produced initial 2,4,5-T residues ranging from 7.9 to 22.2 ppm. Applications in both cases were by "backpack power sprayer." By contrast, Maier-Bode (1972) found only 1 ppm 2,4,5-T on unidentified wild berries in Sweden on the day of treatment by aircraft (table 3).

These various reports indicate initial phenoxy herbicide residues in vegetation can range up to about 220 parts per million for rates of application up to 2 lb/A. Proportionally higher residue levels may be expected for higher rates of application.

GROUND

The term ground used in this report includes both the mineral soil and any overlying organic layers such as the forest floor. Herbicide reaches the ground during application (that portion of spray material not intercepted by vegetation, or lost to the atmosphere) or later in the washing action of rain or leaf fall from treated plants. The distribution of spray material between the overlying organic layers and the mineral soil is obviously determined by the thickness of the organic layers. In forest environments, relatively thick organic layers occur, thus the residue levels in soil are much lower than on rice field levees where there is little or no organic matter.

Bovey and Baur (1972) determined the concentrations of the propylene glycol butyl ether esters of 2,4,5-T applied at 0.5 and 1 lb/A on five pasture and range sites in Texas immediately after treatment. Concentrations of 2,4,5-T ranged from 1 to 3 ppm from 0.5 lb/A applications and 3 to 5 ppm from 1 lb/A treatments in the surface 6 inches of soil. However, on areas with a heavy grass cover, 2,4,5-T at similar rates applied as the triethylamine salt never exceeded 0.1 ppm even when applications were made every six months for a total of five applications (Bovey et al. 1974, Bovey et al. 1975). Soils were sampled at 1 foot intervals to a depth of 4 feet. The bulk of the 2,4,5-T was found in the surface 6-inch layer of soil. Scifres et al. (1977) found less than 0.1 ppm of 2,4,5-T immediately after treatment in the surface inch layer in deep sand soils at three locations in central Texas. Rate of spray recovery averaged 92 percent on the open surface as determined by recovery of 2,4,5-T from mylar cards placed on the soil. In this study a heavy stand of coastal bermudagrass intercepted a large percentage of the 2,4,5-T before it reached the soil.

In other studies, Scifres et al. (1970) showed the influence of vegetation in reducing the amount of herbicide reaching the soil surface For example, grass cover, honey mesquite cover and grass--perennial ragweeds--honey mesquite cover reduced the concentration of herbicide reaching the soil by 42, 61 and 89 percent respectively. Norris et al. (1977) reported maximum soil residues of 2,4,5-T did not exceed 0.1 ppm in the forest floor due to interception of the 2,4,5-T by vegetation and forest floor litter.

In an arid environment Radosevich and Winterlin (1977), reported most of the 2,4-D and 2,4,5-T was intercepted by the woody (chamise) and herbaceous vegetation and litter with only 0.1 percent of the 2,4-D and 0.07 percent of the 2,4,5-T reaching the soil. Most herbicide was intercepted by the litter (>50%).

WATER

Herbicides can enter surface waters by direct application to stream surface, accidental drift from nearby treatment units, in overland flow during periods of intense precipitation, or by leaching through the soil profile. The magnitude and duration of the contamination which might occur from each of these processes is different. Direct application or drift to surface waters is likely to result in the highest concentrations of herbicide in the water, but the duration of entry is short, being largely restricted to the period of application. Therefore, organism exposure may be relatively intense but brief. If overland flow occurs, more moderate concentrations of herbicide could result in streams because stream discharge volumes are likely to be considerably greater than during periods of application. The duration of entry via overland flow would probably be relatively brief being restricted to periods of particularly intense precipitation. If herbicides enter streams by leaching, the concentrations are apt to be quite low, but the duration of entry could conceivably be considerably longer than for either direct application or the overland flow process.

Surface water on pastures and rangeland usually consists of ponds and lakes or moving streams. In forest areas, most surface water is in streams although lakes are common in some areas. Surface waters are avoided by spray equipment, but some contamination may occur incidental to treatment. 2,4,5-T may occur in small amounts in runoff water, however, if heavy rainfall occurs soon after treatment.

In impounded water it is possible, in an extreme case, to get concentrations of 2,4,5-T approaching 1 ppm (1 foot deep lake sprayed with 2 lb/A of 2,4,5-T by accident). However, 2,4,5-T is subject to both microbial and photochemical degradation and the concentrations would decline rapidly after treatment.

Norris and Moore (1971) reported monitoring studies done in the 1960's which showed concentrations of 2,4-D and 2,4,5-T were usually less than

0.01 ppm and seldom exceeded 0.1 ppm in streams adjacent to operational forest spray operations in Oregon. More recent operational monitoring shows the use of a "one swath" buffer is effective in substantially reducing or eliminating herbicide residues in streams (Norris 1978). Similar concentrations of 2,4,5-T would be found under rangeland conditions. Once in the stream, the 2,4,5-T is subject to rapid dilution by the flowing water and is not usually detected at downstream locations.

Occurrence of 2,4,5-T in runoff water has been studied under various conditions after application to pastures and rangeland. Concentration of 2,4,5-T was moderately high (0.4 to 0.8 ppm) in runoff water if heavy rainfall occurred immediately after treatment (Bovey et al. 1975). However, if major storms occurred 1 month or longer after herbicide application, concentration in runoff water was below 0.005 ppm. Dilution from surrounding watersheds is important in dissipation of the herbicide.

OFF-TARGET

Regardless of all precautions there is some degree of drift of 2,4,5-T from treated areas (Bode et al. 1976, Bouse et al. 1976, Goering et al. 1973, Maybank and Yoshida 1969). The main effect of herbicide deposition in nontarget areas is on sensitive vegetation. Some broadleaf crops are affected by extremely low concentrations of 2,4,5-T. Such concentrations would be difficult to detect in soil and water sources as well as vegetation. Visual symptoms of herbicide effects on sensitive plants are often useful indicators although they are sometimes confused with certain plant diseases.

Airborne spray particles are inevitably transported to some extent by air movement to nontarget areas. This can amount to 20 percent of the total spray volume, depending upon the type of nozzles and pressures and other spraying conditions (Maybank and Yoshida 1969). Under other conditions as much as 98 percent of the spray may be deposited within the target area. Smith and Wiese (1972) found that application of

2,4-D at 0.05 to 0.1 lb/A applied to cotton caused significant yield loss. The earlier the cotton was sprayed, the more severe was its damage. 2,4,5-T is less damaging than 2,4-D. Studies by Maybank and Yoshida (1969) indicated drift deposits of herbicide (0.04 lb/A approached those causing injury to cotton. Rates of 2,4-D and possibly 2,4,5-T at 0.5 lb/A or higher can potentially affect adjacent sensitive crops if precautionary application measures are not taken to prevent drift. Spray drift was discussed in more detail in part one of this chapter.

SUBSEQUENT DISTRIBUTION AND FATE

PLANTS - RESIDUES AND FATE

Persistence of 2,4,5-T in treated vegetation is of importance since parts of forage and crop plants may be consumed by man and animals or man may consume wildlife and livestock that have grazed treated areas. Human entry to treated areas may also cause some dermal exposure. Persistence of phenoxys may also be important for the desired phytotoxic effects on weeds and sometimes undesirable in that valuable vegetation may be injured.

Phenoxy herbicide residues decline with time in vegetation through the action of several processes, including volatilization, photochemical or biological degradation on leaf surfaces, weathering (rain washing, cuticle erosion), absorption and translocation, growth dilution, metabolism, excretion, and others. Most field studies only determine residue levels and do not determine the importance of specific residue reduction processes.

Herbaceous Vegetation

Morton et al. (1967) studied the disappearance of 2,4-D, 2,4,5-T and dicamba over a 3-year period from a pasture containing several herbaceous species. No important differences were found in persistence of different herbicides. Most experiments showed half-lives of 2 to 3 weeks after application in green tissue for all three herbicides. The half-life in grass litter was slightly longer (3 to 4 weeks). Shorter residual of herbicides in green tissues was attributed to dilution by growth. Rainfall was important in hastening herbicide disappearance.

Baur et al. (1969) applied 2 lb/A of the 2-ethylhexyl ester of 2,4,5-T alone and with 0.5, 1 and 2 lb/A of the potassium salt or isooctyl ester of picloram to pastures supporting infestations of woody plants. Recovery of 2,4,5-T acid and ester from woody and grass tissues was greatest when applied with picloram. Herbicide concentration in all treatments, however, was usually less than 10 and 0.1 ppm, 1 and 6 months, respectively, after application.

Bovey and Baur (1972) analyzed forage grasses from five locations in Texas with wide variation in grass species, soils, and climate. These areas had been treated with the propylene glycol butyl ether esters of 2,4,5-T at 0.5 and 1 lb/A. An average of 98 percent of the 2,4,5-T was lost from all treated areas six weeks after treatment. After 26 weeks, the herbicide levels in grass ranged from 0 to 51 ppb.

In two separate studies, Bovey et al. (1974, 1975) applied a 1:1 mixture of the triethylamine salts of 2,4,5-T and picloram at a total of 1 and 2 lb/A on pasture land in central Texas. Repeat treatments were made every six months to the same area for a total of five applications. Herbicide content of native grass was highest (28 to 113 ppm) immediately after spraying, degraded rapidly after each treatment, and tended to disappear before each new application was made. There was no accumulation of 2,4,5-T in soils or vegetation. Other investigators report similar results (Scifres et al. 1977, Norris et. al. 1977, Radosevich and Winterlin 1977).

A short-term deferred grazing period after 2,4,5-T application is indicated on the herbicide labels for dairy animals (6 weeks) and meat animals (2 weeks) before slaughter. This deferred period acts as a safeguard to prevent herbicide residues in meat and milk products. From a range-management point of view, deferred grazing after herbicide treatment is important for recovery of desirable forage species once suppression by weeds competition is reduced by spraying. The deferred grazing period will vary according to the grazing system employed; however, five months deferment is usually desirable. This later deferral is to gain maximum benefit from the cultural practice, not to protect animals or to reduce residues in meat or milk.

2,4,5-T residues in raspberry fruits in European forests present a peculiar situation. Based on reports by Olberg (1973) and Olberg et al. (1974), it appears that 2,4,5-T applied at 5.3 lb/A in two formulations in June and July, caused relatively fast leaf wilt, but green berries continued to ripen and became "conspicuously large and beautiful."

Residue levels were determined by methods specified by the German Research Society (not available for evaluation) in fruits picked at various times between 0 and 41 days after application. The results present a confusing picture. Initial residue levels were markedly different in the 2 years of the study. First year results with one formulation show a four-fold decrease in residue level in 41 days but virtually no change in residue level over the same period with a second formulation. The second year, initial residue levels were much higher than the first year by substantial margin. These levels declined relatively quickly, however, with a mean half-life of 8.6 days for the first 15 to 17 days after treatment. There was a marked reduction in the rate of decrease after that time (table 3). By the end of the measurement period, which ranged from 29 to 41 days on different plots, residue levels varied from 0.4 to 2.2 ppm. These levels are substantially greater than the 0.05 ppm residue level permitted in Germany. The results are confounded to some degree by apparent 2,4,5-T residues in untreated fruits. One control set had no detectable levels of 2,4,5-T, but the other three contained residues ranging from 0.14 to 0.6 ppm. The successful development of the fruit after application makes one wonder about the overall effectiveness of the treatment. Some modification of formulation carrier or technique of application might accomplish more complete early season control such that treated fruits do not ripen. As a result of these studies, the season of application of 2,4,5-T in forests nurseries is restricted to that period before fruit-set or after fruit harvest.

Woody Vegetation

Baur et al. (1969) found most of the 2,4,5-T applied at 2 lb/A as the 2-ethylhexyl ester to live oak disappeared in 6 months. However, small amounts, both the acid (0.09 ppm) and ester (0.23 ppm) of 2,4,5-T could be detected 6 months after application. More 2,4,5-T was found in live oak tissue at 1 and 6 months from the top of the plant than the middle and lower stem due to the top portion intercepting more spray initially than lower regions. More 2,4,5-T was found in live oak treated with a combination of 2,4,5-T and picloram than treated with 2,4,5-T alone at equivalent rates.

Brady (1973) indicated radioactive 2,4,5-T persisted three to seven times as long in treated woody plants as in forest soils. The half-life of 2,4,5-T ranged from 5.5 to 12.4 weeks in several southern woody species. All species decarboxylated 2,4,5-T releasing $^{14}CO_2$ with no significant difference between species or doses. After 30 days over 90 percent of applied 2,4,5-T was lost from chamise brush (Radosevich and Winterlin 1977).

Plumb et al. (1977) made a simulated aerial application of 2,4-D and 2,4,5-T as the PGBE ester at a rate of 3 lb/A ae each to a 3 year-old stand of chamise in southern California. They report 2,4,5-T and 2,4-D had a half-life of about 17 and 37 days, respectively, in this vegetation. The rate and extent of decline of these herbicide residues were not as great as is noted in some other studies, very likely because the site was very dry. Plant moisture levels, which were very low at the time of application (about half of normal), declined to less than 30 percent 9 weeks after the application, largely eliminating plant metabolism of the residues (table 3). About 3 ppm 2,4-D and 2,4,5-T were present in the dead dry vegetation 1 year after application. Sprouts from the treated plants did not show formative effects but did contain 0.27 ppm 2,4-D and 0.31 ppm 2,4,5-T one year after application. These plant parts were not present at the time of applications, indicating these residues resulted from the translocation of chemical from treated portions of the plant.

Norris, et al. (1977) determined residues of 2,4,5-T in four species of forest vegetation after two successive annual applications of herbicide (4 lb/A ae as isooctyl ester applied in diesel oil by helicopter in March). Their results show a sharp decrease in herbicide concentration the first month after application (table 3). The mean half-life of 2,4,5-T for all species was about 2 weeks after both the first and the second application. The rate of residue decline slowed after 3 months. One year after application, residues ranged from 0.48 ppm in vine maple foliage to 0.07 ppm in blackberry runners and foliage. 2,4,5-T residues were below detectable limits (0.01 ppm) in all species except vine maple 2 years after the first application. The rate of decline of 2,4,5-T residues in vegetation after the second application was similar to the first except that 1 year after the second application, no detectable residues were present in any of the sprayed vegetation. In this case, at least, two successive annual applications of 2,4,5-T had no appreciable effect on the persistence of the herbicide in four different kinds of vegetation.

Eliasson (1973) applied butoxyethyl ester of 2,4-D to young aspen in a glass house experiment and found a decrease in herbicide residue level with time, despite the fact an extremely high concentration of herbicide was present initially, and after 9 days more than half the sprayed leaf tissue was dead (table 3).

Processes of 2,4,5-T Disappearance in Plants

Basler et al. (1964) and Norris and Freed (1966a,b) established that 2,4-D and 2,4,5-T are decomposed in excised leaves from woody plants. Morton (1966) showed that approximately 80 percent of the 2,4,5-T absorbed by mesquite leaves was metabolized after 24 hours. Numerous other investigations have also shown the importance of metabolism in detoxification and loss of phenoxy herbicides within many plant species.

Leaves and stems of plants are main receptors of foliar-applied herbicides. Aside from their function in decarboxylation, breakdown, and conjugation of the herbicide, leaves and plant parts may abscise from the plant and fall to the soil where the tissue and any residual herbicide is subject to weathering and decay. Aerial parts of plants may also be removed by mowing machines or clipped and consumed by grazing animals. If the herbicide does not kill or stop growth of the plant (many grasses), the herbicide will be diluted by the growth and biomass accretion of the organism.

On plant surfaces, phenoxy herbicides are lost by photodegradation and volatilization in a manner similar to loss from soils. Rainfall is also reported as an important means of accelerating herbicide loss from litter and plant surface (Bovey et al, 1974, Bovey et al. 1975, Eliasson 1973, Morton et al. 1967).

SOILS - RESIDUE AND FATE

Research Monitoring

As indicated from several studies (Bovey and Baur 1972, Bovey et al. 1974, Bovey et al. 1975, Scifres et al. 1977, Norris et al. 1977, Radosevich and Winterlin 1977) under normal application practices, initial levels of 2,4,5-T in soils are usually low and disappear relatively rapidly. In field studies, DeRose and Newman (1947) found 2,4,5-T at 10 lb/A persisted 93 days after application. The investigators concluded persistence was determined by soil microbial activity since 2,4,5-T persisted longer in autoclaved than nonautoclaved soil. Other factors affecting disappearance of 2,4,5-T in soil include soil temperature, leaching, and soil organic matter. Generally, those conditions which favor microbial activity will favor more rapid decomposition of 2,4,5-T.

In 1954, Warren (1954) studied the leaching and rate of breakdown of several phenoxy herbicides in a fine sand, silt loam, and "old" and "new" muck soil types using crabgrass as a bioassay species. He found 2,4-D ester, 2,4,5-T amine and silvex amine readily moved in sandy soil, but little in mineral soils or mucks. Esters of silvex and 2,4,5-T were resistant to leaching in all soils with some movement in sand only. The ester and amine formulations of 2,4,5-T disappeared in two weeks from old muck and in four weeks from new muck and silt loam soil. In sand, 2,4,5-T amine activity dissipated before eight weeks, but some activity of the 2,4,5-T ester occurred after eight weeks. Silvex tended to be more persistent than 2,4-D and 2,4,5-T with some activity of the ester formulation still present after eight weeks in the sand and old muck soils.

More recent research, using gas chromatographic analytical techniques has generally confirmed the results of earlier investigators. Altom and Stritzke (1973) reported the average half life of the diethanolamine salts of 2,4-D, dichlorprop, silvex, and 2,4,5-T were 4, 10, 17, and 20 days in three soil types. Except for 2,4-D the rate of disappearance of the other phenoxys was faster in soil from Oklahoma grasslands than forest. Lutz et al. (1973) studied the movement and persistence of picloram and 2,4,5-T (2 and 4 lb/A) on a North Carolina watershed which averaged a 27 percent slope. Approximately 60 percent of the picloram and 90 percent of the 2,4,5-T disappeared in 15 days. Most of the 2,4,5-T was found in the top 3 inches of soil with no movement of 2,4,5-T beyond 12 in. downslope. In Texas, Bovey and Baur (1972) applied an ester of 2,4,5-T at 0.5 and 1 lb/A to soils at five locations. After six weeks the 2,4,5-T had essentially disappeared from all locations. Soils were sampled to a depth of 3 feet. Similar results were obtained by other workers at other geographical locations (Scifres et al. 1977, Norris et al. 1977, Radosevich and Winterlin 1977).

Plumb et al. (1977) reported on the persistence characteristics of 2,4,5-T applied at 3 lb/A to a chamise site in southern California. Residue levels immediately after application were not determined, but based on residues present 14 days after application (0.9 ppm), 2,4,5-T showed a half-life of about 19 days for the period 14 to 29 days after application (table 4). The rate of degradation changes with time, however. Approximately 1 year after application, the residue level was about 0.05 ppm.

Norris et al. (1977) determined 2,4,5-T residues in forest floor and soil after two successive annual applications of herbicide at 2 lb/A ae applied as the isooctyl ester in diesel oil by helicopter in March. The study area was a cool, moist site in western Oregon (table 5). The rate of decline in 2,4,5-T levels in forest floor after the first application at this site was slower than at the hot, dry site in southern California (Plumb et al. 1977), which may reflect the importance of volatilization and photodecomposition on the loss of phenoxy herbicides from exposed soil surfaces. The rate of loss of 2,4,5-T was quite rapid the first 30 days after the second application, which indicates good adaptation of the microorganisms after the first application. One year after application, residue levels in forest floor were about 0.75 percent of the amount of herbicide originally applied. These data show the strong tendency of forest sites to dissipate 2,4,5-T. Residues were largely confined to the top 6 in. of soil.

Survey Monitoring

Wiersma et al. (1972) reported on analysis of soils for 2,4-D and other

Table 4--Average concentration of 2,4-D and 2,4,5-T in composite soil samples collected from 3 soil depths from a chamise site treated with 3 lb/A ae of each herbicide in southern California (Plumb et al. 1977)

Days after treatment	2,4-D			2,4,5-T		
	Soil depth (in.)			Soil depth (in.)		
	0-4	4-8	8-12	0-4	4-8	8-12
	ppm					
14	1.16	0.16	0.09	0.88	0.06	0.03
29	0.71	0.07	0.05	0.53	0.02	0.02
69	0.22	0.02	0.02	0.29	0.01	0.03
146	0.11	0.02	0.01	0.21	0.02	0.01
379	0.04	0.02	0.02	0.05	0.03	0.03

Table 5--2,4,5-T in forest floor and soil after two successive annual applications, 2 lb/A ae. Herbicide was applied as isooctyl ester by helicopter in March (Norris et al. 1977)

	Months after application					
	0	2	3	6	12	24
	First application					
Forest floor (mg/m^2)[a/]	35.7	40.6	12.1	3.9	1.7	0.7
soil (ppm)[a]						
0-6 in	0.007	0.015	0.077	0.016	0	0
6-12 in	0	0.003	0	0	0	0
12-18 in	0	0	0	0	0	0
18-24 in	0	0	0	0	0	0
	Second application					
Forest floor (mg/m^2)[b/]	137.4	9.7	12.5	4.1	1.5	-[c/]
soil (ppm)[b]						
0-6 in	0.008	0.002	0.003	0.002	0.002	-
6-12 in	0.002	0.001	0	0	0	-
12-18 in	0	0	0	0	0	-
18-24 in	0	0	0	0	0	-

a/ Data for 0,1,3,6 and 12 months are for 9 plots, data for 24 months are from 3 plots.

b/ Data are for 6 plots which received second application.

c/ No samples were collected 24 months after the second application.

chlorophenoxy herbicides by the National Pesticide Monitoring Program staff in 1969. 2,4-D was the only herbicide detected (2,4-D was found in 1.6 percent of 188 samples analyzed with a mean residue level of 0.01 ppm).

In 1970, the National Soils Monitoring Program of the EPA (Carey et al. 1973) sampled soils treated with pesticides in the Corn Belt (an area which uses about one-fourth of the 2,4-D in the U.S.). No 2,4-D or other phenoxy herbicides were detected in soil or crop samples collected, although several insecticides were found. These data indicate that 2,4-D and related phenoxy herbicides are not accumulating in the environment from current patterns of use.

Effects of High Rates of Application or Persistence

Some people are concerned that residues of 2,4-D and 2,4,5-T left in soils in Vietnam might destroy subsequent crops. Early work by Craft (1949), DeRose and Newman (1947) and many others indicated that 2,4-D and 2,4,5-T when applied even at high rates usually do not persist from one growing season to another, due largely to microbial breakdown. Work by Bovey et al. (1968) in Puerto Rico indicated that corn, sorghum, wheat, rice, soybeans, and cotton could be grown in soils without reduction in fresh weight of the crops 3 months after the application of a 1:1 mixture of the -butyl esters of 2,4,-D + 2,4,5-T at 24 lb/A. Similar results were obtained for a 2:2:1 mixture of 2,4-D + 2,4,5-T + picloram at 15 lb/A (except for soybeans, which required 6 months for the phytotoxic effect to disappear). The longer residual effect on soybeans is probably due to picloram because of its greater persistence in soils.

Blackman et al. (1974a & b) reported on recent studies in Vietnam which indicate sensitive crops can be safely grown 4 to 6 months after single applications of the *n*-butyl esters of 2,4-D and 2,4,5-T at rates up to 12 lb/A. The authors indicate the dosage of herbicides in their experiments was considerably higher than would occur in spraying forests or mangroves since their materials were applied directly to bare soil and were not intercepted by herbaceous and woody vegetation. Young et al. (1974a) incorporated a 50:50 mixture of the n-butyl ester of 2,4-D and 2,4,5-T into a soil trench in Utah at the rate of 1,000 2,000, and 4,000 lb/A. After 440 days, 89, 85 and 83 percent respectively of the herbicide was degraded. The rate of loss of the herbicide was rapid considering the low temperatures that prevailed for 7 months during the experiments.

In another study, Young et al. (1974b) reported on the effect of massive doses of 2,4-D and 2,4,5-T sprayed on an area at Eglin Air Force Base in Florida. About ninety-two acres received 1900 lb/A 2,4-D and 2,4,5-T in 1962 to 1964; a second area received 1200 lb/A in 1964 to 1966, while a third area received 340 lb/A of 2,4-D and 2,4,5-T from 1966 to 1970. Chemical analyses of soil cores collected in 1970 from the treated areas showed a maximum concentration, 8.7 ppb of either herbicide, indicating the herbicide had essentially disappeared.

In greenhouse studies using lysimeter columns, O'Connor and Wierenga (1973) found 2,4,5-T degraded rapidly especially in soils previously treated with the herbicide. Biological detoxification of 2,4,5-T applied at 40 and 80 ppm occurred in 43 to 85 days depending upon pretreatment or concentration. The herbicide was not leached below 14 in. in a 60 in. lysimeter. The rates of 2,4,5-T used were 30 to 60 times that used in normal practice.

The Effects of Repeated Treatment on Persistence

Repeat treatments 1 or 2 years following the original treatment are sometimes necessary to control certain brush species with phenoxy herbicides. In two separate studies in Texas, Bovey et al. (1974, 1975) found that 2,4,5-T did not accumulate in soils when applied five times at 0.5 and 1 lb/A every 6 months on the same area. The average concentration did not exceed 95 and 144 ppb, respectively, even when sampled immediately after the last treatment. Most of the herbicide was confined to the surface 6 in. of soil and usually disappeared by the time of retreatment. Soils were sampled at various intervals to a depth of 48 in. The 2,4,5-T was applied as the triethylamine salt in a 1:1 mixture with picloram. In the Oregon forest environment, Norris et al. (1977) reported that two successive annual applications of 2,4,5-T did not increase the persistence of 2,4,5-T. Residue disappearance was at least as rapid after the second application as after the first.

The work in Florida reported by Young et al. (1974a) (see previous section on "High Rates") is an excellent example of rapid disappearance of 2,4-D and 2,4,5-T from frequent repeated applications of massive doses of these herbicides to the soil. In an extensive review of the literature, House et al. (1967) found that 2,4-D and 2,4,5-T essentially disappear from soils a few months after application, regardless of rate applied.

Effects of Pretreatment on Persistence

The microbial degradation of phenoxy herbicides has been thoroughly investigated under laboratory and field conditions (Audus 1964). In field studies, Newman et al. (1952) found that 2,4-D was reduced more rapidly in soils in which it had been decomposed previously. 2,4,5-T disappeared no more rapidly on retreatment than in Duffield silty clay loam. More recent work by O'Connor and Wierenga (1973), however, indicated that 2,4,5-T in lysimeter studies degraded more rapidly following the third herbicide irrigation or treatment presumably because of the presence of a larger microbial population capable of degrading 2,4,5-T than was present at a second irrigation.

Audus (1964) used the term "enrichment" to describe bacterial proliferation in response to a new substrate. Once enriched with a new bacterial population in the soil, the organisms will continue to metabolize the herbicide at a rapid rate so long as the herbicide continues to be supplied to it. If the enriched soil is left for considerable time (60 days) without supplying herbicide, the adapted organisms turn to alternative substrates in the soil, although the state of enrichment is partially retained for long periods in the absence of herbicide.

Processes of Disappearance in Soil

Microbial Decomposition

Persistence of 2,4,5-T in soils is usually two to three times longer than 2,4-D (DeRose and Newman 1947), and very few organisms have been identified as having the ability to decompose the 2,4,5-T molecule (Aly and Faust 1964). Newton (1971) calculated (from studies on the kinetics of degradation by microorganisms) that 2,4,5-T has a half-life of seven weeks in the forest floor. Blackman et al. (1974a & b) noted that in tropical soils, phytotoxic residues from 27 lb/A application of the n-butyl esters of 2,4-D and 2,4,5-T disappeared within 4 weeks. Leopold et al. (1960) found that increasing chlorination of phenoxyacetic acid decreased its water solubility while increasing its adsorption onto activated carbon and organic matter, thus making it less available for microbial degradation. Moreover, Thiegs (1962) noted, from reviewing the literature, that 2,4,5-T was less susceptible to attack by microorganisms because the aromatic nucleus of halogenated phenoxyalkyl carboxylic acids and phenols are more biologically inert in compounds containing the halogen (chlorine) in a position meta (the 5 position) to the phenolic hydroxy.

Investigations by Winston and Ritty (1972) and Reigner et al. (1968) indicated that both 2,4-D and 2,4,5-T are decomposed to form carbon dioxide, inorganic chlorides, and water; chlorophenols are not end-products of this decomposition. Reinhart (1965) provided supporting evidence. The upper half of a 22-acre timbered watershed in northern West Virginia was logged and then 11 acres were treated with 10 lb/A 2,4,5-T ester to kill all vegetation. No odor contaminants (phenols or catechols) were found in numerous water samples taken from the stream draining the treated watershed.

Plant Uptake and Metabolism

Weed and crop plants also absorb and detoxify herbicides by interception of the spray by leaves and stems and uptake of the herbicide from the soil through roots. The fate and detoxification processes of phenoxy herbicides by higher plants will be discussed later. Appreciable loss of herbicide through action of higher plants will occur (Morton et al. 1967). In some cases herbicides are also retained within the tissues of the plant, thereby delaying decomposition.

Chemical Decomposition

Phenoxy herbicide may be degraded by chemical processes in the absence of living organisms. Decomposition may occur by oxidation, reduction, or hydrolysis (Weber et al. 1973). For example, the isopropyl and butyl esters of 2,4,5-T undergo rapid hydrolysis to the acid form in moist soils. Smith (1976) reported less than 20 percent of the esters remained in one soil and none in three others 24 hrs after application.

Photodegradation

Herbicides applied to plant and soil surfaces are subject to decomposition by sunlight. Numerous investigators have shown photolysis of phenoxy herbicides under laboratory and field conditions (Crosby 1976). Crosby and Wong (1973) irradiated aqueous solutions of 2,4,5-T with ultraviolet light and identified the products involved. In aqueous solution, cleavage of the ether bond and replacement of the ring chlorines by hydroxyl and hydrogen occurred. The major products were 2,4,5-trichlorophenols and 2-hydroxy-4,5-dichlorophenoxyacetic acid; 4,6-dichlororesorcinol, 4-chlororesorcinol, 2,5-dichlorophenol and a dark polymeric product. TCDD was not detected among the photodecomposition products. They concluded sunlight can be an important factor in environmental degradation of 2,4,5-T.

Some researchers have shown that 2,4-D, MCPA, 2,4,5-T, and silvex are stable under dry conditions, whereas others have shown the opposite effect (Crosby 1976). Under field conditions, however, herbicides on leaf and soil surfaces are subjected to alternate wet and dry periods due to intermittent rainfall and dew. Baur et al. (1973) and Baur and Bovey (1974) reported considerable loss of dry preparation of 2,4,5-T and 2,4-D from petri dishes under long-wave ultraviolet light (356 nm).

Thermal Loss

Temperatures on the soil surface frequently exceed 140°F (60°C) under summertime conditions. Baur et al. (1973) found significant loss of 2,4,5-T (55%) as the free acid exposed to 60°C but no loss at 30°C after 7 days. The potassium salt of 2,4,5-T adjusted to pH 7.0 showed significant loss (30%) both at 30 and 60°C after 7 days exposure. Baur and Bovey (1974) found exposure of dry preparations of 2,4-D to 60°C resulted in 50 percent loss of the herbicide in one day. In the field it is likely that herbicide not adsorbed or absorbed by soil and plant material would be subjected to rapid ultraviolet and thermal degradation.

Adsorption

2,4,5-T is an organic acid with a pKa of 2.84 and may occur either as an anion or an undissociated molecule in the normal pH range which occurs in field situations (Frissel 1961). Negatively charged anionic herbicides are not readily adsorbed to negatively charged soil colloids (Weber et al. 1973).

Weber et al. (1965) indicated 2,4-D adsorption in soils is due to organic matter, iron and aluminum hydrous oxides, or possibly diffusion into fine pores of inert material. However, in most cases the amounts of herbicide bound to positively charged soil colloids is small (Weber et al. 1973). Weber (1972) studied the relative adsorption of 14 different herbicides by soil organic matter. The acidic herbicides dinoseb, picloram, 2,4-D, and dicamba were adsorbed in relatively low amounts compared to basic and cationic herbicides and the amount adsorbed was inversely related to the water solubilities of the acidic compounds. 2,4,5-T will behave similarly.

O'Connor and Anderson (1974) indicate that organic matter is an important contributor to 2,4,5-T adsorption and in some soil is the only adsorbent of significance. Oxides of Fe and Al did not contribute to 2,4,5-T adsorption in the soils they studied.

Since 2,4,5-T is poorly adsorbed by soils and is relatively water soluble (238 ppm at 20-25°C), some movement can be expected in the soil solution. Available data, however, indicate that the phenoxy herbicides are usually found in the top layers of soil (0 to 6 inches) and thus pose no hazard through leaching into the subsoil or groundwater. Movement of the phenoxys into surface runoff and groundwater is discussed in the following section.

WATER - RESIDUES AND FATE

Streams and Surface Runoff

Research Monitoring

2,4,5-T can enter surface water through direct application, drift, or leaching. These processes have been intensively studied in connection with both experimental and operational applications of 2,4,5-T.

Entry To Streams Via Leaching

On a relative scale, 2,4,5-T is considerably more mobile in the soil than many pesticide materials. On a real scale, however, its movement is small relative to the distance from treated areas to streams (Harris 1967, 1968). Numerous investigators have shown herbicide persistence and mobility in the soil are inversely correlated with organic content.

Many forest soils are typically high in organic matter. Laboratory studies by O'Connor and Wierenga (1973), Edwards and Glass (1971), Lutz et al. (1973), Weise and Davis (1964), Helling (1971 a,b,c) and field studies by Norris, et al. (1977), Plumb et al. (1977), and Bovey and Baur (1972) support the hypothesis that leaching is not an important process for transporting significant quantities of 2,4,5-T to streams.

Entry to Streams Via Overland Flow

This process requires overland flow of water, a phenomenon hydrologists report is relatively uncommon on most forest land. The infiltration capacity of forest floors and soils far exceeds most rates of precipitation except for areas in which soils are badly compacted, are water repellant, or have no surface protection by vegetation. Infiltration capacities in excess of 40 in./hr are not uncommon in many forest environments. In rangeland and agricultural situations, however, this may not be true, and some overland flow may occur. That is not to say that increased outflow of herbicide from treated watersheds does not occur with heavy rains, but that the process in this outflow is more likely to involve mobilization of surface residues from an expanding stream network close to the original stream channel rather than by what is usually viewed as overland (sheet) flow.

Trichell et al. (1968) investigated the loss of 2,4,5-T, dicamba, and picloram from bermudagrass and fallow plots of 3 and 8 percent slopes, using gas chromatographic and bioassay detection techniques. When determined 24 hours after application of 2 lb/A, a maximum of about 2, 3 and 5 ppm of picloram, 2,4,5-T, and dicamba, respectively, were found in runoff water after 0.5 in. of simulated rainfall. Losses of dicamba and picloram were greater from sod than fallow plots, while 2,4,5-T losses were about equal. Four months after application, picloram, 2,4,5-T, and dicamba concentrations in runoff water had diminished to 0.03, 0.04, and 0 ppm, respectively. The maximum loss from the treated area for any herbicide was 5.5 percent with an average of approximately 3 percent.

Edwards and Glass (1971) studied runoff of 2,4,5-T and methoxychlor in Ohio for more than 1 year after application of 10 and 20 lb/A respectively. A total of 5.5 g (0.05%) and 0.8 g (0.004%) of 2,4,5-T and methoxychlor was lost from the treated area in 14 months. The bulk of 2,4,5-T removed in runoff water took place the first 4 months after application and more than half of the loss occurred the first month after treatment. Loss of methoxychlor was relatively uniform and low for the 14-month period from each runoff event.

In North Carolina, Sheets and Lutz (1969) studied the movement of 2,4-D, 2,4,5-T, and picloram from established watersheds in 1967, 1968, and 1969. The watersheds of Halewood clay loam soil supported herbaceous and small woody plants and were unique in that the slope was 35 to 40 percent. Herbicide rate was 2 and 4 lb/A with all herbicides applied as the salt formulations and one ester formulation of 2,4,5-T. In some studies, herbicide could not be detected in runoff water.

Highest concentrations of the herbicide in surface runoff water at the base of small plots were found in 1969 when the application rate was 4 lb/A. Samples taken after the first storm causing significant runoff contained 1.8, 2.7, and 4.2 ppm for 2,4-D, 2,4,5-T, and picloram, respectively. In 1968, concentrations in surface runoff at the base of small plots were 1.2, 0.6, and 0.3 ppm for 2,4-D, 2,4,5-T, and picloram, respectively, the first rain after application. Thereafter, concentrations decreased rapidly. Total removal in runoff from treated plots amounted to 0.04, 0.01 and 0.01 percent of 2,4-D, 2,4,5-T and picloram, respectively.

The investigators indicated that although the concentrations of herbicide in water at the base of surface runoff plots within the watershed was high immediately after application, the levels in water from the flume at the base of the larger watershed were usually below the limits of detection. There was about a four-fold dilution with surface water from untreated land when one-fourth of each watershed was treated. When runoff was low, subsurface flow further diluted surface water and herbicide movement was retarded by adsorption to clay, soil organic matter, and decomposition by soil microorganisms. The authors concluded that low concentrations of 2,4-D, 2,4,5-T, and picloram may appear in runoff water from watersheds sprayed at rates needed for herbaceous and woody plant control. Concentrations in water vary directly with rate of application, percent of the area sprayed, and time, duration, and intensity of the storm.

Bovey et al. (1974) sprayed a 1:1 mixture of the triethylamine salts of 2,4,5-T + picloram at 1 lb/A every 6 months on a native grass watershed for a total of five treatments. Plant "wash-off" was the main source of herbicide detected in runoff water. Concentrations of both herbicides was moderately high (0.4 to 0.8 ppm) in runoff water if 1.5 in. of simulated rainfall was applied immediately after herbicide application. If major storms (natural) occurred 1 month or longer after herbicide treatment, concentrations in runoff water was below 0.005 ppm.

Direct Application or Drift to Surface Waters

Direct application or drift is the principal process by which aerially applied 2,4,5-T used in the forest enters streams. Patric (1971) and Norris and Moore (1971) provide useful compilations of studies of herbicide entry to forest streams. The following paragraphs describe and discuss results of studies of herbicide monitoring for stream contamination in connection with the operational use of phenoxy herbicides in forest and range sites.

Norris (1967) reporting research done by Norris, Newton, Zavitkovski, and Freed, presented data on herbicide residues in streams from several watersheds in Oregon forests treated with 2,4-D, 2,4,5-T or a combination of the two herbicides. All treatments were low volatile esters in diesel oil or water applied by helicopter at rates ranging from 1 to 3 lb/A.

The results show some herbicide is present in nearly every stream which passes through, or is adjacent to, treated areas. Maximum concentrations occurred during or shortly after application and were in the range from 0.001 ppm to 0.13 ppm. With the exception of marshy areas, highest concentrations and longest persistence occur when no provisions were made to avoid direct application to stream surfaces.

The time required to return to nondetectable levels (0.001 ppm) varied with the nature of the area treated and the maximum herbicide concentration observed. Times ranging from less than 1 hour to as much as 4 days have been noted with less than 1 day required in most instances. Norris, Newton, Zavitkiski, and Freed (Norris 1967) also noted a rapid decrease in herbicide concentration with downstream movement. Sampling in an estuary receiving waters from a large forest area which included numerous herbicide treatment areas, showed no detectable phenoxy herbicides (less than 0.001 ppm) in the water.

Through the use of buffer strips and careful attention to details of application, phenoxy herbicide concentrations in forest streams will seldom exceed 0.01 ppm and will not persist for more than 24 hours.

A recent review done for the Environmental Protection Agency by Newton & Norgren (1977) covers most of the important research and considerations involved in the protection of water quality when using silvicultural chemicals. One of the main conclusions is that an ample margin of safety can be easily maintained with very limited untreated buffer strips and the use of positive placement application techniques. The authors' second highest pollution-control priority (after the reduction of the potential for injury to aquatic systems with insecticides) is the maintenance of forest productivity in streamside buffer strips. They suggest that phenoxy herbicides can be used effectively and safely in these areas. The maximum untreated buffer strip recommended when using herbicides is 200 feet for picloram applications during periods of potential heavy rainfall. A buffer width of 1/2 the effective swath width from the center line of the nearest treatment swath is recommended for <u>all</u> phenoxy herbicides. This is based in part on Gravelle's (1976) data, which indicate that important gains to be made from buffer strips are limited to the first 50 feet from the edge of the swath. Beyond 50 feet there is a very low incidence of deposit which varies little with additional distance.

The USDA Forest Service has used 2,4,5-T for approximately 25 years. During this time, forest managers have actively sought to improve application technology including drift control and positive placement of the chemical. Refinements in technology and careful prespray planning can, and have, eliminated excessive 2,4,5-T residues in water. Levels of 2,4,5-T exceeding 0.01 ppm are seldom, if ever, encountered. Levels over 0.001 ppm are rare, and, even then, do not usually last for more than a few hours.

Of all Forest Service water samples collected in Oregon during the last 5 years, only two contained herbicide residues greater than 0.01 ppm. Both instances were traced and found to result from contaminated samples due to improper sample handling. However, even these two samples showed levels of only 0.01 and 0.013 ppm. The first 4 years of samples were taken where 100-foot buffers were used for major streams. The data from the past year came from areas where 200-foot buffer strips were used. There has been no significant contamination with either buffer strip. Thus, it appears there is no need to use buffer strips wider than 100 feet. Actually, the evidence suggests the width could be reduced.

Norris (1967, 1968) looked for the long term entry of 2,4-D and 2,4,5-T into forest streams draining areas receiving these herbicides. In one case, 11 streams in western Oregon were monitored immediately below treatment areas on a regular basis for 9 months after application. In all cases, once the initial stream contamination had declined to nondetectable limits (0.001 ppm in 3 to 72 hours), no further herbicide residues were detected. In a second case, two other watersheds in western Oregon were studied. In one, the treatment area bordered a stream for more than 1.9 miles extending from 200 to 400 yards upslope from the stream. 2,4-D and 2,4,5-T were applied at 1 lb/A ae each as low-volatile esters in oil in the spring. The second area had 25 different treatment areas totalling 395 acres in a 2800-acre watershed which received the same treatment. In both cases, streams were sampled to detect the movement of herbicide from treated areas to the stream, during the first storms of the fall which raised stream levels. No residues were found.

In a midwestern forest, Lawson (1975) sampled stream water during a rising hydrograph to look for storm-induced herbicide runoff after treating two 1.5 acre watersheds on three successive years at a rate of 4 lb/A 2,4,5-T in diesel oil by backpack sprayer. The sampled streams are not perennial streams and flow only in connection with significant storm events. 2,4,5-T residues in water to 2.2 ppm were detected in water collected in connection with the first runoff event which occurred 17 days after application. Less than 0.2 ppm 2,4,5-T was detected in the perennial stream which receives storm runoff from this area. Barely detectable levels of 2,4,5-T were found in samples collected with the next runoff event approximately 7 weeks after application. Subsequent storms did not produce detectable 2,4,5-T residues. These results should not be interpreted as true herbicide runoff in the sense of overland (sheet) flow. It appears more likely to be a case of herbicide mobilization from the bottoms of stream channels which were dry at the time of treatment. No herbicide residues were detected in samples collected during runoff events after either the second or the third application. These latter results are difficult to interpret, but may suggest rapid decomposition of the herbicide by microbial populations adapted to the use of 2,4,5-T after the first application. In any case, it is clear that in this Arkansas forest situation, significant movement of herbicides from treated areas to perennial streams did not occur.

In a similar forest type in Oklahoma, Igleheart et al. (1974) measured 2,4,5-T residues in water collected from streams immediately below four areas treated with 2,4,5-T at 2 lb/A applied by helicopter in May and June. Treated areas ranged in size from 247 to 2000 acres in areas where 20 to 100 percent of the watershed was treated. The results are similar to those of Norris (1967).

In eastern forests, Reigner et al. (1968) used odor tests to look for phenoxy herbicides in streams from four areas treated with butoxy ethanol or emulsifiable acid formulations of 2,4,5-T applied by mist blower. Streams in Pennsylvania and New Jersey were sampled, and in each case, about 0.04 ppm herbicide was detected immediately after application. Residue levels declined about 50 percent in 4 hours, and no residues were detected in samples collected at various intervals over the next 4 weeks. Samples were collected in connection with the first storm to produce more than 1 in. precipitation. The two Pennsylvania streams contained 0.01 and 0.02 ppm 2,4,5-T after the storm, but the New Jersey streams contained no detectable herbicide. This study is limited by the nonspecific detection method.

Pierce (1969) applied 2,4,5-T (and other herbicides) to prevent revegetation on an experimental watershed in New Hampshire. Samples were collected for more than 1.5 years, and the concentration of 2,4,5-T did not exceed 0.001 ppm.

These various studies largely support the conclusion that direct application and drift are the principal sources of phenoxy herbicides in streams. Direct application and drift to surface waters can largely be controlled through careful orientation of spray units to streams and by careful attention to climatic, equipment, and application factors. Buffer strips more than 100 feet in width do not appear to be necessary.

Survey Monitoring

Brown and Nishioka (1967) reported no 2,4-D, 2,4,5-T, or silvex were found in water-suspended sediment mixtures from 11 streams (major rivers) in the western United States in 1965 and 1966. However, insecticides were found at one time or another in small amounts which included aldrin, DDD, DDE, DDT, dieldrin, endrin, heptachlor, heptachlorelpoxid and lindane. Samples were taken monthly.

Data from the U.S. Geological Survey program for monitoring pesticides in streams of the western United States from October 1966 to September 1968 indicated detection of 2,4-D, 2,4,5-T and silvex in small amounts in some rivers (Manigold and Shulze 1969). The highest concentration of herbicide found was 0.00035 ppm of 2,4-D in the James River at Huron, South Dakota in July 1968. The established water quality criteria at that time permitted 0.1 ppm for herbicides. 2,4-D, 2,4,5-T, and silvex occurred 14, 8, and 3 times at the 20 stations of 19 rivers sampled, respectively. Samples were taken monthly with 2,4-D appearing most frequently in spring months in the Arkansas, Huron, and Yakima Rivers in Arkansas, South Dakota, and Washington, respectively. The occurrence of 2,4,5-T was greatest in the Arkansas and Canadian Rivers in Arkansas and Oklahoma. Silvex was found most frequently in the Humboldt River near Rye Patch, Nevada.

Monitoring studies from 20 stations on 19 western streams for pesticides from 1968 to 1971 detected 2,4-D, 2,4,5-T, and silvex in small amounts (Schulze et al. 1973). During this period, 2,4,5-T was the most common herbicide found (109 occurrences), although the number of occurrences of 2,4-D found (103) was similar to 2,4,5-T. The highest concentration of an herbicide was 2,4-D at 0.0097 ppm. Concentrations were highest in water samples containing appreciable amounts of suspended sediments. Greatest occurrence of 2,4-D was in the Huron and Yakima Rivers; 2,4,5-T in Arkansas and Canadian Rivers; and silvex in the Humboldt River in Nevada.

An analysis of 2,4-D, 2,4,5-T, and silvex in streams in Nebraska indicated small amounts of these herbicides were detected with a maximum concentration 0.00053, 0.001, and 0.00008 ppm for 2,4-D, 2,4,5-T, and silvex, respectively (Petri 1972).

An extensive analysis of surface water of Texas in 1970 for 2,4-D, 2,4,5-T, and silvex revealed only trace levels or less of these herbicides (Dupuy and Schulze 1972). Usually less than 1 million acres of brush are sprayed with 2,4,5-T annually. About 2 million acres of pasture weeds are sprayed annually with 2,4-D in Texas out of a total of 106 million acres of range and pasturelands (Hoffman 1975a). Obviously substantial quantities of herbicide are introduced into the Texas environment each year. The lack of significant herbicide residues from these applications is clear evidence of a combination of careful application and favorable environmental conditions that largely restrict herbicide residues to the treated areas.

Impounded Water

Silvex is cited extensively in this section because 2,4,5-T is normally not applied to impounded water sources. The physical, chemical, and biological properties of 2,4,5-T and silvex are quite similar. The propylene glycol butyl ether ester of silvex, a herbicide useful to control aquatic weeds, hydrolyzed almost totally to the acid of silvex in about 2 weeks when applied at 8 lb/A to water overlying Cecil sandy clay loam, Lakeland loamy fine sand, and Brighton soil in plastic pools (Cochrane et al. 1967). Silvex acid increased in concentration in water for a week and then dissipated gradually over a 19-week period. Apparent adsorption of both the ester and acid occurred on the hydrosoil and was followed by gradual diminution of both. The possibility exists that silvex acid and/or a degradation product may be desorbed and readmitted to water.

Bailey et al. (1970) studied the degradation kinetics of the propylene glycol butyl ether ester of silvex and its persistence in water and mud under impounded conditions. The silvex was applied to the surface of three ponds at 8 lb/A. The hydrolysis of the PGBE ester of silvex to silvex obeyed the first order reaction kinetics, the specific reaction rate constants for the three ponds being 0.09 hr^{-1}, 0.10 hr^{-1} and 0.14 hr^{-1}. About 50 percent hydrolysis of the ester occurred in 5 to 8 hours, 90 percent in 16 to 24 hours and 99 percent in 33 to 49 hours. The concentration of silvex in water initially increased, but decreased to zero in three weeks. Adsorption of both the ester of silvex and silvex appeared to occur on the sediment with complete disappearance of both by the fifth week following treatment.

Groundwater

Residues of phenoxy herbicides tend to remain in upper soil layers. The possiblity of 2,4,5-T getting into groundwater supplies in significant amounts is remote even with repeated or high rates of treatment. The interception of these herbicides by vegetation and litter after application and their rapid breakdown and dilution in plants and soils limits their leachability to the lower soil profile.

Linden et al. (1963) studied the possible threat to groundwater using diesel oil (a common carrier for 2,4,5-T sprays) at 53 to 535 gallons per acre. At 53 gal/A the oil did not penetrate the upper layer of soil from 0 to 4 in. At 267 gal/A of diesel oil (with litter removed), 1.5 to 2 ppm oil occurred in the upper 4 in. of soil with traces to 8 in. At 535 gal/A of diesel oil, the upper 4 in. contained 9 ppm oil and the 8 in. depth contained 1 ppm. With the humus layer intact, 1.5 to 2 ppm oil was found in the upper 4 in. layer of a sandy loam soil with only traces of oil within the 8 in. layer. The investigators conclude the use of 53 gallons per acre of diesel oil on forest soil in no way endangers the water table. The use of more than 53 gal/A of diesel oil as an herbicide carrier for 2,4,5-T, silvex or 2,4-D plus 2,4,5-T, even for control of individual woody plants, would be uncommon.

O'Connor and Wierenga (1973) studied the degradation and movement of extremely high rates of 2,4,5-T (57 lb/A) in lysimeter columns in the greenhouse. They concluded that pollution of groundwater from normal application rates of less than 2 lb/A of 2,4,5-T is unlikely because of its relatively slow rate of movement in soil and rapid biological detoxification.

Edwards and Glass (1971) applied 10 lb/A of 2,4,5-T acid to a large field lysimeter in Ohio. The total amount of 2,4,5-T found in percolation water intercepted 2.5 meters deep up to 1 year after application, was considered insignificant.

Bovey and Baur (1972) found no 2,4,5-T or very small amounts at lower soil depths at five widely separated locations in Texas after treatment with the propylene glycol butyl ether esters of 2,4,5-T at 0.5 and 1 lb/A.

Bovey et al. (1975) conducted an investigation to determine the concentration of 2,4,5-T and picloram in subsurface water after spray applications of the herbicides to the surface of a seepy area watershed and lysimeter in the Blacklands of Texas. A 1:1 mixture of the triethylamine salts of 2,4,5-T plus picloram was sprayed at 2.24 2 lb/A every 6 months on the same area for a total of five applications. Seepage water was collected at 36 different dates and 1 to 6 wells were sampled at 10 different dates during 1971, 1972, and 1973. Concentration of 2,4,5-T and picloram in seepage and well water from the treated area was extremely low (<1 ppb) during the 3-year study. No 2,4,5-T was detected from 122 drainage samples from a field lysimeter sampled for 1 year after treatment with 1 lb/A of a 1:1 mixture of the trithylamine salt of 2,4,5-T plus picloram. Picloram was detected in small amounts (1 to 4 ppb) 2 to 9 months after treatment in lysimeter water. Supplemental irrigation in addition to a total of 34 in. of natural rainfall was used to attempt to force 2,4,5-T and picloram into the subsoil.

Processes of 2,4,5-T Disappearance in Water

Phenoxy herbicides are not persistent in water, and significant concentrations, if found, occur for a relatively short time after treatment. Loss of herbicides from treated areas by movement in runoff water is usually a very small percentage of the total amount applied even under intensive natural or simulated rainfall conditions. The phenoxy herbicides rapidly dissipate in streams and are difficult to detect some distance downstream from the point of application. In impounded water they decompose rapidly, especially if adapted microorganisms are present. Insignificant amounts of phenoxy herbicides appear in ground or subsuface water due to their rapid breakdown and their slow movement into the soil profile. In surveys of major river systems in the U.S., 2,4-D and especially silvex and 2,4,5-T appear infrequently in very minute concentrations, well below levels believed to be biologically active.

In addition to the usual degradation processes in water, herbicide residue levels decrease in surface runoff water or flowing water by simple dilution. This is best illustrated in research work or commercial operations where ditch banks are treated for weed control and subsequent water samples are taken at the point of application and at several points downstream. A point downstream is soon reached (depending upon the volume and rate of flow) where the herbicide cannot be detected.

Photodegradation of 2,4-D and 2,4,5-T by ultraviolet light may be significant in the natural environment (Crosby and Wong 1973, Aly and Faust 1964). The rate of 2,4-D photodegradation is increased as the pH of the solutions increase. Fortunately the phenol produced as an intermediate in the degradation of 2,4-D is destroyed by light even more rapidly. It is reasonable to assume that other 2,4,5-T phenoxy compounds undergo similar degradation.

2,4,5-T may be applied to water in rice fields or fields may be flooded soon after herbicide application. Although the pH and temperature of the floodwater that initially enter the ricefield may vary, they reach equilibrium soon after application. The pH of the floodwater at midseason when 2,4,5-T is applied for weed control ranges from 7.3 to 9.0 (Gilmore 1978). The floodwater temperature at midseason (July) when 2,4,5-T is applied for weed control, ranges from 85 to 92°F for maximums or from 74 to 77°F for minimums (Downey and Wells 1975). These conditions favor rapid ester hydrolysis and biological degradation of herbicide residues.

AIR - RESIDUES AND FATE

Sources of phenoxy herbicides in air are from spraying or volatilization from soil, plant, or water surfaces after spraying. Type of spray equipment, weather conditions and herbicide formulation, and carriers all influence loss of herbicides into the air. Control of spray drift is especially important with ground or aerial equipment since phenoxy herbicides may affect valuable vegetation near treated areas.

Initial concentrations in air from spraying or volatilization was discussed earlier. Small spray droplets may drift long distances and affect off-site vegetation. However, the amount of 2,4,5-T or similar herbicide which moves via spray drift or volatilization to nearby nontarget areas is extremely small (but sensitive plants may show characteristic symptoms of exposure).

Grover et al. (1972) studied the relative drift of droplet and vapor of butyl ester and dimethylamine formulations of 2,4-D under field conditions using labelled herbicides. The ground deposit and the airborne spray particles drifting from the target area were collected. The mass of dimethylamine and butyl ester of 2,4-D drifting as droplets was 3 to 4 percent of the material sprayed. No significant amounts of the amine were collected as vapor or particulate drift. However, 20 to 30 percent of the butyl ester of 2,4-D was collected as vapor drift up to one-half hour after spraying. Thus, the drift potential of the butyl ester was about 8 to 10 times greater than the amine formulation in these studies. A similar pattern probably occurs for 2,4,5-T.

Flint et al. (1968) investigated the volatility and vapor pressure of the four most common commercial low-volatile esters compared to a high-volatile ester using gas-liquid chromatography. The order of increasing volatility and the vapor pressure of these esters in mm of Hg at 187°C are as follows: isooctyl - 2.7; 2-ethylhexyl - 3.0; butoxy ethanol - 3.9; propylene glycol butyl ether - 3.9; compared to the reference, isopropyl - 16.7. Similar data have been reported by Grover (1976). Since the butyl ester used in studies by Grover et al. (1972) is considered a high-volatile ester, one would expect reduced vaporization loss from treated areas with low-volatile esters of 2,4-D and 2,4,5-T, as reported by Flint et al. (1968) and Grover (1976).

Monitoring Data

Monitoring data during the spraying season in Canada and the Northwest indicate that the concentration of ester of 2,4-D in the atmosphere varies from 0 to 10 $\mu g/m^3$ or about 0 to 1 ppb (Adams et al. 1974, Hay and Grover 1967). The relative increasing order of volatility of the various esters of 2,4-D is isopropyl, butyl, and isooctyl. At two sampling locations in Washington, the isopropyl ester was found the greatest numbers of days sampled and in highest average concentration in air, followed by the butyl ester of 2,4-D (Adams et al. 1974). Although the isooctylester was found infrequently and in low amounts (0.001 to 0.007 $\mu g/m^2$) on the average in one case, it was found at a maximum concentration of 3.1 $\mu g/m^3$. The researchers were somewhat surprised to find the isopropyl ester since its use was banned in Oregon and parts of Washington.

In other studies, Bamesberger and Adams (1966) collected 24-hour fractions of airborne aerosol and gaseous herbicides at Pullman and Kennewick, Washington field sites for approximately 100 days. The isopropyl ester of 2,4-D was detected most frequently (about 1 out of 3 days) at both sites. Other formulations of 2,4-D were methyl, butyl, and isooctyl. At Pullman, most phenoxy herbicides collected were as larger aerosol droplets, whereas in the hotter, dryer climate at Kennewick, smaller aerosol droplets and gases were most frequent. Herbicides not detected included MCPA, the 2-ethylhexyl ester of 2,4-D, 2-ethylhexyl ester of 2,4,5-T, and the isooctyl ester of 2,4,5-T. The methyl ester of 2,4,5-T was found infrequently (9 out of 99 and 14 out of 102 days) at Pullman and Kennewick, Washington, respectively. Maximum concentrations of phenoxys were the methyl esters of 2,4,5-T and 2,4-D at 3.38 and 5.12 $\mu g/m^3$, respectively.

Cohen and Pinkerton (1966) established that pesticides can be transported from a point remote from their application by winds picking up treated soil, transporting it over short or long distances and depositing it by simple sedimentation or by rain. DDT and other insecticides have been found in rainfall; 2,4,5-T has been found in dust.

Processes of 2,4,5-T Disappearance in Air

The fate of the phenoxy herbicides in air has received limited investigation. Certainly the tremendous space of the atmosphere may quickly dilute and disperse smoke, dust, and other small particles by virtue of air movement. Small amounts of pesticides likewise are quickly diluted to insignificant levels. However, if proper application techniques are not followed, spray drift or vapor may result in sufficient levels of phenoxys to affect nearby vegetation.

Photodegradation of phenoxy herbicides in air probably also accounts for its rapid loss. Destruction of other herbicides in vapor form are known to occur from natural sunlight (Ketchersid et al. 1969).

If attached to dust and other particles, the chemical may eventually settle to the soil surface or occur in rainfall remote from the point of application. Amounts occurring from air movement over long distances are insignificant relative to toxic and phytotoxic effects and accumulation in the food chain.

ANIMALS - RESIDUES AND FATE

Livestock

Early work with 2,4-D, 2,4-DB, MCPA, and MCPB indicated these herbicides did not produce detrimental effects in cattle-grazing treated pastures and that the bulk of the herbicides was eliminated in the urine the first day or two after feeding.

St. John et al. (1964) fed Holstein cows 5 ppm of atrazine, silvex, or 2,4,5-T in daily rations for four days. No residues of these herbicides were found in milk. Silvex (acid) and 2,4,5-T appeared to be totally eliminated in the urine as salts within 5 or 6 days after feeding was started. About 67 percent of the propylene gylcol butyl ether ester of silvex was hydrolyzed to the sodium salt and eliminated in urine.

In actual field grazing trials, Klingman et al. (1966) found from 0.01 to 0.09 ppm of 2,4-D in milk during the first two days after spraying, and lower amounts thereafter. Low-volatile and high-volatile esters of 2,4-D were sprayed on separate pastures at about double the usual rates (2 lb/A). If cows were put into pastures four days after spraying, no residues of 2,4-D were found. The practical lower limit of precision of the method used was 0.01 ppm.

Bjerke et al. (1972) reported residues of phenoxy herbicides in milk and cream after feeding high levels (10 to 1,000 ppm) for prolonged periods of time (2 to 3 weeks). The average residues found in milk at the highest feeding level (1,000 ppm) and the corresponding phenol are in table 6.

Lower limit of sensitivity of the method was 0.05 ppm. Concentrations of phenoxy herbicides were low considering the high levels fed. No residues of 2,4,5-T, 2,4-D, or MCPA, or their corresponding phenol greater than 0.05 ppm were found in milk and cream up to 30, 300, and 1,000 ppm feeding levels, respectively. Residues of silvex were found only at the 1,000 ppm feeding level. No significant difference was found between residues in milk and cream. Residues of all chemicals decreased rapidly upon removal of the chemicals from the feed.

Research by Clark et al. (1975) feeding 2,4-D, 2,4,5-T, and silvex to sheep and cattle confirms earlier work by these and other investigators.

Table 6—Residues of phenoxy herbicides and corresponding phenol in milk after exposing cows to 1000 ppm in their feed for 3 weeks (Bjerke et al. 1972)

Chemical	PPM
2,4-D	0.06
2,4-dichlorophenol	0.05
2,4,5-T	0.42
2,4,5-trichlorophenol	0.23
silvex	0.12
2,4,5-trichlorophenol	0.05
MCPA	0.05
2-methyl-4-chlorophenol	0.06

Residues of 2,4-D, 2,4,5-T, and silvex, and their phenol metabolites fed at 0, 300, 1,000, and 2,000 ppm for 28 days were determined in muscle, fat, liver, and kidney. Muscle and fat contained the least residue; kidneys contained the highest. Liver and kidney contained the highest levels of either 2,4-dichlorophenol or 2,4,5-trichlorophenol. No species difference in regard to 2,4-D, 2,4,5-T, and silvex residue deposition was observed. The doses of herbicides used in this and many other studies represent an exposure in excess of that expected on forage or hay under normal conditions. The higher levels (1,000 and 2,000 ppm) are several-fold greater than encountered in agricultural practices. The investigators conclude that residues of phenoxy herbicide or phenolic metabolites in meat of sheep or cattle are unlikely under proper agricultural uses. It is interesting that no adverse effects, other than decreased weight gain due to anorexia, were observed for any of the herbicides at any level of ingestion. Data for the high feeding level for cattle are given in table 7.

Considering the high level of herbicide fed, the residues are remarkably low. Lower feeding rates resulted in lower tissue residues. Withdrawal from treatment for 1 week before killing resulted in significant reduction in tissue residue levels. These data provide sound evidence that these herbicides or their phenolic metabolites do not accumulate in animal tissue.

Small Animals

The fate of 2,4,5-T in animals exposed in the field may proceed as in controlled experiments discussed below. Female C57BL/6 mice received a single 100 mg/kg subcutaneous injection of 2,4-D and 2,4,5-T acids and the butyl and isooctyl esters of 2,4-D (Zielinski and Fishbein 1967). The esters of 2,4-D disappeared more rapidly than the free acids. No 2,4-dichlorophenol was detected in animals treated with 2,4-D acid or its butyl or isooctyl esters. Pretreatment with the same herbicide enhanced the disappearance rate only for the 2,4-D butyl ester. A relatively prolonged body residence time was observed for 2,4,5-T (<24 hours).

Table 7--Residues of phenoxy herbicides and their phenolic metabolites in cattle fed 2,000 ppm of each for 28 days[a]

	Residues found			
	Muscle	Fat	Liver	Kidney
	ppm			
2,4-D	0.07	0.34	0.23	10.9
2,4-D phenol	0.05	0.05	0.31	1.06
2,4,5-T	1.00	0.27	2.29	27.2
2,4,5-T phenol	0.13	0.05	6.1	0.90
2,4,5-T[b]	0.05	0.05	0.05	0.06
2,4,5-T phenol[b]	0.05	0.05	4.4	0.81
Silvex	0.70	3.77	8.37	23.6
2,4,5-T phenol	0.05	0.05	0.42	0.10
Silvex[b]	0.12	0.67	0.55	1.13
2,4,5-T phenol[b]	0.05	0.05	0.13	0.06

a/ Clark et al. 1975.

b/ Seven days after herbicide removed from feed.

Lindquist and Ullberg (1971) found that after injection of 2,4,5-T-C^{14} to pregnant mice (0.09 mg 2,4,5-T) the radioactive substance did not, to any appreciable extent, reach the embryo. The only organs with higher concentrations than the blood were the kidneys and the visceral yolk sac epithelium. As early as 5 minutes after injection, the concentration in the yolk sac epithelium exceeded that in the blood. Concentration in the brain was low. There was no site of accumulation in the fetal tissues. Labelled 2,4-D accumulated slightly in the visceral yolk sac, passed to the fetus and was rapidly eliminated from all tissues, including the visceral yolk sac (within 24 hours).

Several investigators have studied the fate of 2,4,5-T in rats and dogs (Courtney 1970, Fang et al. 1972 Grunow and Boehme 1974, Hook et al. 1974, Piper et al. 1973a). The 2,4,5-T is widely distributed in all tissues a few hours after treatment, but declines rapidly thereafter. A majority of the 2,4,5-T is excreted (similar to 2,4-D) within one to three days after dosing. Grunow and Boehme (1974) reported conjugates with glycine and taurine, as well as 2,4,5-trichlorophenol metabolite. Fang et al. (1972) indicated highest concentrations were found in the kidneys. Courtney (1970) reported placental and fetal levels of 2,4,5-T were proportional to maternal serum levels but that rat liver homogenates did not metabolize 2,4,5-T. Piper et al. (1973b) showed that the distribution, metabolism, and excretion of 2,4,5-T were markedly altered when large doses are administered in rats. For example, the half-life for clearance of ^{14}C activity from plasma of rats given 5, 10, 100, or 200 mg/kg were 4.7, 4.2, 19.4, and 25.2 hours, respectively; half-lives for elimination from the body were 13.6, 13.1, 19.3, and 28.9 hours, respectively. In dogs, the half-life values were much longer than for rats and appreciable excretion in feces was noted. In urine, three unidentified metabolites were detected, indicating a different metabolism of 2,4,5-T by dogs than rats and may explain why 2,4,5-T is more toxic to dogs than rats.

Wildlife

In actual field studies, Newton and Norris (1968) found that blacktail deer did not accumulate large amounts of 2,4,5-T from browzing in areas that had been treated with 2 lb/A of the herbicide in the Oregon Coast Ranges. Concentrations in flesh rarely reached detectable levels and the ruminant was able to degrade and eliminate the herbicide soon after ingestion.

Erne (1974) found acute and chronic toxicity of 2,4-D and 2,4,5-T in reindeer to be comparable to those observed in laboratory and domestic animals. Residues of phenoxy herbicides were found only occasionally in wildlife and at low concentration. Feeding of phenoxy herbicide-treated vegetation to rabbits and pregnant reindeer for a few months did not affect health or fetal development in offspring.

Honey bee (*Apis mellifera* L.) colonies were fed 2,4,5-T in water at 1,000 ppm (Morton et al. 1974). Concentrations of 2,4,5-T in honey bees from this excessively high rate was 148 ppm but declined to about 5 ppm as soon as the bees began using untreated water. Brood production was reduced during 2,4,5-T feeding, but returned to normal 3 months after 2,4,5-T feeding ceased.

Humans

Although large amounts of 2,4-D, 2,4,5-T, and the related compounds have been manufactured and used. Clinical reports of poisoning are rare. Nielsen et al. (1965) reported a case of suicide with ingestion of the diethylamine salt of 2,4-D. He observed 6.0 g of 2,4-D in the corpse of the victim, corresponding to a lethal dose of 80 mg/kg or more. Seabury (1963) reported another case in which he administered 3.6 g of sodium salt of 2,4-D through intravenous infusion to a patient suffering from disseminated coccidioidomycosis. The patient was troubled with twitchings of the muscles and fell into stupor, but recovered.

Matsumura (1970) determined orally administered 2,4,5-T to man was excreted in the urine as in experimental animals. Volunteers took 100 or 150 mg of 2,4,5-T orally. The 2,4,5-T was readily absorbed and eliminated gradually from the blood plasma, showing a first-order elimination rate. More than 80 percent of the orally administered 2,4,5-T was excreted in the urine unchanged within 72 hours. Little 2,4,5-T was found in urine of workers in a 2,4,5-T factory; however, concentrations in air in the working areas were also less than the recommended maximum concentration (10 ng/mg^3). Other researchers (Gehring et al. 1973, Kohli et al. 1974) reported similar findings to Matsumura (1970). Gehring et al. (1973) found essentially all the orally ingested 2,4,5-T was absorbed into the body and excreted unchanged in the urine.

PART 3: BEHAVIOR AND FATE OF TCDD IN THE ENVIRONMENT

This topic is treated separately from 2,4,5-T because the literature base is smaller and because risk assessment (including exposure analysis) is handled separately in PD-1.

VEGETATION - RESIDUES AND FATE

Crosby and Wong (1977) analyzed the persistence of TCDD in actual herbicide formulations on leaves, soil, or glass plates. When exposed to natural sunlight, most of the TCDD was lost in less than 6 hours from leaves. This loss was due principally to "photochemical declorination." The herbicide formulation provides a hydrogen donor which allows rapid photolysis to occur. Pure TCDD, as used in earlier experiments, would not have been subject to photolysis because a hydrogen donor was lacking. Despite the known persistence of pure TCDD, it is not stable in thin films of formulated herbicide when exposed to outdoor light. Studies are currently in progress at the USDA Forest Service Pacific Northwest Forest and Range Experiment Station to quantify TCDD loss from vegetation and soil under various levels and qualities of light in the forest. They should be completed by October 15, 1979.

Plant uptake of TCDD from soils does not appear to be significant. Soybean and oat plants took up only trace amounts of TCDD in the first 10 to 14 days after exposure to sandy soil containing 200,000 times the amount of TCDD contained in an application rate of 2 pounds per acre 2,4,5-T (with 0.1 ppm TCDD). No detectable TCDD was in the grain or beans at maturity, probably due to normal dilution by plant growth, volatilization, or photodecomposition on the leaf surface, and metabolism. TCDD is not translocated from the point of application on the leaf surface to other parts of the plant and some is washed off with rain water (Isensee and Jones 1975).

SOIL - RESIDUES AND FATE

Earlier laboratory experiments (Kearney et al. 1972) indicated that pure TCDD on soil surfaces was not degraded by sunlight. Crosby and Wong (1977) have demonstrated that TCDD, as it actually occurs in formulated herbicide products, is rapidly degraded (about 15% in six hours) on the soil surface by the action of sunlight. In five soils with widely varying properties, TCDD was found to be immobile even when subjected to leaching (Helling et al. 1973). The possiblity of TCDD entering groundwater is remote (Tschirley 1971). If TCDD is incorporated into soil, it disappears slowly. About half the TCDD is lost after one year (Kearney et al. 1972). It seems unlikely, however, that TCDD would be incorporated in soils under most conditions of use, since it does not leach into the soil. TCDD is not produced from breakdown products of 2,4,5-T in soils or in sunlight (Kearney et al. 1973).

WATER - RESIDUES AND FATE

TCDD is nearly insoluble in water - 0.2 ppb. For this reason, it would be expected to remain on the surface of plants and soil at the application site. Because it is immobile in soils, Kearney et al. (1973) concluded there would be "no ground water contamination problem." In the natural environment, TCDD would be associated with other less water soluble constituents of formulation. They would form a thin film on water surfaces. Such films are expected to be degraded by sunlight, much like the thin films on vegetation or the soil surface studied by Crosby and Wong (1977). Residues might, therefore, be substantially less than would be expected based on research in laboratory systems which suggests that TCDD would be only slowly degraded in water.

The actual levels of TCDD in vegetation, forest floor, soil, and water have not been measured. They can be estimated however, from initial residue levels of 2,4,5-T (Norris et al. 1977) (assuming 2,4,5-T contains 0.1 ppm TCDD) and the TCDD persistence characteristics reported by Crosby and Wong (1977), Kearney et al. (1973) and Miller et al. (1973) apply (table 8). Verification of these values is needed from actual residue studies.

ANIMALS - BIOACCUMULATION

Bioaccumulation means the uptake and at least temporary storage of a chemical by an organism. TCDD is present in such minute quantities in the environment that primary exposure [that is, exposure resulting from direct ingestion (of vegetation or water) dermal absorption, or inhalation] is limited (Norris et al. 1977). Bioaccumulation is a mechanism by which organisms may collect or concentrate TCDD from primary exposure. If significant bioaccumulation occurs these organisms (as food sources for other creatures) could possibly carry toxicologically significant residues. The question is, then, does bioaccumulation occur, and if it does, to what degree? There are three ways to study this question: physical-chemical properties, laboratory studies, and environmental monitoring.

PHYSICAL-CHEMICAL PROPERTIES

Physical-chemical properties are good indicators of the potential for bioaccumulation. Chemicals with low water solubility and high fat solubility have a strong potential for bioaccumulation. DDT is an example of a chemical which is low in water solubility (0.001 ppm), high in fat solubility (86,000 ppm in corn oil) and is known to bioaccumulate in exposed organisms. TCDD is low in water solubility (0.0002 ppm) but is also low in fat solubility (47 ppm in corn oil). The ratio of oil solubility to water solubility is 86×10^6 for DDT and 0.2×10^6 for TCDD. These physical-chemical properties suggest that TCDD would bioaccumulate in exposed organisms, but probably to a lesser degree than DDT. The degree of bioaccumulation depends on the magnitude and duration of organism exposure.

Table 8--Calculated residues of TCDD in the forest after aerial application of 2,4,5-T (containing 0.1 ppm TCDD) at 2 lb/A[a/]

Time after application	Vegetation	Forest floor	Soil	Water
(weeks)	ng/kg[b/]	ng/m^2	ng/kg[b/]	ng/liter[b/]
0	5	4	0.001	1
1	0.001[c/]	0.5[c/]	0.001[d/]	$1x10^{-6}$[e/]
4	—	0.004	0.0009	—
16	--	--	0.0008	—
26	—	—	0.0006	—
52	—	—	0.0005	—

a/ Calculated from Norris et al (1977).

b/ Part per trillion.

c/ Assumes TCDD persistence reported by Crosby and Wong (1977).

d/ Assumes TCDD persistence reported by Kearney et al. (1973).

e/ Assumes TCDD persistence reported by Miller et al. (1973).

LABORATORY STUDIES

Bioaccumulation can also be studied in laboratory animals or in small laboratory ecosystems. Several such studies have been done. Data from laboratory feeding studies of mammals and fish and from laboratory-scale aquatic ecosystems are pertinent.

In laboratory feeding studies involving repeated exposure, Fries and Marrow (1975) report that after six weeks of exposure, rats reached a steady state which was 10.5 times the daily intake. Rose et al. (1976) also report steady state concentration in rates in seven weeks at a little more then ten times the daily intake level. These data establish that in laboratory feeding studies, animals which ingest TCDD in their diet will accumulate TCDD in certain body tissues, at least for as long as exposure continues.

It is also clear, however, that TCDD is not irreversibly accumulated in these feeding studies. Piper et al. (1973), Allen et al. (1975) Rose et al. (1976), and Fries and Marrow (1975) all found a halflife for TCDD residence in the body which ranged from approximately 12 to 30 days. These data indicate that once exposure to TCDD stops, the body burden will decrease. In a feeding study with rainbow trout, Hawkes and Norris (1977) reported limited and preliminary data indicating that on a whole body basis, TCDD levels in fish are approximately of the same order of magnitude as the level of TCDD in the food which they consume.

Several laboratory-scale aquatic ecosystem studies have been conducted with TCDD. Matsumura and Benezet (1973) exposed several organisms to TCDD in model aquatic ecosystems. Unfortunately, in most of their studies the concentration of TCDD in the water was substantially in excess of the limits of its solubility, preventing meaningful interpretation of the data. In one experiment, however, TCDD was adsorbed on sand in the bottom of the aquariums and Matsamura and Benezet found 0.1 ppb TCDD in water and 157 ppb in brine shrimp, to give a concentration factor of 1,570.

Isensee and Jones (1975) also used a laboratory-scale, aquatic ecosystem to study TCDD bioaccumulation in mosquito fish, fingerling channel catfish, algae, duckweed, snails, and water fleas. TCDD was adsorbed on soil which, when equilibrated with the water, resulted in TCDD concentrations in water ranging from 0.05 to 1,330 ppt. Concentrations in excess of 200 ppt exceed the limits of water solubility for TCDD and prevent meaningful interpretation of those bioaccumulation data.

In experiments where the water concentration was less than 200 ppt, Isensee and Jones (1975) reported bioaccumulation ratios (the ratio of the concentration of TCDD in the organism to the concentration of TCDD in the water) ranged from 2×10^3 to 63×10^3. They found a strong, positive correlation between the concentration of TCDD in tissue and concentration of TCDD in water for all organisms. Isensee recalculated these data from a dry weight basis to a fresh weight basis in order to make the data more comparable to other studies. He reported the average degree of bioaccumulation ranged from 2 to 7×10^3 times the water concentration of TCDD. The total amount of TCDD accumulated was directly related to the water concentration. Equilibrium concentrations in tissues were reached in 7 to 15 days. He reports TCDD bioaccumulates to about the same magnitude as many of the chlorinated hydrocarbon insecticides in model aquatic ecosystems.

These results from laboratory studies indicate that organisms exposed to TCDD in their diet or in aquatic ecsosytems will bioaccumulate TCDD. The degree of bioaccumulation which occurs from the use of TCDD-contaminated herbicides in natural ecosystems depends on the magnitude and duration of organism exposure. In laboratory studies, organism exposure is assured through regular addition of TCDD to the food (for feeding studies) or (in aquatic ecosystems) from a substantial reservoir of TCDD adsorbed on sand or soil which continuously releases small quantities of TCDD to water.

In the natural environment, several processes operate to reduce or eliminate TCDD exposure to organisms and thereby minimize the opportunities for bioaccumulation. Crosby and Wong (1977) report TCDD in herbicide formulations disappears rapidly from vegetation and soil when exposed to sunlight. This mechanism would markedly reduce or eliminate organism exposure through dermal contact with or ingestion of contaminated vegetation. In the aquatic environment, the likelihood of 2,4,5-T and TCDD entry to aquatic systems is slight, but if it does occur, chemicals in the water are rapidly diluted and carried downstream with streamflow. TCDD which adsorbs on sediments provides a reservoir of TCDD in the aquatic environment similar to that provided in the model aquatic ecosystem studies. However, in real stream systems, TCDD liberated from the sediments would be quickly moved downstream with streamflow. The opportunity is minimal for bioaccumulation by a particular organism.

ENVIRONMENTAL MONITORING

The third approach to evaluating TCDD bioaccumulation is to look directly for evidence of bioaccumulation in the field. Several efforts have been made, but with markedly different sophistication and sensitivity of analytical methods. For instance, Woolson et al. (1973) analyzed samples of eagle tissues from various regions in the United States. No TCDD was detected. The minimum detection limit, however, was 50 ppb which is not adequate to properly evaluate bioaccumulation of TCDD, considering the inherent toxicity of the molecule.

Young et al. (1976) studied the behavior and bioaccumulation of TCDD in animals from the Elgin Air Force Base site used for equipment development and testing for application of herbicides in Vietnam. The study area received massive applications (1,000 pounds per acre) of 2,4,5-T, much of which contained TCDD in excess of 1 ppm. Analysis of soil from the test site shows TCDD residue levels in the range of 10 to 1,500 ppt. Analysis of rodents, reptiles, birds, fish, and insects shows the presence of TCDD in tissues of at least some of the organisms involved in this test program. The results of this test substantiate the physical-chemical data and the data from laboratory tests which indicate that if TCDD is available to organisms in the field, it will be bioaccumulated. The degree to which herbicide used at Elgin test site was contaminated with TCDD and the massive rates of application, however, make these data not directly applicable to the use of herbicides for any registered purpose in the United States. They are useful to indicate TCDD does have a potential for bioaccumulation.

Other studies done in connection with the registered uses of 2,4,5-T for vegetation control have found relatively little TCDD in biological samples. In 1973-74, the Environmental Protection Agency, cooperatively with the USDA Forest Service, conducted a monitoring program for TCDD in tissues of animals from several areas which had been recently treated with 2,4,5-T in western Oregon and Washington. The analytical methodology employed however, was not adequate to establish the presence of TCDD in those environmental samples. It was adequate to determine which samples did not contain TCDD in the low-to-middle part per trillion range.

Results of the monitoring program showed approximately 84 percent of the samples did not contain detectable levels of TCDD. The remaining samples are described by EPA as "minutely suggestive" for TCDD. In 1976, five of these "possible positive" samples were reanalyzed by two laboratories (participants in the dioxin monitoring program); two samples did not contain detectable TCDD. EPA described the results of analysis of the other three as follows: "Some of the samples analyzed in 1973-74 still appear positive for TCDD. Unfortunately, the results from the two laboratories participating in the confirmation vary widely. The confirmation analysis, therefore, still does not give a precise quantification of the amount of TCDD present. It does appear, however, that from a qualitative standpoint TCDD was present in a small percentage of the forest samples collected in 1973." Assuming three out of five samples (60%) which were possible positives in the 1973-74 analysis are, in fact, qualitative for TCDD, then 9.6 percent of the

1973 samples were positive for TCDD and 90.4 percent did not contain detectible resides.

The EPA beef fat monitoring program which was initiated in 1974, has been completed. Samples of beef fat (85) and liver (43) have been analyzed for TCDD. Approximately 25 percent of these samples are from animals not exposed to areas sprayed with 2,4,5-T. EPA reported in a Draft Dioxin Position Document that one sample showed a positive TCDD level at 60 ppt, and two at 20 ppt; five samples appeared to have TCDD in the range of 5 to 10 ppt. EPA stated, "The analytical method is not valid below 10 ppt, alhtough a recent dioxin implementation plan meeting statement set 9 ppt as the minimum detectable level." Of the 43 liver samples analyzed, one sample may contain TCDD, but the level is too close to the sample detection limits for quantification. A fat sample from the same animal showed no TCDD residue. The results of the EPA beef fat monitoring study indicate bioaccumulation of TCDD in grazing animals is not sufficient to result in regularly detectable levels of TCDD greater than 10 ppt in beef fat and liver.

Newton and Snyder (1978) reported on the analysis of livers from mountain beavers captured 2 months after a forested area in western Oregon was treated with 2,4-D and 2,4,5-T. Analysis of the tissues showed no detectable levels of TCDD with a minimum detection limit of less than 10 ppt. Mountain beavers normally consume large quantities of vegetation, thereby affording them substantial exposure to herbicide-treated plants. In addition, they are a burrowing animal which will put them in intimate contact with herbicide and TCDD present on the soil surface.

Shadoff et al. (1977) looked for accumulation in animals due to the use of 2,4,5-T in the mid-western United States. They did not detect any TCDD (detection limit about 10 ppt) in samples of fish, water, mud, and human milk from areas in Arkansas and Texas. An extensive survey for TCDD residues (with a detection limit of 10 ppt) in aquatic organisms in currently in progress by the USDA Forest Service Pacific Northwest Forest and Range Experiment Station. Organisms are from streams flowing from Oregon forests with a recent history of 2,4,5-T use. The study will be completed by December 1, 1979.

Meselson and O'Keefe (1977), in a preliminary report to Oregon Congressman Weaver, indicated some samples of human milk from areas in which 2,4,5-T is used contained detectable levels of TCDD. They reported three samples out of six from Texas, and one sample out of five from Oregon contained detectable levels of TCDD. The levels detected were at the limits of detection, and were substantially below the 10 ppt level established by EPA in the beef fat monitoring program as the minimum acceptable, reportable level.

The results of these various tests indicate that, if TCDD is present in the environment in a form which is available to organisms, then bioaccumulation will occur if organisms are exposed. This concept is supported, both from an examination of the physical-chemical properties of TCDD, as well as by studies of its behavior in anmals exposed through feeding studies or in laboratory model aquatic ecosystems. The degree to which bioaccumulation of TCDD occurs in the field is dependent not only on the physical-chemical properties of the compound, but also on the persistence and availability of TCDD in the environment. Mechanisms of degradation and dilution which operate in the natural environment reduce the opportunities for organisms to be exposed, and thereby reduce the degree to which bioaccumulation might occur.

Monitoring for TCDD residues in animal samples from areas where 2,4,5-T is used at normal rates of application tend to show little or no detectable bioaccumulation of TCDD. In the beef fat monitoring study, for instance, only three samples out of 63 (exposed group) contained TCDD at levels within the range at which the analytical method is valid quantitatively. The EPA monitoring for TCDD in animal samples from western forests conducted prior to June 1974, showed about 90 percent of the samples did not contain detectable levels of TCDD.

The study of TCDD residues in livers of mountain beavers from areas treated with 2,4,5-T showed no detectable levels of TCDD, with minimum detection limit of less than 10 ppt. A widescale monitoring of water, sediment, fish, beef, and human milk from areas in the midwestern United States where 2,4,5-T has been applied also showed no detectable TCDD residues at minimum detection levels which averaged 10 ppt. These monitoring efforts indicate that substantial bioaccumulation of TCDD (sufficient to produce residue levels in excess of 10 ppt TCDD in the majority of the population) is not occurring in animals in or near areas treated with 2,4,5-T in current operational programs.

This conclusion is not in conflict with recently reported findings of TCDD in fish from the Titawabasee River downstream from the Dow chemical manufacturing plant at Midland, Michigan (Dow 1978a). The residues in the fish, whether they are from plant discharge water or are from the products of combustion (Dow 1978b), did not result from the use of 2,4,5-T as an herbicide.

THERMAL CONVERSION OF 2,4,5-T TO TCDD

It is possible to produce TCDD on heating or burning of 2,4,5-T or 2,4,5-T treated materials in laboratory tests. The conditions of combustion and herbicide concentration are crucial. The tests reported by Baughman and others show TCDD formation when 2,4,5-T is heated in a closed container under alkaline conditions such that the sodium salt of trichlorophenol is a significant degradation product. The amount of herbicide employed in these tests was very high. Langer et al. (1973) showed control of the decomposition reaction to produce trichlorophenol was necessary since heating above the decomposition point (300°C) produced no TCDD. Concentration of herbicide is very important because the formation of TCDD is apparently a bimolecular reaction; that is, it requires the joining together of two molecules of sodium 2,4,5-trichlorophenate. If conditions of heat and alkalinity are conducive to the condensation of the phenol to form TCDD, then the extent of condensation varies with the number of molecules available to interact with one another.

Experiments like those of Baughman and others are useful only to show that thermal production of TCDD is chemically possible. Experiments which use closed systems and high concentrations of 2,4,5-T drastically overestimate the levels of TCDD which might be produced in burning situations in the field because (a) the concentrations of herbicide are several times greater than the levels of 2,4,5-T which occur in the field, and (b) heating is prolonged and uniform, but combustion does not actually occur. Temperatures at which thermal decomposition of TCDD occurs (800°C) are not attained in these test situations. Actual burning, of course, will result in temperatures near those used in laboratory tests only briefly. As temperatures approach 800°C, thermal decomposition of TCDD will also occur. When combustion can take place with a free exchange of air, temperatures above 1,200°C are common. Under these conditions we expect complete oxidation of 2,4,5-T, trichlorphenols, TCDD, and similar chemicals.

There are only limited experimental data on how much TCDD is produced when 2,4,5-T is burned. Watts and Storher (1973) noted burning and heating of such 2,4,5-treated products as vegetation, meat, and fat did not produce detectable TCDD. Sensitivity of their analysis was not adequate to detect environmentally important quantities of TCDD. Present metholdology with sensitivities approaching 10 ppt is sufficient.

The most pertinent data come from a laboratory experiment in which grass treated with 2,4,5-T at 12 pounds per acre was burned under conditions somewhat resembling those which might occur in the field (Stehl and Lamparski 1977). Their study showed an approximate 0.00016 percent conversion of 2,4,5-T to TCDD. This involved a semi-closed system, however. Thus, any TCDD which might normally have been lost to the air as vapor or adsorbed on smoke particles in forest burning was captured and retained in this system.

The amount of TCDD produced is dependent on the concentration of 2,4,5-T in the vegetation. Norris et al. (1977) determined the persistence of 2,4,5-T in Oregon forests. Calculated levels of TCDD which might be produced by burning, assuming the conversion ratio reported by Stehl and Lamparski (1977) are in table 9.

Clearly, the amount of TCDD produced depends to a major degree of when burning occurs after treatment. 2,4,5-T is occasionally used to desiccate brushfields prior to burning. Burning may take place from 1 to 3 months after the application resulting in the possible TCDD levels of 14 and 0.2 parts per trillion, respectively. In some brush types, burning is delayed for 12 months or more. Immediately after application the level of TCDD present on the vegetation is approximately 10 parts per trillion, assuming the 2,4,5-T contained 0.1 parts per million TCDD. Research of Getzender and Hummel (1975) and Crosby and Wong (1977) indicates the TCDD orginally applied will be largely gone within 1 month of the application. Therefore, the levels of TCDD which might be produced by burning are not expected to substantially exceed TCDD levels present as a result of the original application of herbicide.

Preliminary research results from the Dow Chemical Company indicates several dioxin isomers may be formed in trace amounts during the combustion of many substances (not contaminated with or associated with 2,4,5-T). Fossil fuels, automotive exhaust, trash burners, cigarette smoke, and charcoal-grilled meats have all been found to produce or contain minute quantities of various dioxin isomers, including in some cases the 2,3,7,8-tetrachloro isomer (Dow 1978b). The validity of this research remains to be substantiated, but in any case, these sources of dioxins are not associated with the registered uses of 2,4,5-T as an herbicide in any way.

Table 9--2,4,5-T residues on vegetation (measured) and TCDD (calculated) that might be produced by burning vegetation

Months after application	2,4,5-T	Possible TCDD level if burning occurs at time indicated
	ppm	ppt
0	95	152
1	9.1	14
3	0.10	0.16
6	0.07	0.11
12	0.01	0.02

a/ From Norris et al. (1977).

b/ Percent conversion is 0.00016% (Stehl and Lamparski 1977).

PART 4: ANALYSIS OF EXPOSURE-NONAPPLICATORS

EXPOSURE VIA AIR

Bamesberger et al. (1966) indicated 2,4,5-T was found infrequently and in low concentrations in air-sampling studies in Washington state. In high use areas, however, one might expect concentrations similar to 2,4-D as reported by Adams et al. (1974). Average concentrations of the ester of 2,4-D in air in Washington during the spraying season was 0.1 $\mu g/m^3$. Assuming a person would inhale 30 cubic meters of air per day, the exposure would be 0.003 mg per day. The threshold limit values in air adopted by the American Confernece of Governmental Hygienists in 1977 were 10 mg/m^3 for 2,4-D or 2,4,5-T (Anonymous 1977b).

A medical evaluation was made of 64 men engaged in the manufacture of 2,4,5-T in the Dow Chemical Plants (Johnson 1971). No adverse effects in human health or clinical results were found when compared to 4,600 men not exposed to 2,4,5-T. Some workers were exposed to 2 to 8 mg (inhalation) daily of 2,4,5-T for >960 days (total of 10,000 mg 2,4,5-T).

The highest concentration of phenoxys in air probably occurs during application. Russian workers (Fetisov 1966) found concentrations of the sodium salt of 2,4-D up to 22.4 mg/m^3 after spraying. Akesson (1978) however, has shown a maximum of 20 $\mu g/m^3$ of herbicides downwind from typical aerial application sprays. TCDD has not been measured in the air in spray areas, but possible levels can be calculated based on an assumed 2,4,5-T:TCDD ratio of $1{:}1x10^{-7}$ and the levels of herbicide above.

EXPOSURE VIA FOOD

No research data or reports were found on suicidal attempts or accidental ingestion of large amounts of 2,4,5-T. Three reports on the fate of 2,4,5-T in man taken orally in moderate amounts indicated a majority of the 2,4,5-T is eliminated unchanged in the urine a few hours after ingestion (Gehring et al. 1973, Kohli et al. 1974, Matsumura 1970). Doses as high as 150 mg (2.2 mg/kg) were taken (Matsumura 1970). No detrimental effects were noted. Oral intake of these proportions, however, would be uncommon.

Measurable amounts of 2,4,5-T were found only in two food samples in FDA market basket surveys in 1966-1967 and one sample in 1967-1968. No 2,4,5-T has been found in food since 1968 in the FDA studies. A total of over 2,000 samples were collected and analyzed. Highest 2,4,5-T concentration in the 1966-1967 samples was 0.19 ppm. Only two residues of silvex were found. These occurred in dairy products collected in 1965-1966 and were 0.018 and 0.029 ppm (EPA 1978). Therefore, based on FDA market basket surveys, the amount of phenoxy herbicides in food is virtually undetectable.

The most direct exposure of man to 2,4,5-T through food products is probably via plants. However, research has shown that phenoxy residues in forage and agronomic crops usually disappears rapidly. Since most weeds in crops are treated in early spring, residues disappear by harvest time. Devine (1970) analyzed 27 samples of rough rice from Texas, Arkansas, and Louisiana for residues of 2,4,5-T at intervals from 50 to 84 days after application of 2,4,5-T for weed control. No detectable residues (0.01 ppm) were found. Rice straw contained residues which varied from <0.01 ppm to 1 ppm. In the case of pasture and rangeland plants, which may intercept relatively high amounts of phenoxy herbicides (up to 200 ppm), residues can be avoided in meat and milk products by deferring grazing for milk cows on the treated area a few days to a few weeks and removing meat animals from treated pastures two weeks before slaughter. These restrictions appear on current product labels.

Even when wildlife species or livestock graze on pastures immediately after spraying, only small amounts of phenoxy herbicide may appear in meat or milk. It disappears after a few days due to rapid loss of the herbicides from forage and by normally rapid excretion from the grazing animal. Klingman et al. (1966), in actual field grazing trials with cattle, found 0.01 to 0.09 ppm of 2,4-D in milk the first two days after spraying 2,4-D 2 lb/A and lower amounts thereafter. No residues of 2,4,5-T were found in milk from cows put into pastures four days after spraying. Bjerke et al. (1972) found no residues of 2,4-D, 2,4,5-T or MCPA, or their corresponding phenols greater than 0.05 ppm in milk from cows exposed to 30, 300, or 1,000 ppm 2,4,5-T in their feed level. Residues of silvex were found only at the 1,000 ppm feeding level. Clark et al. (1975) concluded residues of phenoxy herbicides or phenolic metabolites in meat of sheep or cattle are unlikely under normal patterns of 2,4,5-T use.

In field studies, Newton and Norris (1968) found that blacktail deer did not accumulate large amounts of 2,4,5-T grazing browse that had been treated with 2 lb/A. Concentrations in tissue rarely reached detectable levels and the ruminant was able to degrade and eliminate the herbicide soon after ingestion. Obviously game animals may graze in treated areas immediately after spraying, but in most cases spray areas are substantially smaller than the home range of large game animals thus exposure is not continuous. Game animals are likely to constitute a vanishing small proportion of the average human diet in the U.S., but may be an important component in the diet of a few individuals.

Fish and other aquatic organisms are also important components of the diet of man. Occurrence of significant amounts of phenoxy herbicides in the FDA market basket survey in fish products was not indicated. Research shows that most fish do not accumulate large amounts of the phenoxy herbicides (<1 ppm), even when the herbicide is applied directly to water surrounding the fish. Degradation of phenoxys occurs in water sources. Fish also have the capability to eliminate and degrade the phenoxys.

Bioaccumulation of TCDD in aquatic ecosystems under experimental conditions has been demonstrated (Isensee and Jones 1975), but in the natural environment they remain largely undetected (see bioaccumulation of TCDD in Part 3 of this chapter).

EXPOSURE VIA WATER

Residues of phenoxy herbicides, tend to remain in upper soil layers and are rapidly degraded. It is unlikely that groundwater would be polluted from current registered uses of phenoxy herbicides, thus exposure is considered zero.

Surveys of surface waters by the U.S. Geological Survey program of major rivers in the western United States over a period of years indicated that the highest concentration of a phenoxy herbicide was 0.00097 ppm 2,4-D. Researchers have found that even in streams adjacent to aerial spraying operations in the forest, concentrations of 2,4-D, 2,4,5-T, or other herbicides seldom exceed 0.01 ppm. After application, concentrations of the herbicide rapidly diminish by dilution, The preponderance of stream water samples from operational monitoring programs in forest land have not contained detectable residues of 2,4,5-T. Even when ditch banks were sprayed directly so spray fell into the stream, the maximum 2,4,5-T found after applications at 2 lb/A was 0.04 ppm. Herbicide could be found only in the treated area, but none 1 mile downstream.

Therefore, considering that only small and intermittent portions of the total land area are treated, the risk of exposure of the general population in the U.S. to significant levels of the phenoxy herbicides in water is remote. The greatest potential for exposure occurs if domestic water is taken from very small streams in or immediately downstream from treated areas. An extensive research base shows: (1) such exposure would be infrequent because most small watersheds are never treated, and those that are seldom yield water contaminated with herbicides, and (2) when contamination does occur it is low (less than 0.1 ppm, usually less than 0.01 ppm 2,4,5-T) and transitory (less than one hour to a few days).

PART 5: EXPOSURE ANALYSIS - APPLICATORS

The Environmental Protection Agency RPAR notice (Position Document 1 or PD-1) for pesticide products containing 2,4,5-T reported six rebuttable presumptions against registration (or presumptions of risk). In all but one, scenarios regarding spray practices involving 2,4,5-T were used to establish assumptions for calculating a presumed level of application exposure. When these levels of exposure were compared with estimated no adverse effect levels (for reproductive and fetotoxic effects), EPA concluded ample margins of safety did not exist. The assumptions used in the scenarios in PD-1 substantially over estimate exposure resulting in calculations of margins of safety which over estimate risk.

Calculation of accurate margins of safety is dependent equally on correct identification of no-adverse-effect-levels and correct determination of the nature, magnitude and duration of exposure. The purpose of this section of the report is to provide information on the nature, level, and duration of exposure applicators (or those in or near spray operation areas) receive from spray practices currently in use. This section contains three major sections: (1) description of the exposure situations which result from spray practices currently in use in each of the four major commodity areas (timber, range and pasture, rights-of-way, and rice), (2) an analysis of exposure in which various exposure assumptions are used in a factorial approach to calculate adjusted levels of exposure and margins of safety, and (3) an estimation of maximum exposure based on direct measurement and expressed in absolute terms.

PRESUMPTIONS OF RISK AND METHODS FOR EVALUATING EXPOSURE

The Environmental Protection Agency Notice of Rebuttable Presumption Against Registration and Continued Registration of Pesticide Products Containing 2,4,5-T contains the conclusions that the following rebuttable presumptions against registration or presumptions of risk arise:

1. TCDD alone and 2,4,5-T containing 0.05 ppm TCDD can produce oncogenic effects in mammalian species (EPA 1978, page 17128).

2. The difference between the no-adverse-effect-level and the calculated dermal exposure level of a back-pack sprayer for both 2,4,5-T and TCDD do not constitute an ample margin of safety with regard to teratogenic effects (EPA 1978, page 17139).

3. The difference between the no-adverse-effect-level and the calculated dermal exposure level of a sprayer using tractor-mounted, low-boom equipment for both 2,4,5-T and TCDD does not constitute an ample margin of safety with regard to teratogenic effects (EPA 1978, page 17140).

4. The difference between the no-adverse-effect-level and the calculated dermal exposure of persons exposed directly beneath the spray plane for only 2,4,5-T does not constitute an ample margin of safety with regard to teratogenic effects (EPA 1978, page 17140).

5. The difference between the no-adverse-effect-level and the calculated (inhalation) exposure level of persons exposed directly beneath a spray plane for only 2,4,5-T does not constitute an ample margin of safety with regard to teratogenic effects (EPA 1978, page 17141).

6. The difference between the no-adverse-effect-level and the calculated cumulative exposures of oral, dermal, and inhalation exposure level for both 2,4,5-T and TCDD does not constitute an ample margin of safety for those instances that single route exposures had exceeded ample margins of safety (EPA 1978, page 17141).

Appendix 3 contains extracts from PD-1 showing the exposure scenarios, assumptions, dose levels, and no-adverse-effect levels for presumptions of risk two through six.

Presumption of risk no. 1 (oncogenic effects) is based solely on the toxicology of 2,4,5-T and TCDD. The EPA PD-1 does not include an analysis of exposure in relation to a no-adverse-effect-level for oncogenic effects. The USDA policy on conduct of activities of joint Pesticide Assessment Teams precludes consideration of the toxicology associated with presumptions of risk. Therefore this assessment team report does not comment on presumption of risk no. 1.

The other five presumptions of risks (two through six, listed above), include both elements of toxicology and an analysis of exposure (to determine exposure or dose level). The toxicological basis for these five presumptions is identified in PD-1 and is based on "reproductive and fetotoxic" effects or teratogenicity. The exposure levels consistent with "no-adverse-effect" for teratogenicity were determined in the PD-1 as 20 mg/kg/day for 2,4,5-T and 0.03 μg/kg/day for TCDD. These no-adverse-effect levels are an integral part of the exposure scenarios from which the presumptions of risk arose. For the reason stated above, the Assessment Team does not evaluate these no-effect-levels. This report does evaluate exposure in these and alternative scenarios.

There are two major methods for reviewing the exposure analyses: the factorial method and the absolute method. The factorial method starts with the exposure scenarios as presented in PD-1. It identifies both the overt and hidden assumptions in a particular scenario, presents an alternate or modified set of assumptions, and develops a set of correction factors by which the exposure level should be multiplied in order to adjust for the modified assumptions. This is particularly useful in demonstrating the effect of various exposure assumptions on the calculated margin of safety. A range of assumptions can be evaluated quickly; for instance, if a particular scenario uses a 40 lb/100 gal. concentration of spray and 8 hours of exposure per day but the reader wishes to determine the effect of a 10 lb/100 gal spray and a 4-hour exposure day. The "correction factor" of 0.25 x 0.5 = 0.125 can be applied to either the previously calculated level of exposure (0.125 x exposure) or margin of safety (1/0.125 x safety margin) to obtain an adjusted value.

The absolute method is used by the EPA in the PD-1. It calculates de novo in stepwise fashion the estimated exposure for a particular exposure situation based on a series of assumptions. We have used the absolute method by keying preliminary data derived from one experiment involving exposure of human to 2,4,5-T with estimates of dermal contact based on field-use experience.

A third approach, which would be a modification of the absolute method could be considered. The absolute method as used herein and in the PD-1 tends to rest largely on single-source documents for a given scenario. It may be more valid to derive exposure potentials from the large body of data on drift from various kinds of equipment and calculate the dermal and inhalation interception of drift for persons in various dress at various distances. This could easily be accomplished jointly by persons involved in drift and exposure research and those involved in regulatory and hazard-evaluation work. Some efforts along this line have already been initiated (Akesson 1978) Although this approach has much to recommend it, it was beyond the scope of this assessment team.

Included in this report are calculated "margins of safety." The EPA PD-1 presents the data necessary for the calculations of the margin of safety (the no-adverse-effect-level divided by the calculated dose level) but does not explicitly state what consititutes an "ample margin of safety." Both the set of conditions or assumptions and the applicable acceptable safety margin associated with a presumption of risk should be clearly stated along with all statements of risk. This would enable all interested parties (including non professional groups) to assess the applicability of particular assumptions and margins of safety to their own circumstances.

An exposure analysis involves three types of exposure - environmental, consumer, and occupational; and three routes of exposure - oral, dermal, and inhalation. Although environmental exposure has been the principal focus of citizens' groups opposed to the use of 2,4,5-T and other chemicals, it was concluded by EPA that the present evidence shows this to be inconsequential with regard to the no-adverse-effect-levels which were identified in the PD-1 (EPA 1978). Consumer exposure was also shown to be inconsequential but was added to the total in the cumulative calculations that resulted in the assumption of unacceptable level (EPA 1978, page 17138). The other presumptions of risk (Nos. 2,3, 4, and 5) all involved occupational exposures primarily through dermal or inhalation routes. In judging any risks from occupational exposure, higher levels of presumptive exposure are acceptable because of its voluntary nature. Potential for over-exposure in any given situation can also be reduced through special protective measures.

Data on exposure for numerous exposure situations are needed. The scenario process involves making certain reasonable assumptions pertinent to the scenario being analyzed. In the absence of hard data, it is necessary to use the judgment of qualified, experienced individuals.

It is vital to the credibility of any hazard analysis to present the assumptions on which it rests as clearly as possible. These were not all explicitly stated in EPA's Position Document No. 1. Hidden assumptions can seriously mislead inexpert persons as to the applicability of the conclusions. There are several steps in hazard analysis which must be exposed to public judgment as part of the process of identifying whether the assumptions are reasonable or absurd. Other steps characterize an adverse effect as a "reasonable" or an "unreasonable" effect (which under FIFRA is the basis for EPA action). The use of "worst case" assumptions (particularly when several worst case assumptions are multiplied in sequence) can lead to unreasonable or improbable conclusions. The assumptions, reasonableness of adverse effects, and the use of worst-case situations in estimating risk need critical scrutiny.

Actual exposure time to a pesticide during the work day and work year is less than it would first appear. The information needed to compute exposure times is in 14 calculation summaries at the end of each commodity group portion in the "Exposure of applicators according to use pattern" section in Part 5 of this chapter. A summary table is at the end of the section.

Some confusion may exist in terminology. In this report the following definitions are used. The time spent at the treatment site is called "application time"; the time the sprayer is actually operating is called "nozzle time;" the portion of the nozzle time during which the worker intercepts the spray drift is called "drift time." For example, the typical back-pack sprayer on rangeland has 6 hours per day of application time, but because of the distance between stems (targets), the nozzle time is 6 seconds per minute and the walking and searching time is 54 seconds per minute. The sprayman works at spraying for 2 days per week over a 5-week period and does other ranch chores the balance of the week. Aircraft application results in the least exposure to field workers because the workers are upwind and at least one swath width away, while foliar application with power hand guns have the greatest exposure time. For most application situations, the application of 2,4,5-T is incidental to other activities and the worker will operate in only one or a few sites, but in rights-of-way and helicopter crews there are a number of commercial applicators applying the chemical for several months each year.

EXPOSURE OF APPLICATORS ACCORDING TO USE PATTERN

FORESTS

Aerial Application

Formulation and Containers

2,4,5-T is available for use in rehabilitation, site preparation, and release in forestry aerial applications as low-volatile emulsifiable esters (butoxyethanol, 2-ethylhexyl, propylene glycol butyl ether, and isooctyl esters) containing 4 or 6 lb ae per gallon. Several mixtures of 2,4,5-T with other herbicides are also used. Tordon 155 (1 lb ae picloram and 4 lb ae 2,4,5-T as the isooctyl ester), brushkiller (2 lb ae each of 2,4-D and 2 lb ae 2,4,5-T as low-volatile esters), and Banvel 310, 320, 510, and 720 (dicamba with 1 or 2 lb of 2,4,5-T per gallons as esters or amine salts). Invert drift reducing formulations of 2,4,5-T containing 1 or 2 lb ae alone or in combination with 1 or 2 lb ae of 2,4-D are also available. Containers are 1 or 5 gallon cans and 30 or 55 gallon steel drums.

Several adjuvants may be used to increase either viscosity or surface tension and reduce droplet drift. These include: bifluid invert emulsifiers, Norbak, Lo-Drift, Nalco-Trol, and foaming agents.

Method of Application

Helicopters such as the Bell G3B, Hiller 12E, Llama Allouette, or Bell 206 are usually used to aerially apply 2,4,5-T in forestry. A few applications are made with Bell 205 and larger helicopters. The most common conventional application equipment consists of a 36 to 40-foot spray boom equipped with 18 to 22 flat fan, hollow core straight stream (jet), or Raindrop nozzles operated at 20 to 45 psi pressure. Nozzles are oriented on the boom from straight down to directly back along the airstream; an angle of 30° to 45° from the horizontal and directed back is common.

Satisfactory results from phenoxy herbicides require a deposit of 72 droplets per square inch of plant surface (Behrens 1957). Spray equipment used in aerial applications requires nozzles which provide sufficient droplets to meet this requirement and retain enough size to reduce movement from the spray target area by drift. A D6-46 hollow cone nozzle produces a range of droplets with a volume mean diameter (VMD) of 300 to 400 microns and deposits 70 to 90 percent of the spray within 96 to 130 feet when applied at 50 feet in elevation in a 6 mph wind. If the D6-46 nozzles are directed straight back, VMD is increased to 400 to 600 microns and deposits of 85 to 98 percent of the spray volume are deposited within 6 to 96 feet when applied at 50 feet in elevation in a 6 mph wind. D8 jet nozzles with drift-reducing additions produce droplets with a VMD of 800 to 1,000 microns and a deposit of 95 to 98 percent with no drift when applied at 50 ft. elevation in a 6 mph wind (Akesson and Yates 1978, USDA Forest Service 1978). Specialized spray equipment is less commonly used to apply high viscosity drift-reducing sprays, or foam sprays. For maximum drift control near sensitive crops, a Microfoil Boom is quite often used.

The average spray tank holds 120 gallons with up to 400 gallons on larger helicopters. Actual spray loads average 60 to 80 gallons on the smaller helicopters (Bell 3GB or Hiller 12E) due to safety considerations related to air density effects. The spray system is calibrated to apply 1 to 20 gallons of spray mix per acre in 1 or 2 passes in a 55- to 100-foot spray swath. Sprays are applied at 40 to 60 MPH (up to 90 MPH with larger helicopters) at a height of 30 to 50 feet above the vegetation.

Rate and Timing of Application, Carrier and Operating Conditions

2,4,5-T is applied during one of four spray seasons: Budbreak or dormant (Feb.-Mar.), early foliar (May-July), late summer foliar (mid-July mid-August), and late foliar (mid-Sept. - early Oct.) (table 10).

Chemical is applied to the treatment area at a rate of 3/4 to 4 lb of a.e. per acre. The average rate is slightly more than one pound per acre, reflecting widespread dilution with 2,4-D. When 2,4,5-T is used alone, 2 lb/acre is the most commonly used dosage in 5 to 10 gallons total spray, with 10 gallons prevalent in the Northwest and 5 gallons in the East.

2,4,5-T is diluted and suspended in one of three kinds of carriers -- oil, water, or oil-in-water emulsions. Oil is used for dormant or budbreak sprays in the spring on deciduous species. Water carriers are used for foliar sprays during the growing season. Emulsions are used for evergreen brush species or when leaves of deciduous species have fully developed and conifers are inactive.

Aerial spray operations are normally conducted when winds are less than 6 MPH, temperatures are less than 70°, relative humidity is above 50 percent, and when vegetation is free of excessive moisture or ice. Precipitation must not be falling or about to fall, and air turbulence must be calm enough so as to avoid disrupting normal spray patterns. Conditions suitable for treatment may exist for only a short period of time each day and may not occur at all on some days. Usually only about 1 to 4 hours of proper conditions exist in any day to permit spraying. From 50 to 80 acres are treated per hour of actual operation depending on amount of mixture per acre and distance from treatment area to helispot. Each hour of operation involves about 10 minutes of nozzle time (table 11).

Time Required for Treatment and Number of Applications

Aerial application companies that do most of their business with agricultural crops are also used for forestry. Most aerial spraying in the forest is done by contract application. Most forest operations

Table 10--Timing and purpose of aerial applications of 2,4,5-T in forestry by geographic section

Section	Rehabilitation and site preparation	Release
NORTH	mid-July - mid-August	mid-July - mid-August
SOUTH	April - July	April-July
ROCKY MOUNTAINS	June - July	Feb.-Mar. mid-July - mid-August
PACIFIC COAST	Feb.-Mar. - May-July	Feb.-Mar. May-June late July - Sept.

Table 11--Helicopter horsepower, chemical load and working speed for aerial application of 2,4,5-T in forestry

Model	Horse-power	Chemical load[a/]	Working speed
		pounds	mi/hr
Bell 47G-3B1	270	800	80
47G-3B2	280	1,000	88
Hiller UH 12E	305	1,050	90
Hughes 300	180	700	60
300-C	190	1,025	99
500 (Turbo)	317	1,400	90
Alouette II	360	1,320	112
SA-341	600	1,660	152

a/ Chemical load under restricted agriculture category.

require a pilot (to apply chemical and ferry ship from area to area) and one or two ground personnel. Ground personnel are responsible for helicopter servicing, operating equipment, mixing the formula to be applied, loading helicopters with the herbicide mixture, and moving vehicles between helispots.

The landowner may also supply a chief inspector and one or more observers to properly monitor application. An additional person is sometimes required to keep application records and to monitor and record weather conditions.

Treatment units vary in size from 1 to 700 acres but average about 30 acres. It may take 10 to 30 minutes to treat 30 acres, depending on volume of spray per acre and travel distance between helispot and treatment area. A helicopter using a Microfoil Boom and a 55-foot swath width treats 6.6 acres per minute at 60 MPH and 4.95 acres per minute at 45 MPH.

The following time is required to treat each acre:

1. Fill or refill 30 seconds (50 to 80 gallon load).

2. Travel to and from treatment site - 30 to 90 seconds.

3. Alignment with prior treatment swath - 30 to 60 seconds (where flagmen are not used).

4. Application - 2 to 4 minutes (50 to 80-gallon loads). Half of this is nozzle time, half is in turns. Additional time is usually spent in reconnaissance and pilot-orientation flights prior to treatment).

The application sequence may include one site-preparation spray applied after harvest and before planting, followed by one or more release sprays at 2 or 3 year intervals for a total of one to three treatments (rarely four or five) during the first 15 years in a 25 to 120-year rotation. Most of acreage presently treated by aerial methods is in the South and on the Pacific Coast, but there is a large potential in the North.

Exposure During Application

Personnel exposure on aerial spray operations is variable depending on job and conditions. The most common aerial spray crew organization is pilot, loader (who also mixes the spray), contract supervisor, and one or two observers. Of these, only the pilot and loader have direct contact with the spray solution. The pilot sits in an enclosed, but not airtight, cockpit when spraying. He may occasionally be exposed to the herbicide at the loading site. Return flights through the previous spray cloud do not usually occur because the large droplet formulations used settle quickly. Ground personnel are exposed only during the actual mixing and loading operations. About 10 minutes per spray day is spent in formulating the batch mix, plus about 10 minutes in loading aircraft. The mixing tanks and loading devices are closed systems. The mechanic-mixer-loader is the only person who handles the herbicide concentrate. PD-1 did not show an exposure scenario for mechanic-mixer-loaders. Use of gloves when handling any mixing or loading functions will reduce exposure to near zero as noted in later sections. Persons other than pilot and mechanic, such as contract administrators, inspectors, and timekeepers do not participate directly in the operation and so receive only incidental exposure. Helicopter crews normally maintain safety procedures consistent with the much more toxic insecticides which is part of their normal experience.

Nozzle time is about one hour per spray day. Helicopters do not apply material directly over people. Flag persons are not used in aerial applications in the West; they are used in some Microfoil Boom operations in the South. Flag persons must move to a new position before the helicopter reaches the spot at which they were initially positioned in order to be in position for the next spray swath. They continually move upwind and into the unsprayed area. Flag persons are also normally positioned off the treatment area, out beyond the application cutoff point. Direct contact with spray droplets is minimal. On still days, the "tail" of the adjacent swath will occasionally result in limited exposure. Persons doing environmental sampling are required not to contaminate themselves by visiting the spray operation or traveling through the treated area. About 75 percent of the total forest acres treated annually with 2,4,5-T is done by aerial application (table 12).

Additional Exposure Possibilities

No re-entry is necessary immediately following aerial treatments. Areas sprayed for site preparation are usually planted 3 to 4 months after treatment. Exposure to people using the forest areas for dispersed recreation or hunting could occur, but odors from the oil and phenol residues and the wilting and browning of foliage forewarn visitors to the area that treatment has taken place. Because 2,4,5-T and TCDD degrade rapidly in the environment, exposure diminishes rapidly following treatment.

The average tree-planting crew size is about 10 people. Each planter will plant 1 to 2 acres per day. The maximum amount of treated area that one planter would normally plant during a season or year is about 100 acres. Exposure of planters therefore is negligible.

Protective Equipment

Pesticide users must read the label of the particular herbicide they are to use. Most 2,4,5-T labels warn people to avoid swallowing or to avoid contact with clothing, eyes, and skin. Most aerial spray workers wear protective clothing such as coveralls, caps, and gloves which are removed between exposures.

Table 12--Forest area treated annually with 2,4,5-T by aerial application - all ownerships

Region	Total acres of commercial forest land	Acres treated[a/]	Lb ae per acre	Lb used	Commercial forest land treated
	million	thousand		thousand	percent
North	177.9	1.5	2	3	<0.001
South	192.5	614.0	3	1,842	0.319
Rocky Mt.	61.6	<1	2	<1	<0.001
Pacific	67.6	261.0	2.5	652	0.386
TOTAL	499.6	876.5		2,497	0.175

a/ Based on 1976 and 1977 data.

Possible Alternatives

Refer to tables 14-19, chapter 1. The exposure considerations presented here are very similar for chemical alternatives for 2,4,5-T. For nonchemical alternatives, potential intoxication and accident rates are described later in Part 5 of this chapter.

Ground Application with Tractor Mistblower - Broadcast Treatment

Formulation and Containers

2,4,5-T is available for pine release as low-volatile, emulsifiable isooctyl and butoxyethyl esters in several formulations (table 13). These products are available in 1 gallon or 5 gallon cans and 30 or 55 gallon steel drums.

Recent FIFRA ammendments (PL 95-396) permit the use of any application method not specifically prohibited on the label. Current mistblower application labels (Vertac) require that operators wear full protective clothing, goggles, and respirators.

Methods of Application

The most common method of application is by a mistblower mounted on a medium-sized crawler tractor or with a mistblower mounted on a trailer pulled by a crawler tractor or wheel skidder. The mist blower has a 2-foot long outlet tube containing three nozzles. The direction of spray, duration, and droplet size can be controlled. Droplet size ranges from 90 to 250 μm with an average of 150 μm. Nozzles may be directed at any angle from straight up to straight down. The maximum vertical reach is 30 to 40 feet. The mistblower is mounted on the back of the tractor or trailer facing away from the operator.

The tractor or skidder moves away from the treated area into the untreated area. The tractor moves at about 2 miles per hour depending

Table 13--Formulations of 2,4,5-T for pine release

Manufacturer	Chemical product name	ae lb/gal	EPA Reg. No.
Vertac	Brush Rhap LV4T	4	39511-24-AA
"	" " LV6T	6	39511-22-AA
"	" " LV OXY 4T	4	39511-26-AA
"	" " LV OXY 6T	6	39511-27-AA

on the amount of obstacles, soil condition, or steepness of slope. Tractors are limited to slopes of 30 percent or less. Tractor-mounted spray tanks hold about 100 gallons. The trailer-mounted tanks hold about 160 gallons.

Application on National Forests is limited to windspeeds under the canopy of less than 6 mph, relative humidity greater than 50 percent, temperatures less than 70 degrees, vegetation free of snow or ice. Precipitation is not occurring or about to occur and air turbulence is not sufficient to affect normal spray patterns. As a practical matter, applicators generally follow the same rules on all other lands.

Rate and Timing of Application and Number of Applicators

Application by tractor-mounted mist blowers is used primarily in the South. Formulations used vary by type of treatment. From 1.5 to 2 lb ae per acre is used for release, and 2 to 4 lb ae per acre is used for site preparation, rehabilitation, and understory treatments. 2,4,5-T esters are diluted and applied with oil, oil-water, or water carriers at a total mix rate of 5 to 10 gallons per acre. Only one application is made per year with intervals between treatments of 3 to 5 years. Only two or three applications are made during a rotation period of 30 to 80 years. In the South, the application interval for uneven-age management of southern pines is about 15 years. The size of treatment areas varies considerably from about 10 to 300 acres. The average treatment size is about 40 acres.

Time Required for Treatment and Exposure During Application

Crew size varies from a tractor operator working by himself to situations where he has as many as two additional helpers. The helpers are responsible for operating the tank trucks and mixing the chemical. They also load the spray tanks. Mixing and loading takes 10 minutes per refill; 3 to 4 refills are necessary each day.

About 5-8 acres are treated per hour. From 2 to 8 hours each day is usually suitable for spraying with the actual daily treatment period averaging about 4 hours. Applications are made under calm conditions (winds less than 5 mph) and usually during mid-April to mid-July. About 12 percent of the total forest acres treated annually with 2,4,5-T is done by ground application with tractor mistblower - broadcast treatments (table 14).

Additional Exposure Possibilities

No re-entry is necessary immediately following this type of application. Exposure to people using the forest areas for dispersed recreation or hunting could occur, but odors from the oil residues and the wilting and browning of foliage forewarn visitors to the area that treatment has taken place.

Planting normally follows site preparation by 3-6 months or more. The average planting crew is about 10 people. Each planter will plant 1 to 2 acres per day. The maximum amount of treated area that would normally be planted during a season or year is about 200 acres.

Protective Equipment

Goggles, respirator, gloves, and full protective clothing are required by the product label for these uses. Pesticide users must read the label of the particular herbicide they are to use. Most 2,4,5-T labels warn people to avoid swallowing or to avoid contact with clothing, eyes, and skin.

Possible Alternatives

Refer to tables 14-19, chapter 1. The exposure considerations are very similar in rate of application, but alternative chemicals are not applied by mist blower.

Table 14--Forest area treated annually with 2,4,5-T by tractor mistblowers
- all ownerships

Region	Total acres of commercial forest land	Acres treated[a]	lb ae per acre	Total lbs used	Commercial forest land treated
	million	thousand		thousand	percent
North	177.9	2	2	4	0.001
South	192.5	132	3	396	0.069
Rocky Mts.	61.6	0	-	0	0
Pacific Coast	67.6	6	2	12	0.009
TOTAL	499.6	140		412	0.029

a/ Based on 1976 and 1977 data.

Ground Application with Backpack Mistblowers - Broadcast Treatment

Formulation and Containers

Several low-volatile ester 2,4,5-T formulations, such as butoxyethanol, 2-ethylhexyl, isooctyl, and propylene glycol butyl ether are used with backpack mistblowers. Products for this use are available in 1- and 5-gallon cans and 30- and 55-gallon steel drums.

Methods of Applicaion

Backpack mistblowers are used to broadcast treat competing vegetation beneath pole-size timber for understory control. This use is almost entirely limited to more or less level terrain in the South. The equipment tank capacity is usually 3 gallons. Applicators normally use string to keep track of progress and work abreast of one another about 20 feet apart. Droplet size varies from 90 to 250 μm with an average of about 150 μm. This is usually a "fill-in" job and so is not a continuous operation during a season. Backpack mistblowers are not used where large contiguous areas make the use of tractor-mounted equipment more practical. They are used where only scattered spots require treatment.

Rate and Timing of Application and Number of Applications

Backpack mistblowers are used to apply 2,4,5-T on a broadcast basis to foliage in young conifer stands at a rate of about 2 pounds ae per acre. The season of use is early foliar (May to July). Applications are usually required only once during a rotation of 30 to 60 years. However, in some cases, this method is used to increase crop tree growth where understory vegetation competition for moisture or nutrients in the soil has become severe.

Each applicator usually treats 3 to 5 acres per day. The herbicide is diluted in 5 to 15 gallons of water which is applied to 1 acre. During late-season treatments, one-half gallon of diesel oil is sometimes added to the mixture to increase penetration and effectiveness.

Application is restricted to periods when wind speeds are less than 5 mph; thus, actual spraying is done only about 4 hours per day, with 2 hours nozzle time.

Time Required for Treatment and Exposure During Application

Most areas treated by this method are small and are treated within 1 day or less. Crew size is small, mostly 2 to 3 applicators although 5 or 6 occasionally work together. Less than 5 minutes are required to refill a mistblower. About five refills are made per applicator per day. About 2 percent of the total forest acres or less, is treated annually with 2,4,5-T by backpack mistblowers - broadcast treatment (table 15).

Protective Equipment and Additional Exposure Possibilities

Pesticide users must read the label of the particular herbicide they use. Most 2,4,5-T labels warn people to avoid swallowing and contact with clothing, eyes, and skin. No reentry is necessary immediately after this type of application. No followup planting is involved.

Possible Alternatives

Refer to tables 14-19, chapter 1. The exposure considerations are very similar when chemicals are applied similarly.

Ground Application with Backpack Sprayers and Tree Injectors - Individual Stem Treatment

Formulation and Containers

Ester formulations of 2,4,5-T are used for individual stem treatments by

Table 15--Forest area treated annually with 2,4,5-T by backpack mistblower - all ownerships

Region	Total acres of commercial forest land	Acres treated[a/]	lb ae per acre	Total lb used	Commercial forest land treated
	million	thousand		thousand	percent
North	177.9	2	2	4	0.001
South	192.5	16	3	48	0.008
Rocky Mts.	61.1	0	2	0	0
Pacific Coast	67.6	6	2	12	0.009
TOTAL	499.6	24		64	0.005

a/ Based on 1976 and 1977 data.

backpack sprayers. Amines are preferred for injection. Recent FIFRA amendments permit the use of any application method not specifically prohibited on the label, and numerous combinations of 2,4,5-T with 2,4-D, dicamba, and picloram are used. Products for this use are available in 1- and 5-gallon cans, 30- and 55-gallon steel drums.

Method of Application

Backpack and garden sprayers are occasionally used for basal sprout control and basal treatment of individual stems. Spray is applied directly on the stump or lower 6 inches of individual stems. Crew speed is highly variable depending on the density of the vegetation to be treated. Spray droplet size is normally large. A straight stream is used in most basal stem applications. This method is used primarily for spot treatment in forests.

Tree injection involves several methods of direct application, such as frill, or hack and squirt in which the chemical is applied to the stem by a cutting tool with an automatic injection apparatus (hypo-hatchet or tree injector) or into cuts in the bark with a squirt can or squirt bottle, Cuts are made at intervals of 1 to 4 inches apart around the stem located near the root collar or up to about 4.5 feet above the ground. The 2,4,5-T used for injection is usually the amine salt applied in a nondiluted form. It is permissible, however, to use an ester-in-oil solution up to 32 pounds acid equivalent per 100 gallons (aehg).

Rate and Timing of Application and Number of Applications

Backpack garden sprayer application is made by spot treatment to individual stems or stumps at a rate of about 2 lb per acre. Applications are usually made once during a rotation, but may be repeated as a cultural improvement method to control understory vegetation in pole-sized or mature stands where competition for moisture or nutrients becomes severe. Only spot spraying is required due to spacing of stems or stumps to be treated.

Applications can be done at any time, but are usually made during the summer foliage season (mid-May through July) and the dormant season (late November through March). Tree injection applications can take place year-round, but most of it is done during the fall dormant season when using 2,4,5-T in oil, or in spring and summer when using the amine concentrate. One milliliter is injected or squirted into each frill or cut when using the concentrate; the frill is filled when using the oil mixture.

Time Required for Treatment and Exposure During Application

Individual stem and stump treatment projects do not require the degree of advanced planning necessary for tractor and helicopter projects. Most acres treated by this method are small and are treated within 1 day or less. Crew size is small, usually 6 or less. Refills require less than 5 minutes. About six refills are made per applicator per day, depending on equipment used.

Each applicator treats about 3 to 5 acres per day depending on amount to be treated and density of vegetation. Although the applicator works about 8 hours per day, usually less than 4 hours is involved in actual treatment. This method involves considerable no-spray time spent walking between spots to be treated. These treatments are applied directly to the stems or stumps. With the direct coarse spray the applicator usually does not come in contact with spray. A spray cloud or mist situation such as occurs with insecticides for mosquito control is not created. About 11 percent of the total forest acres treated annually with 2,4,5-T is done by ground application with backpack sprayer and tree injection - individual stem treatment (table 16).

Protective Equipment and Additional Exposure Possibilities

Pesticide users must read the label of the particular herbicide they use. Most 2,4,5-T labels warn people to avoid swallowing or to avoid contact with clothing, eyes, and skin. Coveralls and gloves are often

Table 16--Forest area treated annually with 2,4,5-T by backpack sprayer and injector - all ownerships

Section	Total acres of commercial forest land	Acres treated	lb ae per acre	Total lb used	Commercial forest land treated
	million	thousand		thousand	percent
North	177.9	92	2	184	0.052
South	192.5	28	3	84	0.015
Rocky Mts.	61.6	0	0	0	0
Pacific	67.6	5	2	10	0.007
Total	499.6	125		278	0.025

worn. Leaking hoses and valves on backpack equipment are the major sources of exposure. Rubber gloves can reduce exposure, and periodic maintenance can reduce leakage. No re-entry provision is necessary immediately after this type of application, nor would re-entry result in significant exposure. No followup planting is involved.

Possible Alternative

Refer to tables 14-19, Chapter 1. The exposure considerations are very similar when application methods are identical. When using injection and backpack sprayers, only phenoxy herbicides, perhaps in combination with picloram, are likely substitutes. See calculation summary no. 1.

CALCULATION SUMMARY NO. 1: USE INFORMATION FOR EXPOSURE, AERIAL APPLICATION - FOREST

1. Commodity: Forest

2. Equipment: Aircraft (Helicopter), nozzles (no whirl plate, aligned with slipstream)
D6 900 μm VMD
D6-46 46 μm VMD

	Situation: Typical (>50%):	Situation: Extreme (10-20%):
3. Target: Brush, for site preparation & conifer release		
4. Rate:	1.5-2 lb/A	3 lb/A
Dilution:	20 lb/100 gal 8 to 10 gal/A	40 lb/100 gal
5. Exposure Times:		
Day:		
Application Time:	6 hrs/day	6 drs/day
Nozzle Time:	1 hr/day	3 hr/day
Drift Time and/or fraction direct exposure occurs:	15 sec/day	1 min/day
Week:	2 days/week	4 days/week
Year: 5.8 hrs/day & 5.7 days/year is the average work. Upper 15% is 5.4 hrs/day & 14 days/ year	6 days/year	14 days/year
6. Treatment Area: Total acres or units:	1 site up to 180 acres/day usually 1 to 3 hrs.	
Days or units of work per year:	6 to 14 such units/yr. Assume 100 A sites and 90% of crews service 6 sites per year and 10% of crews service 14 sites/year.	
7. Population Exposed: Supervisor, timekeeper, observer		
Number of exposed workers:	Industry will use 2 ground personnel. U.S.F.S. will use 4 ground personnel. They are not in the treated area, but may be 50-100 feet from the boundary or on some other topographic feature. Cannot be exposed unless a wind swirl catches the drift. This may occur once per site for 15-45 seconds.	
8. Dress: Work clothes - long pants, long sleeve shirts, hard hat, boots.		
9. Workers and Exposure Time:		
Round the single 15 sec exposure up to 1 min.		
1 min/day x 6 days/year = 6 min/year	2,476 workers @ 6 min/year	
1/day x 14 days/year = 14 min/year	120 workers @ 14 min/year	

Aerial Application

Formulation and Containers

Registered products for range and pasture brush and weed control include numerous low-volatile esters formulations of 2,4,5-T and amine formulations of 2,4,5-T/picloram (Tordon 225) and 2,4,5-T/dicamba in ratios of 1+1 and 2+2, respectively. All products are available in 1, 5, 30, and 55-gallon cans or drums.

Method and Rate of Application

About 90 percent of all rangeland brush control is done by broadcast spraying using fixed-wing aircraft. A variety of agricultural equipment is used, ranging in capacity from 160 to 450 gallons and delivering 1-4 gallons per acre with VMD of 250-500 μm and an average VMD of 300 μm.

Aerial application to mesquite and sand-shinnery oak entails three rates of application, depending on specific site requirements. Approximately 137,000 acres are treated at the rate of one pound of 2,4,5-T ester in 1-4 gallons of water, oil or water-oil emulsion per acre, most is 4 gallons per acre as a 1:4 oil-water emulsion containing 25 pounds acid equivalent per 100 gallons (aehg) 2,4,5-T (table 17). A minor acreage is treated with one pound in two gallons (50 aehg mixtures) of emulsion. Volumes of one gallon per acre do not disperse well with concentrations of 100 aehg and are not used.

Another 500,000 acres are treated with 1/2 pound 2,4,5-T per acre, mostly in 2 to 4 gallons of water-oil emulsion at a 25 aehg concentration. A portion of this acreage is treated at one gallon per acre of 50 aehg mixture. About 400,000 acres of mesquite are treated with a mixture of picloram and 2,4,5-T containing 1/4 lb 2,4,5-T per acre as the amine salt. This is usually applied in one, two, or four

Table 17--Aerial applications of 2,4,5-T is mesquite and oak savannah

	Rate/A	Vol/A	Conc.	Acres/yr
	lb ae	gal	aehg[a]	
Mesquite/shinnery oak	1 lb	2-4	25-50	137,000
	1/2	1-2	25-50	500,000
	1/4	1-2	12.5-25	400,000
Oak savannah	2	2-6	33.3-100	541,000

a/ Acid equivalent per 100 gallon

gallons per acre as a water spray of 12.5 to 25 aehg 2,4,5-T plus an equal amount of picloram. Dicamba is used in place of picloram on some of this acreage (table 17).

Oak savannah receives a higher rate of application than mesquite. Aerial application also accounts for 90 percent of the oak range treatments, with dosage ranging up to 3 pounds per acre in 6 gallons water-oil emulsion (50 aehg) and the average being 2 pounds per acre in 4-6 gallons. A total of 541,000 acres is treated in this way, all by fixed-wing aircraft (table 17).

Time Required for Treatment and Exposure During Application

Aerial treatment of rangelands uses larger aircraft and lower volumes per acre than most other applications of 2,4,5-T. This results in a large number of acres treated per batch and per aircraft loading and resultant relatively low exposure of the mixer-loader.

Fixed wing aerial applications cover 100-300 acres per hour and 30 to 450 acres per load. A typical day is 3 hours of operation in the early morning and 3 hours in the late afternoon and evening. The season for treatment usually lasts 1-4 weeks, depending on moisture conditions. Applicators will not usually be applying 2,4,5-T during the remainder of the year, because no crops or utility rights-of-way are treated with fixed-wing equipment during complementary seasons (table 17).

A typical aerial application crew consists of a pilot and mechanic-mixer-loader, who may be involved in several operations during one season, and two flag persons, who are employees of the local ranch. The pilot and mechanic normally wear coveralls and gloves while handling herbicides. The flaggers normally wear broad-brim hats and long-sleeved shirts, traditional ranch attire.

Normal spraying operations for a one-airplane crew includes a pilot, two to prepare and load the herbicides in the aircraft, and two flaggers to accurately mark swath passes. No flaggers are used if foam markers are used. Spraying is done with a slight cross wind with the flaggers walking against the wind before each pass of the airplane. The flaggers move to the next swath when the aircraft is approaching about 300 feet away. The flaggers do not receive appreciable spray since they are not beneath the aircraft during spraying. The pilot "shuts off" the spray 50 feet before the end of the pass and delays spraying until 50 feet is covered on the next pass. The mixing crew measures the required amount of carrier (diesel oil and water) and 2,4,5-T. The carrier and herbicide is vigorously mixed until the desired emulsion is attained. The tank mix is then pumped into the spray hopper through an opening in the bottom of the hopper. Cut-off valves minimize spillage when the loading hose is disconnected. The pilot remains in the aircraft during the loading operation. The crew is exposed intermittently to 2,4,5-T for about 4 hours, usually early morning, during a normal spraying day.

There is little opportunity for exposure after treatment. Normal range management practice allows 3 to 6 months delay between treatment and range stocking while the grass cover develops.

Ground Application

Ground equipment accounts for 10 percent of range improvement work and nearly all of the pasture maintenance with 2,4,5-T. The principal method is backpack or garden sprayers used either for spot sprays in mesquite or pasturelands, or as basal sprays in oak savannahs. High-mounted boom sprayers are also used in low-mesquite stands (table 18).

Backpack Sprayers

Backpack sprayers used for basal and spot sprays entail mixtures of 8-16 aehg in oil for bark treatment and 6-8 aehg in water-oil emulsions for basal-stem treatments. Pasture spot sprays utilize 4-6 aehg in water.

Table 18--Estimated total area treated by the various ground methods

Type	Rate/acre	2,4,5-T concentration	acres
	lb ae	aehg[a]	
Mesquite	1/2 lb	8	75,000
Oak savannah	2	16	60,000
Pasture	1/2	4-6	1,000,000

a/ Acid equivalent per 100 gallon

The typical crew for hand sprayers is 1-4 persons. The area covered ranges from 1/4 to 1 acre per man-hour and crews normally wear long-sleeved shirts or coveralls. Treatments are seldom above waist level, and hats, though usually worn, are not necessary to protect from spray deposits.

Most exposure is the result of leaky hoses and valves. Careful maintenance can prevent exposure perhaps more than protective clothing.

Tractors

A small area of mesquite is treated with high-mounted boom rigs on special tractors. This equipment is used on about 75,000 acres a year of low brush in dense stands. Typical tractor sprays entail the use of 0.67 lb 2,4,5-T in 10-20 gallons oil-in-water emulsion per acre. This equipment normally carries a 200-400 gallon tank that must be refilled approximately every 20 acres with the 3.3 to 6.7 aehg mixture.

A typical crew consists of a tractor operator and an assistant who mixes and loads. The tractor driver is exposed briefly but occasionally moderately, if wind carries spray to him when making turns. The loader is exposed while mixing and loading. His exposure is greater than that of the tractor driver. Both persons typically wear coveralls and broad-brim hats. A crew normally treats 50-100 acres per day. See calculation summaries 2-5.

Alternative Herbicides for Ground Application

Tordon 225^{R} can be substituted for 2,4,5-T or silvex for mesquite control using low and high boom sprayers. Silvex can be substituted for 2,4,5-T for oak control using a low and high boom sprayer or backpack sprayer. Undiluted 2,4-D can be substituted for 2,4,5-T or silvex for oak control, cut surface application only. There is no effective chemical substitute for 2,4,5-T for mesquite control using backpack sprayer.

CALCULATION SUMMARY NO. 2: USE INFORMATION FOR EXPOSURE, AERIAL - RANGE AND PASTURE

1. Commodity: Range & Pature

2. Equipment: Fixed wing aircraft. Nozzles: 15° into the airstream, no whirl plates
   D6 (10 ea) @ 1 gpa
   D8 (12 ea) @ 2 gpa (50% are these), VMD 300-400 μm
   D12 (22 ea) @ 4 gpa

	Situation: Typical (>50%):	Situation: Extreme (10-20%):
3. Target: Mesquite, oak and other woody plants		
4. Rate:	0.5 lb/A	1-2 lb/A
Dilution: 2% treated at 2 lb/A; 6% treated at 1 lb/A	25 lb/100 gal 50% use Nalcotrol	50 lb/100 gal
5. Exposure Times:		
Day:		
Application Time:	2 hr	
Nozzle Time:	1 hr	
Drift Time and/or fraction direct exposure occurs:	6 min	20 min
Week:	3-6 days/week	
Year: Over a 10 week period (70 days) planes will operate a max. of 20 days, treating typical field of 500 A (1/2 mi x 1.56 mi or 8,250 feet or 206 passes) each day. There are 2 flaggers (1 on each boundary, not 100 feet from the boundary as in rice) exposed. 18 min/run, exposed once per 3 runs, unless nalcotrol used, then once per 10 runs.	30 days/yr	9 days/yr
6. Treatment Area: Total acres or units:	9-30 500 A fields/yr; various ownerships	
Days or units of work per year: There are about 75 planes (150 flaggers); 25 operate 30 days @ 500 acres per day treating 13,000 acres each or a total of 375,000 acres, 25 operate 20 days treating 10,000 acres or 250,000 acres, & 25/9 days for 4,500 ea or 112,000 acres, for a total of 737,000 acres in Texas.	9-30 days	
7. Population Exposed: Flagmen		
Number of work sites:	30	9
Number of exposed workers:	50	50
Total number of flagmen:	150	

8. Dress: Work clothes - blue jeans, long sleeve shirt, levi jacket, kepi, wide brim hat, leather boots.

9. Workers and Exposure Time:

500 A = 206 passes x 18 sec drift x 1/3 passes = 20 min/site x 30 sites = 10 hr/year

x 1/10 passes = 6 min/site x 30 sites = 3 hrs/year

x 9 sites = 54-3 hr/yr

25 flagmen @ 10 hr/yr

25 flagmen @ 1 hr/yr

100 flagmen @ 1-6 hrs ($\bar{x}$ = 3 hrs)/yr

CALCULATION SUMMARY NO. 3: USE INFORMATION FOR EXPOSURE, TRACTOR LOWBOOM - RANGE AND PASTURE

1. Commodity: Range & Pasture

2. Equipment: Tractor Mounted low boom
30 psi, #8002 or 8003 fan pt. nozzle, VMD ca. 200-300 μm

	Situation	
3. Target: Oak & mesquite sprouts on range	Typical (>50%):	Extreme (10-20%):
4. Rate:	2 lb/A	
Dilution:	10 lb/100 gal	
5. Exposure Times:		
Day:		
Application Time:	3-4 hrs	
Nozzle Time:	45 min-60 min	
Drift Time and/or fraction direct exposure occurs:	1 day/week	3 days/week
Week:	1 day/year	3 days/year
Year:	3 hr/year	7 hr/year
Rancher does own application on 40-100 A. If more needs treatment he will use commercial applicator. Will treat about 5 A in about 5 min with 15 min return & reloading, or 15 A/hr & 15 min nozzle time/hr. With 3-4 hrs/day application time, the units will be completed in 1-3 days. 200-500 units covering about 20,000 A are treated annually, Texas		
6. Treatment Area: Total acres or units:	200-500 units; 20,000 A	
Days or units of work per year:	1-3 days work/yr; 1 unit/man/yr	
7. Population Exposed: Sprayman		
Number of work sites:	1	500
Number of exposed workers:	200	

8. Dress: Work clothes - blue jeans, long sleeve shirt, levi jacket, wide brim hat, kepi, leather boots

9. Workers and Exposure Time:

15 min/hr x 3 hr/year = min/yr; 500 workers @ 45 min/year or
15 min/hr x 7 hr/year = 105 min/yr; 200 workers @ 1 hr 45 min/yr or
90% of acreage is 40 A & 10% is 100 A

CALCULATION SUMMARY NO. 4: USE INFORMATION FOR EXPOSURE, TRACTOR HIGHBOOM - RANGE AND PASTURE

		Situation: Typical (>50%):	Extreme (10-20%):
1.	Commodity: Range & Pasture		
2.	Equipment: Tractor mounted, high boom		
3.	Target: Mesquite & oak		
4.	Rate:	2 lb/A	
	Dilution:	10 lb/100 gal	
5.	Exposure Times:		
	Day:		
	Application Time:	4 hr/day	
	Nozzle Time:	2 hr/day	
	Drift Time and/or fraction direct exposure occurs:	assume 2 hr/day	
	Week:	6 days/week	
	Year: These are larger commercial rigs and spray for 15 min each load instead of 5 min. About 15 min nozzle time & 15 min loading time. There are about 15 such rigs in Texas (5 operators @ 1 rig & 5 @ 2 rigs). They will treat about 5000 A over a 6 to 8 week period, Texas	6-8 weeks/year	
6.	Treatment Area: Total acres or units:	75 A/day, 5000 A/yr, various ownerships	
	Days or units of work per year:	6 days x 8 weeks = 48 days	
7.	Population Exposed: Sprayman		
	Number of exposed workers:	15	

8. Dress: Work clothes - blue jeans, long sleeve shirt, levi jacket, wide brim hat, kepi, leather boots, gloves

9. Workers and Exposure Time:

   2 hrs x 6 days x 8 weeks = 96 hr/yr

   15 workers @ 96 hr/year

CALCULATION SUMMARY NO. 5: USE INFORMATION FOR EXPOSURE, BACKPACK SPRAYER - RANGE AND PASTURE

		Situation: Typical (>50%):	Situation: Extreme (10-20%):
1. Commodity:	Range & Pature		
2. Equipment:	Backpack, hand pressure, 30 psi, T-jet 8004, VMD 300 μm		
3. Target:	Mesquite or oak stems in rangeland or pasture		
4. Rate:			
Dilution:	Mesquite	8 lb/100 gal	
	Oak	16 lb/100 gal	
5. Exposure Times:			
Day:			
	Application Time:	6 hr/day	6 hr/day
	Nozzle Time:	0.6 hr/day	1.2 hr/day
	Drift Time and/or fraction direct exposure occurs:		
Week:		2 days/week	4 days/week
Year: 60 sec travel time stem to stem; results in typical ratio of 6 sec/60 sec nozzle time (10 percent).		10 days/year	20 days/year
6. Treatment Area:	Total acres or units:	30	50
	Days or units of work per year:	1	1
Sprayman will be ranch employee; cover 3-5 A per day, working about 2 days/week over a 5 week period. About 8-10,000 A are treated this way per year in Texas. One sprayman will treat a maximum of 50 A/yr; if more needed, another applicator is contracted.			
7. Population Exposed:	Sprayman		
	Number of work sites:	1	1
	Total number of exposed workers:	334 or	200

8. Dress: Work clothes - blue jeans, long sleeve shirt, levi jacket, wide brim hat, kepi, leather boots.

9. Workers and Exposure Time:

0.6 hr/day x 6 hr/day x 10 days/year = 6 hr/year

334 workers @ 6 hr/yr

or 200 workers @ 12 hr/yr

or 200 @ 6 hrs & 20 @ 12 hrs

Aerial Application

Formulations and Containers

Numerous formulations of 2,4,5-T, alone and in premix combinations, are available for aerial application on rights-of-way. Low-volatile emulsifiable esters include propylene glycol butyl ether, butoxyethanol, 2-ethylhexyl and isooctyl esters. The formulations used most commonly contain 4 lb ae per gallon. Tordon 101 (0.54 lb ae picloram and 2 lb ae 2,4-D as triisopropanolamine salts) is frequently tank mixed with 2,4,5-T. The most popular containers are 30 and 50-gallon steel drums.

Method of Application

Aerial application on rights-of-way is totally accomplished with helicopters. The ships are generally equipped with a Microfoil Boom with a nozzle orifice of 0.060 inches inside diameter. The Microfoil Boom is shaped similar to an airfoil. It can be trimmed in flight to release the herbicide solution into the still trailing air of the boom. This equipment produces very uniform droplets, approximately 0.094 inches VMD, which fall like gentle rain. Elimination of fines and swirling vortices enables the pilot to place the herbicide very accurately on the right-of-way. Another version of the Microfoil Boom has nozzle orifices 0.028 inches inside diameter which produce droplets in the diameter range of 1700-2000 μm. The Microfoil Boom is used on approximately 90 percent of the aerially treated right-of-way acreage. The remaining 10 percent is generally treated with one of the inverting systems such as the bifluid or Spray-disk.

Helicopter tank capacity varies from 50 to 250 gallons. Boom lengths range from 10 to 30 feet and spray swaths range from 20 to 60 feet. Speed of application ranges from 25 to 30 mph.

Rate and Timing of Application

Aerial applications are broadcast foliar treatments made between May and September depending on geographic area. Weather restrictions are particularly important in rights-of-way treatments. Conditions suitable for application tend to occur for very short periods during the day, and may not occur at all on some days. Consequently, treatments tend to be made between 5 and 9 a.m. and 5 and 9 p.m. Operationally, crew productivity ranges from 6-15 acres per hours in good weather. A typical work day is 4 hours application time with one hour nozzle time.

An important treatment in the northeastern U.S. is a tank mix of 2 gallons 2,4,5-T (8 lb ae 2,4,5-T) plus 2.5 gallons Tordon 101 or Amdon 101 applied in a total volume of 25 gallons per acre (32 lb aehg 2,4,5-T) with water as the carrier. In southeastern U.S. a major treatment is 1.5 gallons 2,4,5-T (6 lb ae 2,4,5-T) plus 2 gallons Tordon 101 or Amdon 101 applied in 15 gallons per acre with water carrier (40 aehg 2,4,5-T). A standard cycle, i.e., number of years before the same acre is retreated, in the Northeast is 5 years. A standard cycle in the southeastern U.S. would be 3 years.

Time Required for Treatment and Number of Applicators

There are an estimated 50-75 crews involved with aerial application of herbicides on rights-of-way. A crew typically consists of three people - the pilot, a mechanic-service person, and the mix truck driver, who also serves as loader. The mix truck driver is the most likely to be exposed but exposure time is brief, limited to mixing and loading periods. No flaggers are involved. Personnel exposure is considered to be minimal. The herbicides are pumped from the drums, through the mix truck, to the helicopter in a closed system.

Acres Treated

Based on data used for the economic analysis of 2,4,5-T applied aerially (a weighted average of 7.4 lb ae 2,4,5-T per acre), approximately 1,526,294 lb of 2,4,5-T are applied with this treatment. Aerial application accounts for about 30 percent of the rights-of-way acres treated with 2,4,5-T each year (table 19).

Protective Equipment and Additional Routes of Exposure

Crews applying 2,4,5-T aerially will dress according to the weather. This will usually include boots, pants, and shirts--long-sleeved shirts in cool weather and short-sleeved when warm. Hardhats and safety glasses may be worn and may be required for the loader and mechanic. There are no standard management practices which would require re-entry into a treated area.

Additional practices include close inspection of equipment as required for FAA and state licenses, and use of spray thickeners or other drift control measures when specified. Buffer zones are maintained around water, homes, and sensitive crops. All applications are made in close cooperation with public and private agencies. Clean clothes daily is a recommended practice.

Selective Basal and Cut Stump Application

Formulations and Containers

Various formulations of 2,4,5-T, alone and in premix combinations are available for selective basal and cut stump treatments. Low-volatile esters include propylene glycol butyl ether, butoxyethanol, 2-ethylhexyl, and isooctyl esters. The formulations commonly contain 2 lb ae 2,4,5-T plus 2 lb ae 2,4-D, 4 lb ae 2,4,5-T plus 1 lb ae picloram (Tordon 155), or 4 lb ae 2,4,5-T. The most popular containers are 30 and 55-gallon steel drums.

Table 19--Right-of-way acres treated annually with 2,4,5-T by aerial application

	Acres treated annually	% of total ROW acreage
Railroad	27,386	1.1
Pipeline	19,391	0.9
Electric	159,479	3.2
U.S. Total	206,256	2.2

Methods of Application

Both treatments are applied totally from the ground and have been combined in this discussion since the treatments are essentially the same. The nature of what is treated changes in that the stem is cut off before the stump is sprayed. Both treatments are an individual stem/stump type of treatment.

The great majority of acres treated (approximately 90%) are treated with handgun equipment connected to a central source, a tank truck (200-400 gallon capacity) with pumping unit and reels of hose. The remaining 10 percent is treated with 5 gallon knapsack sprayers or 3 gallon back-pack mist-blowers with a special wand attachment for basal stem/stump treatment.

The sprayer speed is determined by the walking speed of the individual. With walking time from spot to spot, the handgun or sprayer is actually spraying only 50-60 percent of the time. The application must wet the entire lower 21 to 14 inches of the stem or thoroughly soak the stump. All exposed roots are also treated in both treatments.

Rate and Timing of Application

Applications made with either hose and handgun or knapsack sprayer use the same herbicide concentrations. The major treatments in decreasing order of use are (1) 1 gallon Tordon 155 per 100 gallons oil (4 lb aehg 2,4,5-T), (2) 4 gallons of a 2,4-D - 2,4,5-T mixture per 100 gallons oil [8 lb acid equivalent per 100 gallons (aehg) 2,4,5-T], and (3) 3-4 gallons 2,4,5-T per 100 gallons oil (12-16 lb aehg 2,4,5-T). Basal treatments usually require 40-125 gallons of herbicide mixture per acre when applied with these equipment. Stump treatment requires 35-55 gallons of herbicide mixture per acre. The maximum use rate is 10 lb/A 2,4,5-T.

Motorized back pack mistblowers do not hold as much volume so the herbicide concentration is increased but fewer gallons are applied per acre. The important treatments for this method of application are (1) 3.5 gallons Tordon 155 per 100 gallons oil (14 lb aehg 2,4,5-T) and (2) 15.5 gallons of a 2,4-D - 2,4,5-T mixture per 100 gallons oil (31 lb aehg 2,4,5-T). 2,4,5-T is not used alone. Basal treatments are usually applied at rates of 15-25 gallons of herbicide mixture per acre while stump treatments are applied at 15-20 gallons of mixture per acre.

The herbicide application and the air carrier generation are two separate operations with a backpack mistblower. This gives the equipment a unique potential. The operator increases engine rpm's to blow leaves, sawdust, and other trash away from the root collar or stump. Then, after reducing engine rpm's, the herbicide valve is opened for actual treatment. The lack of extraneous litter around the root collar permits satisfactory control with less herbicide per acre.

Knapsack sprayers and motorized backpack mistblowers play minor, but unique, roles in rights-of-way management. They are most commonly used for spot treatments, small areas, or areas inaccessible to other equipment.

Basal or stump-spraying treatments are generally applied on a four year cycle. Crew productivity ranges from 1/2 - 2/3 acres per hour. These treatments can generally be applied during the normal working day (within weather limitations) and can be applied year round, theoretically. Obviously snow and ice can create operational problems.

Time Required for Treatment and Number of Applicators

A typical crew consists of a truck driver, two spraying personnel, and a foreman. All personnel could be involved with herbicide application during the day's activities. Assuming one hour per day is spent in travel and one hour in loading and refilling, there would be approximately three hours of actual nozzle time in the remaining six hours. However, since the application is only being made to the lower portion of stems or to stumps, this exposure would be minimal. Boots and pants will generally prevent skin exposure other than that resulting from leaky equipment and mixing.

The number of applicators is unknown. Given the estimated acres treated annually (244,931), 0.5 acre/hour/crew productivity, 5 hours/day application time, 5 days/week, 8 months/year treating season and 4 men per crew, there are approximately 1,808 full-time applicator equivalents required to apply basal treatments. Similarly, 76 full-time applicator equivalents are required to spray all acres with the cut stump treatment (table 20; table 5 - Chapter 3).

Acres Treated

Based on data used for the economic analysis of 2,4,5-T applied by these treatments, 1,071,737 lb of 2,4,5-T are applied in a selective basal treatment and 25,396 lb of 2,4,5-T are applied as a cut stump treatment (table 20; table 5 - Chapter 3).

Protective Equipment and Additional Routes of Exposure

No special equipment is required beyond label requirements. Additional practices include spray thickeners or other drift-control measures when specified, clean clothes recommended daily, buffer zones around water and homes, and treatments are not applied to wet stems. There are no standard-management practices which would require re-entry into a treated area.

Conventional Foliar Broadcast (Vehicular Mounted Sprayer)

Formulations and Containers

Various formulations of 2,4,5-T, alone and in premix combinations are available. Low-volatile emulsifiable esters include propylene glycol butyl ether, isooctyl, 2-ethylhexyl, and butoxyethanol esters. The formulations commonly contain 2 lb ae 2,4,5-T plus 2 lb ae 2,4-D or 4 lb ae 2,4,5-T. The most popular containers are 30 and 55-gallon drums.

Table 20—Rights-of-way acres treated annually with 2,4,5-T by selective basal or cut stump applications

	Acres treated annually	% of total ROW acres
	selective basal	
Railroad	43	0
Highway	733	0.003
Electric	234,254	4.7
U.S. Total	235,030	1.8
	cut stump	
Highway	3,373	0.04
Electric	6,528	0.13
U.S. Total	9,901	0.07

Methods of Application

The methods discussed here involve only ground equipment. Vehicular mounted sprayers are common for treating highway and railroad rights-of-way. However, uniquely different and highly specialized equipment are used for railroads. Highway equipment is usually a sprayer unit mounted on a truck or trailer. Railroad equipment is either a spray train or a Hyrail unit. In all cases the equipment (with boom or nozzle configuration attached) moves at a constant speed.

Highway equipment uses spray booms with conventional flat fan or flooding tips. Some equipment with off-center nozzles which permits herbicide application to the side of the vehicle is sometimes used while driving on the shoulder. Highway equipment could have a mobile boom that extends out over the right-of-way for added swath width. Herbicide applications will control undesired herbaceous and woody species.

Railroad useage of 2,4,5-T is largely directed to woody plant control. Woody-plant control as the primary treatment objective tends to occur under the communication wires. Consequently, treatments from Hyrail units involve a mobile boom with some nozzle configuration such as off-center tips, Directa-Spray or oscillating straight stream nozzles. Brush control from a spray train is done with turrents or handguns mounted on the spray car.

Tank capacities for highway equipment and Hyrail units generally range from 1,000-2,500 gallons. Spray trains have access to 10,000 gallon tank cars. Spray swaths may range from 5-50 feet as required. Equipment speeds range from 3-10 mph. Spray thickeners or other drift reducing measures are very important and commonly used.

Rate and Timing of Application

Conventional foliar-broadcast applications cover a variety of weed-control situations. The rates of 2,4,5-T per acre are adjusted to the particular weed problem. The most versatile concentration is one gallon of a 2,4,5-T - 2,4-D mixture per 100 gallons water (2 lb aehg 2,4,5-T). Highway treatments apply 40 gallons of this mixture per acre (0.8 lb ae 2,4,5-T/acre). High volume railroad applications, i.e., spray trains, apply this mixture at an average of 300 gallon per acre (6 lb ae 2,4,5-T/acre). Low volume railroad applications, i.e., Hyrail units, commonly use 2.5 gallons of the 2,4,5-T - 2,4-D combination per 25 gallons of water applied at the rate of 25 gallons per acre (5 lb ae 2,4,5-T/acre).

Applications generally follow a four-year cycle. Since these treatments are applied to foliage, the spray season is essentially the 5-month period from May through September. Weed control around bridge structures, on the roadbed ballast area, and in the yards is of higher priority to the railroads; however, so brush-control treatments tend to occur later in the growing season (July through September). Wind and weather limitations are the major restrictions for these treatments. Crew productivity ranges from 1-10 acres per hour for highway applications and 10-30 acres per hour for railroad treatments.

Time Required for Treatment and Number of Applicators

Highway and Hyrail crews typically consist of one driver for the equipment and one operator for the spray boom or nozzles. Both would be involved with loading. A railroad representative accompanies all applicator units when on the tracks as a safety precaution. This person's job is to maintain contact with the central dispatcher for track clearance and has no involvement with the herbicide application. Highway representatives tend to monitor contractors for job performance but have no involvement with the application. Spray train applicator crews typically consist of four people. The supervisor monitors speed and pressure and looks for sensitive areas and crops; the other three people act as applicators. Two are responsible for the wider side of the right-of-way, the pole side (side with communication lines), and one is responsible for the narrow side of the right-of-way, the off-pole side.

All crews are estimated to spend one hour per day in travel time and one hour loading and refilling for an application day of approximately 6 hours and 2 to 3 hours nozzle time. Sprayer operation on railroads is only 4-5 hours per day. Railroad applicators have the unique problems associated with interfacing their operation with continuous rail usage. Consequently, considerable time, 1-3 hours per day, is spent waiting for track time or track clearance.

Assuming crew productivity of 1 acre/hour/day, 6 hours/day, 5 days/week, 5 months/season, 2 members/crew, and 58,447 highway acres treated, 178 full time equivalents of personnel would be involved in treating highway right-of-way with a conventional broadcast application. Assuming crew productivity of 3 acres/hour/day, 4 hours/day, 5 days/week, 3 months/season, 3 members/crew and 99,996 railroad acres treated annually, 114 full time equivalents of personnel would be needed to treat the railroad right-of-way.

Acres Treated

Based on data used for the economic analysis of 2,4,5-T applied by this method, 620,748 lbs 2,4,5-T are applied as a conventional foliar broadcast application (table 21).

Protective Equipment and Additional Routes of Exposure

No special equipment is required beyond label requirements. Additional practices include wind speed limitations, buffer zones around water, and homes and clean clothes recommended daily. Spray thickeners or other drift-control measure are used when specified. Almost all railroad brush-control treatments include the thickener Nalco-trol. There are no standard management practices which would require re-entry into a treated area.

Table 21--Rights-of-way acres treated annually with 2,4,5-T by conventional broadcast foliar applications

	Acres treated annually	% of total ROW acres
Railroad	99,996	4.1
Highway	58,447	0.3
U.S. Total	158,443	0.7

Broadcast and Selective Foliar Ground Applications

Formulation and Container

Numerous formulations of 2,4,5-T, alone and in premix combinations, are available for foliar applications. Low-volatile emulsifiable esters include propylene glycol butyl ether, isooctyl, 2-ethylhexyl, and butoxyethanol esters. Amine salt formulations are also used such as the dimethylamine salt of 2,4,5-T in Banvel 710 (2 lb ae 2,4,5-T plus 1 lb ae dicamba). Formulations of 2,4,5-T commonly contain 2 lb ae 2,4-D plus 2 lb ae 2,4,5-T. Tordon 101 (0.54 lb ae picloram and 2 lb ae 2,4-D as triisopropanolamine salts) is frequently tank mixed with 2,4,5-T. The most commonly used containers are 30 and 55-gallon drums.

Method of Application

Broadcast foliar application, as used here, is the treatment of all woody plant species. In a selective foliar application only specific clumps of brush are treated. Lower pressure is used for selective foliar than for broadcast applications. Since fewer stems may be treated and lower pressure is used, the total volume per acre is less for selective foliar than for a broadcast treatment. Broadcast foliar application with handguns is used only on electric rights-of-way. Pipeline, highway, and electric rights-of-way are treated to some degree with selective foliar application because they are applied with a handgun not directly attached to a vehicle. The handgun is typically operated by personnel walking on the ground.

Nearly all of the acres are treated with hose and handguns connected to a central source, a tank truck with 200-400 gallon capacity. A very small amount, approximately 2 percent, is treated with 3 gallon backpack mistblowers. The sprayer, in effect, moves at the walking speed of the individual as the applicator sprays the plant foliage. With the constant walking and treating, the handgun is on only 50-60 percent of the time. Droplets are usually 200-400 μm in diameter in the normal pattern of the adjustable handgun.

Rate and Timing of Application

Four important treatments applied with hydraulic sprayers and handguns are (1) 1 gallon 2,4-D - 2,4,5-T combination per 100 gallons water (2 lb aehg 2,4,5-T), (2) 1 gallon 2,4,5-T alone per 100 gallons water (4 lb aehg 2,4,5-T), (3) 0.5 gallon 2,4,5-T + 0.5 gallon Tordon 101 or Amdon 101 per 100 gallons water (2 lb aehg 2,4,5-T), and (4) 1 gallon Banvel 710 per 100 gallon water (2 lb aehg 2,4,5-T). The foliage is sprayed to wet. Broadcast foliar treatment may require 250-300 gallons total volume per acre. Selective foliar treatment may require 150-250 gallons per acre.

The motorized backpack mistblower is used essentially for spot treatments. Herbicide concentration used in the backpack mistblower is 5 gallons 2,4,5-T plus 5 gallons Tordon 101 or Amdon 101 per 100 gallons water (20 lb aehg 2,4,5-T). This mixture is applied at the rate of 20-25 gallons per acre.

Foliage applications generally follow a 4-year cycle. Treatments are usually applied May through September. Crew productivity ranges from 1/3 - 2 acres/hour. Treatments can be applied throughout the day subject to wind and weather limitations.

Time Required for Treatment and Number of Applicators

A typical crew consists of a truck driver, 2 spray personnel, and a foreman. All personnel are likely to be involved in the herbicide application during the day's activities. Approximately one hour per day is spent in travel and one hour per day in loading and refilling.

Assuming crew productivity of 1/3 acre/hour, 6 hours of application/day, 5 days/week, 5 months/spray season, 4 people/crew, and 43,927 acres treated, 800 full time equivalents of applicators would be needed for broadcast foliar ground application. For a similar set of assumptions, excepting crews productivity at 1.5 acre per hour and 29,400 acres treated, 356 full time equivalents would be needed for selective foliar ground application.

Acres Treated

Based on data used for economic analysis of 2,4,5-T applied by this method, 342,631 lb ae 2,4,5-T are applied as a broadcast foliar ground application on electric rights-of-way, and 152,880 lb ae 2,4,5-T are applied as a selective foliar ground application on rights-of-way (table 22).

Protective Equipment and Additional Routes of Exposure

No special equipment is required beyond those required by the herbicide label. Additional practices include buffer zones around homes and water, clean clothes recommended daily, and spray thickeners or other drift-control measures used when specified. Spray is directed parallel to right-of-way edge rather than perpendicular to avoid right-of-way damage. There are no standard-management practices which require re-entry into a treated area.

See calculation summaries 6-12.

Table 22--Rights-of-way acres treated with 2,4,5-T by broadcast or selective foliar application

	Acres treated annually	% of total ROW acres
	----------broadcast foliar----------	
Electric	43,927	0.9
U.S. Total	43,927	0.9
	----------selective foliar----------	
Pipeline	2,635	0.12
Highway	5,614	0.03
Electric	21,151	0.43
U.S. Total	29,400	0.10

CALCULATION SUMMARY NO. 6: USE INFORMATION FOR EXPOSURE, AERIAL - RIGHTS-OF-WAY

1. Commodity: ROW - aerial

2. Equipment: Helicopter with microfoil boom, 060 (3/32") nozzle

	Situation: Typical (>50%):	Situation: Extreme (10-20%):
3. Target: Mixed brush		
4. Rate:	8 lb/A	
Dilution:	32 lb/100 gal	
5. Exposure Times:		
Day:		
Application Time: 5-9 am; 5-9 pm	6 hr	
Nozzle Time:	6 min/hr, 36 min/day	
Drift Time and/or fraction direct exposure occurs:	None	
Week:	5 days/week	
Year: (May-September) No flagger or ground observer used. Loader & mechanic too far from application site to receive drift.	22 weeks/year	
6. Treatment Area: Total acres or units:	206,256 A	
7. Population Exposed: Loader, mechanic, pilot		
Number of exposed workers:	156	

8. Dress: Work clothes - long trousers, long sleeve shirt, some hats, work boots, about 1 month in summer will wear T-shirt

9. Workers and Exposure Time:

156 workers @ 66 hrs/year nozzle time; no exposure time during application but loader-mixer may be exposed during mixing/loading functions.

CALCULATION SUMMARY NO. 7: USE INFORMATION FOR EXPOSURE, SELECTIVE BASAL - RIGHTS-OF-WAY

		Situation	
		Typical (>50%):	Extreme (10-20%):
1. Commodity:	ROW - selective basal		
2. Equipment:	Powered hydraulic handgun nozzle - 5500 adjustable cone tip		
3. Target:	Mixed brush	Handgun or knapsack mistblower	
4. Rate:		6.4 lb/A	6.2 lb/A
Dilution:		8 lb/100 gal	31 lb/100 gal
5. Exposure Times:			
Day:			
	Application Time:	6 hr/day	
	Nozzle Time:	3 hr/day	
	Drift Time and/or fraction direct exposure occurs:	0.3 hr/day 10%	
Week:		5 days/week	
Year:		34 weeks/year	
6. Treatment Area:	Total acres or units:	235,030	
7. Population Exposed:	Foreman, driver, 2 spraymen		
	Number of work sites:	3 A/day, 15 A/week, 520 A/season	
	Number of exposed workers:	Max 1808	

8. Dress: Work clothes

9. Workers and Exposure Time:
1808 workers @ 87 hr/year

CALCULATION SUMMARY NO. 8: USE INFORMATION FOR EXPOSURE, CUT STUMP - RIGHTS-OF-WAY

		Situation	
		Typical (>50%):	Extreme (10-20%):
1. Commodity:	ROW - Stump spray after cutting		
2. Equipment:	Powered hydraulic handgun	Handgun	Misthlower
3. Target:	Cut stumps - mixed species		
4. Rate:		3.2 lb/A	4.6 lb/A
Dilution:		8 lb/100 gal	31 lb/100 gal
		40 gal/A	15 gla/A
5. Exposure Times:			
Day:			
Application Time:		6 hr/day	
Nozzle Time:		3 hr/day	
Drift Time and/or fraction direct exposure occurs:		No drift, but contamination may be 5% or 15 min/day	
Week:		5 day/week	
Year:		34.7 weeks/year	
6. Treatment Area:	Total acres or units:	9,901 A	
7. Population Exposed:			
	Number of exposed workers:	76	

76 workers @ 15 min x 5 day x 34.7 weeks = 43 hours/year

8. Dress: Work clothes

9. Workers and Exposure Time:

76 workers @ 43 hrs/year

CALCULATION SUMMARY NO. 9: USE INFORMATION FOR EXPOSURE, SELECTIVE FOLIAR - RIGHTS-OF-WAY

1. Commodity: ROW - Selective foliar

2. Equipment: Bean 785 spraymaster (handgun)

	Situation: Typical (>50%):	Situation: Extreme (10-20%):
3. Target: Mixed brush		Mistblower
4. Rate:	6 lb/A	5 lb/A
Dilution:	2 lb/100 gal 300 gal/A	20 lb/100 gal 25 gal/A
5. Exposure Times:		
Day:		
Application Time:	6 hr/day	
Nozzle Time:	3 hr/day	
Drift Time and/or fraction direct exposure occurs:	1.5 hr/day	
Week:	5 day/week	
Year:	22 week/year	
6. Treatment Area: Total acres or units:	29,400 A/season/330 = 39 crews	
Days or units of work per year:	1/2 A/hr/crew; 3 A/day/crew 15 ac/week; 330 ac/season/crew	
7. Population Exposed: Sprayers in 4 person/crew		
Number of exposed workers:	356 workers	

8. Dress: Work clothes

9. Workers and Exposure Time:
Equivalent of 356 workers @ 165 hrs/season

CALCULATION SUMMARY NO. 10: USE INFORMATION FOR EXPOSURE, BROADCAST FOLIAR ROADSIDE - RIGHTS-OF-WAY

1. Commodity: ROW - foliar, roadsides

2. Equipment: Truck mounted with boom
   Nozzle - off center nozzles 150-OC nozzle 1500-1600 nozzle or 1-3 sets

	Situation: Typical (>50%):	Situation: Extreme (10-20%):
3. Target: Roadside, mixed brush		
4. Rate:	0.8 lb/A	
Dilution:	2 lb/100 gal 40 gal/A	
5. Exposure Times:		
Day:		
Application Time:	6 hr/day	
Nozzle Time:	5 hr/day	
Drift Time and/or fraction direct exposure occurs: (1 min/20 min)	15 min/day	
Week:	5 days/week	
Year:	22 weeks/year	
The 5 day/week, 22 week per year is a maximum assumption. Assumes a crew moving across the country with the season and using 2,4,5-T every day.		
6. Treatment Area: Total acres or units:	58,447 A	
7. Population Exposed: Driver and sprayman		
Number of exposed workers:	178 workers @ 5 days/week 22 weeks/yr or may be 1780 workers @ 5 days/week for 2 weeks/year.	

Driver in cab, removed for spray. Sprayman sets up high, less exposed that farm tractor driver with low boom and 8003 nozzles, plus roadside usually uses drift control agent.

8. Dress: Work clothes

9. Workers and Exposure Time:

   178 workers @ 27.5 hr/year

   or 1780 workers @ 2.75 hr/yr

CALCULATION SUMMARY NO. 11: USE INFORMATION FOR EXPOSURE, BROADCAST FOLIAR (RAILROAD) - RIGHTS-OF-WAY

1. Commodity: ROW - Foliar, broadcast, ground railroad

2. Equipment: Hi-Rail (HR) (highway or railroad), OC nozzles, directed spray, oscillating nozzle clusters, etc., straight stream spray train (ST) - John Bean spray gun 785 spraymaster, 1 1/4" & 2" mystery nozzle

	Situation: Typical (>50%):	Extreme (10-20%):
3. Target:		
4. Rate:	ST 6 lb/A HR 2 lb/A	
Dilution:	ST 2 lb/100 gal HR 8 lb/100 gal	
5. Exposure Times:		
Day:		
Application Time: HR-tracktime	4 hr/day	
Nozzle Time:	3 hr/day	
Drift Time and/or fraction direct exposure occurs:	6 min/day	
Week:	5 day/week	
Year:	13 weeks/year	
Hi-Rail uses Nalcotrol, coarse		
6. Treatment Area: Total acres or units:	10 A/hr/crew	
Days or units of work per year:	40 A/day; 200 A/week, 2600 A/season/crew; 99,996 A treated/year ÷ 2600 = 38 crews	
7. Population Exposed:	3 people (2 HR, 4 ST)	
Number of exposed workers:	114 workers, equivalent	

8. Dress: Work clothes - long pants, long sleeve shirt, for a month boots, may have T-shirt for 1 month, jackets for 1 month

9. Workers and Exposure Time:

$$6 \text{ min} \times 5 \text{ days} \times 13 \text{ weeks} = \frac{390 \text{ min}}{60} = 6.5 \text{ hr}$$

equivalent of 114 workers @ 6.5 hr/year

CALCULATION SUMMARY NO. 12: USE INFORMATION FOR EXPOSURE, BROADCAST FOLIAR (ELECTRIC) - RIGHTS-OF-WAY

1. Commodity: ROW - Foliar broadcast, ground, electric right-of-way

2. Equipment: Bean 785 spraymaster (handgun)

	Situation: Typical (>50%):	Situation: Extreme (10-20%):
3. Target: Mixed brush		Mistblower
4. Rate:	6 lb/A	5 lb/A
Dilution:	2 lb/100 gal 300 gal/A	20 lb/100 gal 25 gal/A
5. Exposure Times:		
Day:		
Application Time:	6 hr/day	
Nozzle Time:	3 hr/day	
Drift Time and/or fraction direct exposure occurs:	1.5 hr/day	
Week:	5 day/week	
Year:	22 week/year	
6. Treatment Area: Total acres or units:	43,927 A	
Days or units of work per year:	0.5 A/hr/crews, 2 A/day 10 A/week, 220 A/season per crew 43,927 A/season/220 = 200 crews	
7. Population Exposed: Driver, foreman, 2 sprayers		
Number of exposed workers:	800	

8. Dress: Work clothes

9. Workers and Exposure Time:

1.5 hr x 5 x 22 = 165 hrs/season

equivalent of 800 workers @ 165 hrs/season

Formulation and Container

1. Formulation--Amine salts of a water soluble liquid are used in rice. Principal amines used are diethanol, triethanol, dimethyl, triethyl, and isopropyl amines.

2. Package size and description--2,4,5-T amine is packaged in 5, 30 and 55-gallon metal drums.

Methods of Application

Aerial

About 97 percent of the 2,4,5-T is applied to rice by aircraft. Fixed-wing planes apply 99 percent of it; a few helicopters are used in some years. Boom-nozzle sprayers mounted on fixed-wing planes are used to apply 2,4,5-T. Tank capacities range from 100 to 250 gallons. Boom length is 70 percent of the length of the wingspan for the plane. Swath coverage ranges from 30 to 50 ft. depending on the size of the plane. Speed of spraying is 85-105 mph. Spray droplets size range from 100 to 300 μm in diameter (90% of the droplets are in this range; 10% of them are above or below this range). Drift-control agents are used with 2,4,5-T spray mixtures.

Ground

Only about 3 percent of the 2,4,5-T is applied by ground; this is used mainly for levee spraying. A light-weight, 4-wheel drive machine equipped with tank, pump, boom, and nozzles straddles the levee and sprays a 5 to 6-foot swath. The spray is released just above the rice canopy in a volume of 15 to 20 gpa. Spray pressure is 20 to 40 psi.

Rate and Timing of Application (Fixed-Wing Aircraft)

1. Rate--1 lb/A ai.
2. Dilution--1 qt. of 4 lb/gal ai per 3 gal; this is applied to 1 acre.
3. Pressure--20 psi, maximum.
4. Carrier--water.
5. Volume--3 gpa.
6. Spray ht.--5-10 ft. above crop.
7. No. applications--one application per season in 90%+ of the fields.
8. Acres treated per hr.--80 acres can be sprayed with one aircraft.
9. Hours suitable for spray each day--5 hr. per day (5:30-7:30 a.m.; 6:00-9:00 p.m.).
10. Season during which spraying takes place--last week of May through first week of August.

Time Required for Treatment and Number of Applicators (2,4,5-T Use Area)

1. All aerial applications are by commercial applicators.
2. No. of pilots--307.
3. No. of farmers--6,555.
4. Size of average site treated and time required to treat site--46 acres; 35 minutes.
5. Pilot and loaders--one pilot and one loader (pilot helps load plane).
6. No. of flaggers--1 or 2 (about 50% of the time there is one flagman and 50% of the time there are two flaggers).
7. Length of exposure--pilot, 35 minutes; flaggers, 25 minutes; loadman, 5 minutes.
8. Time required for loading--5 minutes.

Acres Treated (Air)

1. Total acres treated.

   Arkansas--------------172,000

   Mississippi----------- 99,000

   Louisiana------------- 17,000

   Missouri-------------- 4,000

   Total---------------292,000

2. Percentage of total acres in 2,4,5-T use area (1,075,000 acres)--27%.
3. Percentage of total rice acreage in U.S.--12%.
4. Total pounds active ingredient used--air, 292,000 lb; ground, 8,000 lb.

Exposure During Application

Aerial Application

The normal procedure of applying 2,4,5-T aerially to ricefields is to use a pilot for the aircraft, two flagmen, one on each end of the field, to guide the pilot, and one workman at the landing strip who drives the spray tank truck and helps load the aircraft (USDA-SEA-AR 1978). 2,4,5-T is hauled to the airstrip by the farmer or herbicide supplier in 5, 30, or 55-gallon drums. The herbicide is mixed with water in open 55-gallon drums and pumped into the aircraft through a closed hose system on the spray tank truck. The aircraft then flies across the ricefield covering a strip that ranges from 30 to 50 feet and using the flagmen as guides. The flagmen move upwind after they have lined up the pilot and before the aircraft comes directly over them; hence, the flagmen are not directly sprayed with 2,4,5-T. Since they are moving upwind, exposure to the spray is kept to a minimum. Because the aircraft travels across the ricefield at a low altitude (5-10 above the crop) flagmen must move before they would be sprayed directly (Smith et al. 1977).

Ground Application

About 8,000 acres of rice levees are sprayed each year with 2,4,5-T. Levees are sprayed with a 4-wheel-drive, light-weight machine operated by one man. The operator also mixes and loads the herbicide mixture. If the average rice farmer sprays 46 acres of rice land, a total of 3 acres of rice would be treated (table 13, chapter 4). This would be about 4 miles of levees [(43,560 x 3) ÷ 6) ÷ 5,280]. About 4 hours would be required to spray all the levees on 46 acres (spraying, mixing, and ferrying time). However, the actual spraying time would be about 1.3 hours. Each farmer treats only the levees on his farm. Presently, custom applications are not used to spray levees.

If a farmer had 500 acres of rice, the operator of the spraying machine would be exposed to the spray for a total of 14 hours (actual spraying time).

Additional Routes of Exposure

Under normal conditions workmen seldom re-enter rice fields soon after spraying with 2,4,5-T at midseason (the time when most of the 2,4,5-T is applied for weed control). The field is re-flooded or water is added to increase the flood depth soon after 2,4,5-T spraying. However, the ricefield is equipped with floodgates in each levee so that the water enters from the canal on the high end and subsequently fills the paddies successively with the slope of the field. There is little need for the irrigation man to enter the ricefield because the floodgates regulate the water in each field. The fields are entered after the rice matures and when the floodgates must be removed to drain the field; this is 40 to 45 days after applying 2,4,5-T.

When ricefields are sprayed during the early season (3 to 6 weeks after crop emergence) workmen may enter the field soon after treatment to adjust floodgates, to fill drain furrows, and to check growth and development of the rice crop. However, most fields are treated with 2,4,5-T at midseason when re-entry of the field is infrequent. Re-entry of ricefields after spraying with 2,4,5-T is not regulated.

When rice fields are sprayed by ground applicators the operator is exposed to the spray during mixing and spraying in the field. However, the boom is located to the rear of the operator which reduces exposure to the spray.

Time required for these practices with number of individuals and exposure time for each--the water-man (irrigation man) would be the only person exposed (1 individual per farm). Exposure time would be less than 1 hour per day during the 7 days after application.

Protective Equipment

Normal work clothes. Flagmen move before the airplane sprays them directly. They usually flag upwind so that the spray does not drift on them; however, there is little wind movement at time of spraying (less than 5 mph).

Size of Rice Farms in 2,4,5-T Use Area and Number of Workers Exposed

No. rice farms in Arkansas in 1977 (Arkansas Cooperative Extension Service (1978e)..6,441

No. rice farmers in Arkansas in 1977 (Arkansas Cooperative Extension Service 1978g)..5,100

Rice acreage in Arkansas in 1977 (table 1, Chapter 4)...........347,000

Avg. no. rice acres/farm (calculation)..............................130

Avg. no. rice acres/ farmer (calculation)............................164

The data from Arkansas can be extrapolated to Mississippi, northern Louisiana, and Missouri because their production systems are similar to Arkansas: Extrapolations would indicate the following averages:

No. rice farms in 2,4,5-T use area, 1975-77........................8,269

No. rice farmers in 2,4,5-T use area, 1975-77......................6,555

Rice acreage in 2,4,5-T use area, 1975-77 (tables 1 and 4, Chapter 4)...1,075,000

Avg. no. rice acres/farm, 1975-77 (from above calculation)..........130

Avg. no. rice acres/farmer, 1975-77 (from above calculation).........164

In order to maintain a satisfactory cropping (crop rotation) system, the farmer needs 3 to 4 times his rice acreage in the total farm. On the alternate acres he may produce soybeans, grain sorghum, small grains, cotton, lespedeza, or fish (catfish or minnows). He also may have some land devoted to surface water storage for irrigation use. Therefore, a good assumption would be that the average rice farmer manages a total of 3.5 times the acres he has in rice. If this assumption is used, we can calculate the number of acres that each farmer manages--164 X 3.5 = 574 (the avg. size of a rice farm). Usually a rice farm will contain more acres than cotton or soybean farms because of the cropping system required for growing rice.

In 1975-77, 300,000 acres of rice were treated with 2,4,5-T. This is 28 percent of the total acres in the 2,4,5-T use area (300,000 ÷ 1,075,000 X 100). Although some farmers treat all of their rice acreage with 2,4,5-T, others do not apply any 2,4,5-T. A good assumption is that, on the average, the rice farmer would treat 28 percent of his rice acreage with 2,4,5-T or 46 acres (164 acres/farmer X 28%) with 2,4,5-T.

Therefore, only 8 percent of the acreage on each farm is treated with 2,4,5-T each year [(46 ÷ 475) X 100].

Aerial Application

An aerial applicator can spray 46 acres of rice in 35 minutes (this includes time for loading, ferrying, and spraying the field) (Eichler 1978b). A loadman will help the pilot fill the plane; this requires about 5 minutes. About one-half of the fields are sprayed using 2 flagmen and half using one flagman--this averages to be 1.5 flagmen/field. The actual spraying time is about 25 minutes. Therefore, for a 46-acre field the exposure time would be:

Workmen	Exposure time (min.)
Pilot (1 X 35)	35
Flagmen (1.5 X 25)	38
Loadman (1 X 5)	5
Total man-minutes to spray a 46-acre rice field	78

If we extropolate the above data to the total 2,4,5-T use area, we get the following data for the 6,555 rice farmers each with an average of 46 acres of rice sprayed with 2,4,5-T:

Workmen	Man-hours
Pilot (0.58 hr. X 6555)	3,802
Flagmen (0.63 hr. X 6555)	4,130
Loadmen (0.08 hr. X 6555)	524
Total man-hours involved in 2,4,5-T spraying in 2,4,5-T use area	8,456

Most spray jobs are done during the early morning (5-8 a.m.) or late afternoon (6-9 p.m.) when the wind is below 5 mph.

The number of pilots registered to apply phenoxy herbicides in Arkansas and Mississippi in 1976 (Jan.-Sept.) was 242 and 82, respectively. The number of aircraft inspected to apply phenoxy herbicides in Arkansas and Mississippi in 1976 (Jan.-Sept.) was 211 and 118, respectively. The number of operators registered to apply phenoxy herbicides in Arkansas in 1978 (Jan.-Sept.) was 198; this value is not known for Mississippi. An operator may or may not be a pilot. About 90 percent of the pilots and aircraft in Arkansas and Mississippi spray phenoxy herbicide on rice. However, they may not all be applying 2,4,5-T. We estimate that most of them apply some 2,4,5-T on rice. Most of the phenoxy herbicides applied to rice in Missouri is by operators located in Arkansas. The above data were obtained from Pay (1978b, data for AR) and McCarty (1978, data for MS). Data are not available from Louisiana but some of the spray jobs are done by operators, pilots, and aircraft located in Arkansas and Mississippi. It is safe to assume that in Louisiana the number of pilots and aircraft would be proportional to the acreage sprayed in Arkansas and Mississippi. If this is the case, then the following data are indicated for number of pilots exposed to 2,4,5-T:

State	No. Pilots
Arkansas	218
Mississippi	74
Louisiana	15
Total	307

For each pilot exposed to 2,4,5-T there is one loadman exposed.

Therefore, 7,169 (worst case) people are exposed to 2,4,5-T each year; these include pilots, loadmen, and flagmen.

These data indicate that pilots are exposed to 2,4,5-T for longer periods than other workmen. On the average, a pilot is exposed to 2,4,5-T for 12.4 hr/yr., compared with 1.7 hr/yr for a loadman, and 0.65-2.25 hr/yr for a flagman. Although these are average exposure cases, the exposure time per year of each class of workman would be relatively low, even if the exposure time were multiplied by a factor of 10- to give 124, 17, and 6.3-22.5 hours exposure time per year for pilots, loadmen, and flaggers. The high exposure person (pilots) in this group is protected most of the time by the airplane; he is in the cockpit ahead of and above the spray (tables 23 and 24).

Although one flagger has a nozzle time exposure of 25 minutes, he receives contact with spray drift for only 1 pass out of 10. The spray dispensed by the airplane settles while the plane completes a 0.25 mile turn to start another pass. About 18 seconds are required to complete the turn. Flaggers wear ordinary field clothes--long pants, long-sleeved shirts, caps or hats, and leather boots. They do not use special protective gear.

Ground Application

About 8,000 acres of rice levees are sprayed with 2,4,5-T annually. This is the acreage of levees in 50,000 acres of rice. Each farmer treats the levees on his farm; custom applicators are not used. A total of 1,087 operators would be required to spray the levees on all 50,000 acres of rice. If a farmer had 500 acres of rice, the spray operator would be exposed for 14 hours actual spray time annually. A total of 100 operators would be required if all 50,000 acres were in 500 acre ownerships.

See calculation summaries 13 and 14.

Table 25 summarizes the number of applicators and their annual exposure time for various methods of application in each commodity group.

Table 23--Number of workers exposed annually to 2,4,5-T in rice production

State	Workmen		
	Pilot	Loader	Flaggers[a/]
	No. of people exposed/yr.		
Arkansas	218	218	5,213
Mississippi	74	74	866
Louisiana	15	15	387
Missouri	---	---	---
Total	307	307	6,555

a/ 1.5 flaggers per farm for spraying 46 acres of rice with 2,4,5-T. A total of 6,555 farmer operations in the 2,4,5-T use area.

Table 24--Man-hours of exposure to 2,4,5-T for classes of workmen in the total 2,4,5-T use area

Workmen	No. persons exposed/yr.	Man-hours of nozzle time/yr	Man-hours of nozzle time per man/yr.
Pilot	307	3,802	12.4
Loadmen	307	524	1.7
Flagman[a/]	6,555	4,130	.63
Flagmen[b/]	1,835	4,130	2.25

a/ Low exposure case--assumes each rice farmer treats 28% of the average acreage with 2,4,5-T.

b/ High exposure case--assumes 28% of the rice farmers treat all (164 acres) of the average acreage of rice.

CALCULATION SUMMARY NO. 13: USE INFORMATION FOR EXPOSURE, AERIAL RICE

1. Commodity: Rice

2. Equipment: Fixed wing aircraft, 40 foot swath VMD 250 m (range 100-300 m)

	Situation: Typical (~50%):	Situation: Extreme (10-20%):
3. Target: Weed in rice crop		
4. Rate:	1.0 lb/A	
Dilution:	33 lb/100 gal	
5. Exposure Times:		
Day:		
Application Time:	25 min	272 min
Drift Time and/or fraction direct exposure occurs:	1 min/day	10.9 min/day
Week: 1 day or 1 field/worker	1 min/week	10.9 min/week
Year: 1 day or 1 field/worker	1 min/year	10.9 min/year
6. Treatment Area: Total acres or units:	46 A	500 A
Days or units of work per year:	1	1
7. Population Exposed: Flagman	1	2
Number of work sites:	1	1
Number of exposed workers:	6,555	(total @ 1.5/field)
8. Dress: Work clothes - blue jeans or khakis, long sleeve shirt, cap or wide brim hat, work boots		
9. Workers and Exposure Time:	Assume 90/10 distribution 5,900 @ 1 min	60 @ 11 min

*Drift time: Drift only occurs at end or start of a pass and only then in dead calm, this will be about 1/10 of passes, when it occurs, it will have disappeared in 18 seconds or time it takes for a turn. There are 33 passes per 46 A field x 18 sec = 594 sec x 1/10 equals 60 sec or 1 minute

Equivalent of 6,555 workers @ 1 min/year
or 603 workers @ 10.9 min/year

CALCULATION SUMMARY NO. 14: USE INFORMATION FOR EXPOSURE, BOOM SPRAYER - RICE

1. Commodity: Rice

2. Equipment: 4-wheel drive, low boom sprayer

	Situation: Typical (>50%):	Extreme (10-20%):
3. Target: Weeds on levee; field boundaries and interior dikes		
4. Rate:	1.0 lb/A	
Dilution:	5 to 7 lb/100 gal 15 to 20 gal/A	
5. Exposure Times:		
Day:		
Application Time:	1.3 hrs/day	7 hrs/day
Nozzle Time:	1.3 hrs/day	7 hrs/day
Drift Time and/or fraction direct exposure occurs: *Assume fraction of drift time/nozzle time is the same as in Staiff et al. (1975) which provides the base level exposure used by EPA.	1.3 hrs/day*	7 hrs/day
Week:	1 day/week	2 day/week
Year:	1.3 hr/year	14 hrs/year
6. Treatment Area: Total acres or units:	46 A	500 A
Days or units of work per year:	1	1
7. Population Exposed: Sprayman		
Number of work sites:	1/worker	1/worker
Number of exposed workers: Note: The units of work can be done by 2667 or 245 workers, but not by both. Perhaps 10% or 25 units would be 500 A operations; 25 workers would be exposed at 14 hrs rather than 1.3 hrs.	2667 or	245
8. Dress: Work clothes - blue jeans or khakis, long sleeve shirt, cap or wide brim hat, work boots.		
9. Workers and Exposure Time:	Assume 90/10 distribution 2,400 @ 1.3 hrs	25 @ 14 hrs

Equivalent of 2,667 workers @ 1.3 hrs/year
or 245 workers @ 14 hrs/year

Table 25--Application methods, distribution of effort, persons and hours per year potentially exposed

Commodity	Method	Percent of acreage	Number of persons	Exposure time hr/yr
Timber	Backpack mistblower	2		
	tree injection	11		
	Tractor mounted mist blower	12		
	Helicopter - D6 - nozzle	37	1,238	0.1
			60	0.23
	D6-46 nozzle	38	1,238	0.1
		100	60	0.23
Range & pasture	Backpack handpress	1	300	6
			20	12
	Tractor mounted low boom	2	450	0.75
			20	1.75
	Tractor mounted high boom	9	15	96
	Fixed wing aircraft	88	25	1
		100	100	3
			25	10
Rights-of-way	Hydraulic power gun			
	Selective foliar	4	356	165
	Broadcast foliar	6	600	165
	Selective basal	35	1,808	87
	Stump	1	76	43
	Vehicle mounted - Highway	9	178	28
	Vehicle mounted - Hi-Rail	15	114	6.5
	Helicopter - microfoil	30	156	0
		100		
Rice	4-wheel drive mounted low boom	3	2,400	1.3
			25	14
	Fixed wing aircraft	97	5,900	0.67
		100	60	0.18

ESTIMATION OF EXPOSURE BY THE FACTORIAL METHOD

The factorial method uses the exposure scenarios as presented in PD-1 (EPA 1978) as the base to which corrections are applied. The assumptions both explicit and implied are adjusted according to the actual exposure which results from specific patterns of use (see earlier section, "Exposure of applicators according to use pattern" in Part 5 of this chapter). The adjustment is applied as a decimal correction factor which can be used to correct either the calculated exposure level (as done in this section) or directly to the calculated margin of safety. In this report, adjusted margins of safety were calculated by dividing the no-adverse-effect levels specified in PD-1 by the exposure levels corrected by the factorial method.

The factorial approach to modifying estimates of exposure is used in this section to (1) determine the effects of a few reasonable changes in assumption on the magnitudes of the safety margin, and (2) calculate safety margins for exposure situations as we believe they exist in practice.

THE FIRST PRESUMPTION OF RISK - ONCOGENIC EFFECTS

The oncogenic effects presumption of risk was not based on exposure in PD-1 (EPA 1978). The toxicological properties of 2,4,5-T and TCDD were the sole criteria used, therefore this report makes no further evaluation of the first presumption risk.

THE SECOND PRESUMPTION OF RISK - DERMAL EXPOSURE/BACKPACK SPRAYER

The effect of assumptions on the safety margins is illustrated by comparing the scenario for backpack sprayers using the assumptions in PD-1 (EPA 1978) and by an alternate set of assumptions. The following assumptions were stated or implied in the scenario describing the dermal exposure of a spray applicator using a (hand pressure) backpack sprayer on a right-of-way, pasture, or rangeland in PD-1:

1. Applicator is female, pregnant, in the first trimester, and weighs 60 kg.
2. Finished spray: 1.6 lb ae/32 pints or 40 lb ae/100 gallons.
3. Applicator is exposed at a rate of 10.5 ml/hr, the maximum single value available (or 0.177 pints/day).
4. Applicator wears no protection; only short-sleeved shirt, open-necked, no gloves, no hat.
5. Application wand was directed upward or horizontal a portion of the time.
6. Application exposure is 8 hrs per day.
7. The applicator is exposed daily from the 15th through the 60th days of pregnancy.
8. Ten percent of the dermal dose of 2,4,5-T and TCDD is absorbed.
9. The rate of dermal absorption is the same as from oral exposure.

A close examination of these assumptions is necessary to determine if they have a rational and orderly relationship to actual conditions. The following considerations should be given to these assumptions (numbered to correspond to numbers above):

1. The stated assumption by the EPA is that the spray applicator be a female of child-bearing age, but the "hidden" assumption is that she is pregnant. The assumption that a pregnant woman is a backpack sprayer is obviously fundamental to risk assessment involving teratogenic or fetotoxic effects. The frequency of this assumption being satisfied currently or in the future needs consideration. No cases of female spray operators involved in the application of 2,4,5-T were identified by Norris and Klingman (1979). Since the data on which the no-adverse-effect-level are based involved daily exposure from the 6 to 15 days of pregnancy in rats, this is translated in terms of human fetal development as being during the 15th to 60th day in the first trimester, which as a further restriction consitutes another hidden assumption.

It is not clear how to translate the improbable event of a human in the first trimester of pregnancy involved in spraying 2,4,5-T on the appropriate days into the quantitative terms of a probability coefficient necessary to compute the hazard. We shall, therefore, continue to use this assumption in this and subsequent scenarios, but only because to exclude it aborts the scenario. This risk needs to be identified in a more quantitative fashion.

2. The "typical" concentration of 40 lb/100 gallons in a finished spray is not typical. The EPA figure seems to have been chosen as being typical on the basis of being near the midpoint of concentrations found on all the registered labels [shown in the Exposure Analysis by the EPA 2,4,5-T Working Group (Reference No. 164 in EPA 1978) as being from 2.5 lb to 100 lb/100 galllons] rather than identifying the frequency with which various concentrations are used in practice. Some very high spray concentrations are registered presumably to allow the flexibility to deal with an intractable, but rare, pest problem. The most common, and therefore typical, concentration for use with backpack sprayers is 8 lb/100 gal. or 1/5 that used in the PD-1 calaculation. Application of this "correction factor" (0.2) decreases exposure thereby increasing the margin of safety from 3:1 to 15:1 and from 43:1 to 215:1, for 2,4,5-T and TCDD respectively.

3. The assumed rate of exposure of 10.5 ml/hour is taken from the single highest value obtained from a set of 10 measurements (Wolfe, et al. 1974, Reference No. 166 in EPA 1978). Ordinary scientific practice is to use the mean value of a set of replicates rather than a single high or low extreme value, because the extreme low value has the same probability of being a correct forecast as an extreme high value, but both a lower probability of occurring than the mean. This was done in spite of the fact that the authors of the source document observe in their paper that exposure rates were measured for a brief period and clearly stated that "maximum exposure levels would probably rarely be maintained throughout a

full working day considering the variation in values obtained." The PD-1 did not identify the choice of exposure rate as a single extreme value, but presented the value in a way which leads the reader to believe the mean value was chosen: "Exposure ranged from 0.1 to 6.3 mg/hour, with a mean of 3.6 mg/hour (6 ml/hour)" (EPA 1978). The Working Group paper (Reference No. 164 in EPA 1978) made it clear that 6.3 mg/hour is used, but the PD-1 makes it appear that 3.6 mg/hour is used. The authors of the source document have stated that they object to the use of the extreme value rather than the mean as being a meaningful interpretation of their data. The potential exposure rate is therefore corrected by a factor of 0.6.

4. Applicators do not normally work while dressed as described in PD-1, and did not do so in the experiment cited in the PD-1 (Wolfe et al. 1974) nor in another paper cited later (Wolfe et al. 1959, Ref. No. 145 in EPA 1978). The technique used in both of these studies was to fasten cellulose pads to various parts of the body over the clothing or protection actually worn. The amount of chemical deposited on any segment of the epidermis is then calculated from the amount on the patches and a theoretical exposure pattern developed to show the contribution of each part of the body. In the studies cited, no spraymen were actually dressed in short-sleeve shirts, etc.; this was a theoretical model. Examination of the detailed data supporting the data cited for dermal exposure (Ref. No. 166 in EPA 1978) reveals the following distribution; hands - 62.3 percent; forearms - 25.4 percent; V of chest - 2.2 percent; back of neck - 1.3 percent, face 8.8 percent.

Thus, simply wearing a long-sleeved shirt and gloves reduces the exposure by 87.7 prcent or increases safety by a factor of 8 bringing the margin of safety to 344 and 1720, respectively for 2,4,5-T and TCDD. If a wide-brim hat and button-up shirt is worn the exposure is further reduced to at least 91.2 prcent. If, as shown in Wolfe et al. (1959), a Type I cape is worn with hat and gloves, exposure will be reduced by more than 98.6 percent, probably by 99.3 percent. We may dress the applicators (in our subsequent scenarios) in the Type I cape, etc., and reduce the exposure level by 99 percent, increasing the margin of safety by 100 or use only a long-sleeve shirt, buttoned up, with hat and gloves and increase the margin of safety by 10. If other scenarios with other modes of dress are desired, appropriate changes in the correction factors will permit calculation of the correct margin of safety.

5. The experiments in the source document were for mosquito control instead of brush control; this means that conditions were more conducive to exposure of personnel than they should have been due to smaller droplet size, angle of the wand, and in one case, indoor spraying. It is our judgment that these factors should reduce exposure by at least a factor of 2, but since we lack specific data we will not enter this correction at this time.

6. The assumption that an applicator who works an 8-hour day is exposed for 8 hours per day is not correct. Their exposure is limited by a number of factors including weather conditions, preparation time, travel time, etc. The approximate time spent in treatment per day is: pastures and range - 6 hours; forests - 4 hours; right-of-way - 6 hours. Since the largest proportion of the 2,4,5-T applied by backpack sprayers is on powerline rights-of-way, the principal scenario will utilize that illustration.

7. The no-adverse-effect-level is expressed as a daily dose and based on daily doses from the 6th to the 15th day of a 21-day pregnancy according to the source document. In terms of human fetal development this translates to a daily exposure for 45 consecutive days between the 15th and 60th days of pregnancy. It can be argued that the terata (birth defects) are formed on a single day within

that time span, but if so the exposure causing the terata would be a result of accumulation of chemical from several preceeding days doses. Several assumptions are possible. The simplest is that exposure occurs on each 45 days. A more complex assumption is that a narrow window exists and that daily exposure for 7 days prior to the window would provide a dose reflecting the experimental exposure. The seven days is chosen based on data from Newton (1978) showing excretion from dermal doses to be slower than oral doses. Either assumption requires a change in the exposure factors. If we assume that persons doing this type of spraying engage in it for 2 work days per week or 28.6 percent of the possible time and round that up to 1/3 of the time, we decrease exposure by a factor of 3 in both cases. However, we must not forget that in one case we are limiting access in that exposure must occur over a precise 6.5 week period of the pregnancy and in the other it must occur during a single week of the pregnancy. We will not put in a reduction factor to reflect the probability that a narrow window of 1 day or 1 week would occur during spraying season, but assume that it does happen. The reduction factor of 0.33 being used here applies to both kinds of assumptions and reflects 2 days per week over the 5 weeks that back-pack sprayers work on the range.

8. The assumption that 10 percent of the dermal dose of 2,4,5-T and TCDD is absorbed is weak in that the derivation of this figure is not explained. It appears the work of Serat, Feldman, and Maibach (1973) (which showed a 5.8% absorption for 2,4-D and a 15% absorption for DDT) was used on the basis that 2,4-D could be compared to 2,4,5-T and DDT could be compared to TCDD (the citation used in PD-1 was not explicit). While it is risky to use analogs since each chemical has its own set of specific properties, we appreciate the problem confronting the Working Group and the need to identify some useful absorption values. 2,4-D is a reasonable analog for 2,4,5-T. Lavy (1978b) reported data which related urine excretion of 2,4,5-T with dermal exposure. He concluded about 4

percent of the 2,4,5-T which came in contact with the skin was actually absorbed (and excreted). The analog comparison between TCDD and DDT is not as good. DDT is poorly water soluble and highly lipid soluble, while TCDD is poorly water soluble and poorly lipid soluble. This characteristic will significantly reduce the dermal penetration of TCDD in comparison with DDT. What is inexplicable is why the values for 2,4-D and DDT were apparently averaged in PD-1. We will accordingly slightly reduce the absorption figure of 15 percent to 10 percent for TCDD, keeping it as it is in the PD-1, but believing that it should be much lower. There is strong justification for not using a 2,4,5-T absorption rate of 10 percent. We shall use 5 percent to keep the calculations simple. This will reduce the exposure for 2,4,5-T by 1/2 (a correction factor of 0.5). The exposure for TCDD is unchanged.

9. The experiments which provide the basis for the no-adverse-effect-level used oral doses whereas the exposure in this scenario is by the dermal route. Concentration from oral doses of 2,4,5-T reach a maximum within 24 hours. But those from dermal doses do not do so for 48 hours (Newton 1978). This will result in a decrease in the effective concentration by a factor of 2, or require a correction factor of 0.5.

Thus we are able to construct a new scenario using a modified set of assumptions as follows:

	Modified Assumption	Correction factor
1.	Applicator is female, pregnant, in the first trimester and weighs 60 kg.	--
2.	Finished spray: 8 lb ae/100 gal.	0.2
3.	Potential exposure rate is 6.0 ml/hour	0.6
4.	Applicator wears long-sleeve, button-up shirt and wide brim hat, kepi	0.7
5.	Applicator is still assumed to be spraying for mosquitoes.	--

6.	Applicator has 36 min nozzle time per day	0.075
7.	Applicator works at nozzle 2 days per week	0.33
8.	Absorption rate of 2,4,5-T is 5% and for TCDD is 10%	0.5 --
9.	Dermal absorption rate is 1/2 oral rate	0.5
	Cumulative exposure correction factors:	$\frac{2,4,5\text{-T}}{0.00052}$; $\frac{\text{TCDD}}{0.001}$

Based on the assumptions in Appendix 3 the EPA calculated that an unacceptable risk of the woman applicator bearing a child with a birth defect exists. We calculated the margin of safety used by EPA (from PD-1), the margin of safety derived from the modified assumptions, above, and the margins of safety from two additional modifications in dress (table 26).

This exercise shows (1) that the selection of assumptions has a profound effect on calculated dose levels (or margins of safety), and (2) that when assumptions are used which more reasonably reflect conditions encountered in actual practice, a large margin of safety exists. In the following paragraphs the factorial approach is used with assumptions which are derived from the earlier section on "Exposure of applicators according to use patterns" in Part 5 of this chapter. The scenarios used in the PD-1 (EPA 1978) are used as the basis for this new evaluation of exposure.

THE THIRD PRESUMPTION OF RISK - DERMAL EXPOSURE/TRACTOR MOUNTED BOOM

The following assumptions were stated or implied in PD-1 in the scenario describing the dermal exposure of a spray applicator driving a tractor mounted with a low boom sprayer on rangeland or right-of-way.

1. The applicator is female, pregnant, in the first trimester, and weighs 60 kg.
2. Finished spray: 1.6 lb ae/32 pints or 40 lb/100 gallons.

Table 26--Backpack sprayer dermal exposure and margin of safety

	2,4,5,T		TCDD	
	Exposure mg/kg/day	Margin of safety	Exposure g/kg/day	Margin of safety
No-adverse-effect-level, PD-1[a]	20		0.03	
Calculated dose level, PD-1[a]	6.8	3	7×10^{-4}	43
Modified assumptions exposure level	0.0035	5,656	7×10^{-6}	41,208
Add gloves[b] (CF[a] $= 7.4 \times 10^{-5}$)	0.0005	39,611	1×10^{-7}	285,714
Add gloves and Type I cape ($CF = 7.4 \times 10^{-6}$)	0.0005	396,110	1×10^{-8}	2.85×10^{6}

a/ EPA (1978)

b/ CF = cumulative exposure correction factor

3. Applicator is exposed at a rate of 0.048 pints/day (this is the extreme rate or 8.5 times the mean rate).
4. Applicator wears no protection: short-sleeved shirt, open neck, no gloves, no hat.
5. Applicator is spraying a herbicide.
6. Applicator exposure is 8 hours per day.
7. Applicator is exposed daily from the 15th to the 60th day of pregnancy.
8. Ten percent of the dermal dose of 2,4,5-T and TCDD is absorbed.
9. The rate of dermal absorption is the same as for oral exposure.

Many of the same arguments apply to the assumptions which were presented in the discussion of the second presumption of risk. For the third scenario, only the assumptions which are different from the second are discussed here.

2. The concentration of finished spray used in tractor-mounted spray booms are lower than those in back-pack sprayers: Rights-of-way 2 lb/100 gal. on 58,447 A; range, 10 lb/100 gal. on 75,000 A; rice 5 lb/100 gal. on 8,000 A. In our scenario we will use a finished spray of 10 lb/100 gal. because this rate is used on the largest acreage and therefore is the most typical. If 2 or 5 lb/100 gal are desired it is a simple matter to calculate an adjustment of the safety factor as shown before. The 10 lb/100 gal. concentration requires a correction factor of 0.25.

3. The exposure for the tractor-mounted spray boom is computed from the paper by Staiff et al. (1975) (Ref. No. 147 in EPA 1978) and again the single highest experimental value from 20 exposures is used. The exposures found by Staiff et al. range from 0.01 to 3.4 mg/hr with a mean of 0.4 mg/hr. The EPA value is 8.5 times larger than the mean, and the exposure becomes 0.0056 pts/day in the terms used by EPA rather than 0.048 pts. The correction factor for the exposure level is 0.118.

4. Scantily garbed operators as assumed in the EPA scenario is not the usual practice. This will be corrected in the modified scenario. Inspection of Staiff, et al.'s original data reveal some information not emphasized in their publication. The principal dermal contamination is to the hands. This is acquired during loading operations; 3.36 mg were on the hands after loading, and less than 0.006 mg were on the hands after spraying (99.82% after loading, and 0.18% on hands after spraying). Thus a correction factor of 0.0018 would be appropriate if gloves were worn only during loading! The use of typical work clothes (long-sleeve shirt, long trousers, wide-brim hat, leather boots, and kepi) require a correction factor of 0.7 . If gloves are worn the correction factor becomes 0.01 (Wolfe et al. 1974) or 0.002 (Staiff et al. 1975).

6. This scenario is for a tractor driver spraying mesquite sprouts with a low boom on the range. He is a ranch employee who will typically treat 40-50 acres once a year. A few persons may treat up to 100 acres per year. This will take about 3 hrs to treat 45 acres and his exposure will be about 15 minutes per hour or 45 minutes per day or per year. This results in a correction factor of 0.75 hrs/8 hrs or 0.094.

7. On the typical job the sprayman will work 1 day per year. Since the daily dose level is predicted on receiving such a dose for 45 consecutive days (15th to 60th day of pregnancy) the correction factor is 1 day/45 days or 0.02. The extreme case requires a correction factor of 2.25/45 or 0.05.

We can set forth the modified assumptions as follows:

Modified assumptions	Correction factor
1. The applicator is female, pregnant, in the first trimester, and weighs 60 kg.	--
2. Finished spray: 10 lb/100 gal	0.25

3.	Applicator is potentially exposed to 4 mg/hr or 0.0056 pts of spray per day	0.118
4.	Applicator wears leather boots, long trousers, long-sleeve shirt, kepi, wide brim hat	0.7
5.	Applicator is spraying a herbicide	—
6.	Applicator is exposed 6 hrs/day	0.094
7.	Fraction of trimester exposed	0.02
8	Five percent of the 2,4,5-T is dermally absorbed Ten percent of the TCDD is dermally absorbed	0.5 —
9.	The rate of dermal absorption is 1/2 that for oral	0.5

Cumulative correction factor:	2,4,5-T	TCDD
	$9.7x10^{-6}$	$1.9x10^{-5}$

Under the conditions stated in this scenario, and only when these assumptions are met, the dose levels shown below result. The margin of safety calculated from PD-1 (EPA 1978) did not constitute an ample margin of safety for a pregnant woman according to EPA. The exposure levels shown for what we believe to be conditions which actually exist show margins of safety which are much larger. In addition to results of the detailed scenario (above), the results of incorporating some other assumptions are also shown (table 27).

THE FOURTH PRESUMPTION OF RISK - DERMAL EXPOSURE/AERIAL APPLICATION

The following assumptions were stated or implied in the scenario describing the dermal exposure of a person standing directly under the airplane or helicopter during application on an unspecified commodity.

1. The exposed person is female, pregnant, in the first trimester, and weighs 60 kg.
2. Finished spray: 4 lb/10 gal or 40 lb/100 gal.
3. The rate of application is 4.0 lbs/acre.
4. The person is exposed to 31 mg/day of 2,4,5-T.
5. The person wears no protection and few clothes; has bare head, neck, shoulders, forearms, hands, and even bare thighs.

Table 27--Tractor mounted boom sprayer dermal exposure and margin of safety

	2,4,5-T		TCDD	
	Exposure mg/kg/day or season	Margin of safety	Exposure μg/kg/day or season	Margin of safety
No-adverse-effect-level, PD-1[a/]	20		0.03	
Calculated dose level, PD-1[a/]	1.8	11	$1.8x10^{-4}$	167
Modified assumptions for season	$1.7x10^{-5}$	$1.1x10^{6}$	$3.4x10^{-9}$	$8.8x10^{6}$
Use 2.25 workdays		$4.4x10^{5}$		$3.5x10^{6}$
Add gloves		$7.7x10^{6}$		$5.0x10^{7}$

a/ EPA (1978)

6. The airplane spray system is set for insect control and produced droplets with an MMD of 109 μm from a solvent mixed from Shell solvent No. 2 and medium grade diesel.
7. The person is standing directly beneath the airplane during the application.
8. The person does this for 8 hours.
9. The person is so exposed daily for 45 days during the first trimester.
10. Ten percent of the dermal dose of 2,4,5-T and TCDD is absorbed.
11. The rate of dermal absorption is the same as for oral absorption.

The modifications to the PD-1 assumptions differ from those in previous scenarios in the following respects:

2. The concentration of finished sprays range from 20 - 50 lb/100 gal. In forestry 20-40 lb/100 gal are used on about 410,000 A; on range and pasture 25-50 lb/100 gal on 725,00 A; on rights-of-way 32 lb/100 gal on about 200,000 A; and on rice 33 lb/100 gal are used on about 290,000 A. The largest acreage is on range and the concentration of 30 lb/100 gal will be chosen as most typical for this scenario. This requires a correction factor of 0.75.

3. The rate of use is 1/4 to 2 lb/A for range, 1.5 to 3 lb/A for forests, 1 lb/A for rice and 8 lb/ac for rights-of-way. The figure of 2 lb/A will be used in this scenario since it will be constructed using range as "typical", even though it is in the extreme, or high 20 percent for range. Forestry uses average less than 2.5 lb/A and rice uses are never more than 1 lb/A. The ROW rate of 8 lb/A is not considered because the placement of the potentially exposed persons precludes interception of drift. The correction factor for the rate of 2 lb/A is 0.5. However, this correction and the one for concentration should not be used simultaneously. A given rate of application should produce the same amount of chemical per unit volume of air and area of interception surface regardless of concentration as more drops will

be produced with less concentrated sprays. We will omit the correction factor for concentration (0.75) and use the factor for rate (0.5).

4. The exposure level of 31 mg per person cited in PD-1 is within the expected limits for a person working directly beneath an aircraft for 8 hours. The rate of 0.46 lb/A would deposit 4.26 mg/ft^2 per pass if 90 percent were deposited on target as shown in the source document (Caplan et al. 1956). The PD-1 describes the exposed area as head, neck, shoulders, forearms, hand, and thighs. The mode of dress is not clear, but appears to be a pair of shorts and sneakers. The exposed dermal area is at least 15 ft^2 and the theoretical exposure level would be 64 mg/person. The PD-1 describes the exposure condition as being directly beneath the aircraft for 8 hours. The source document derived the exposure level figure from a 2 hour exposure, apparently from a single pass and remaining in position for the next 2 hours. There is no condition under which a person would be directly under a spray plane. Any such episode would be in the accident category rather than the occupational exposure category. The EPA did not make it clear how and why the person was directly under the spray plane. The research cited in the EPA analysis (Caplan et al. 1956) was undertaken to determine the feasibility of aerial application of malathion over towns for mosquito control. No such uses are contemplated for 2,4,5-T. No persons are directed to work under a spray plane, or any other sprayer, and in fact are directed not to be in the application zone. The persons who may be positioned near a treatment zone are flaggers, observers, timekeepers, supervisors, etc. The person with the highest exposure potential for exposure is the flagman, when one is used. Flagmen are usually positioned just beyond the treatment boundary and move upwind as the aircraft starts its run from the opposite end of the field in order to be in position for the next run. This scenario uses the flagger as the closest approximation to the PD-1 scenario.

5. If the flagman is clothed in a long-sleeved shirt, trousers, and hat instead of having all primary epidermal areas bare, the exposure will be reduced by 90 percent to give a correction factor of 0.1.

7. Moving the flagger off to the side just a little will, according to Caplan, further reduce exposure 90 percent, resulting in a further correction factor of 0.1. Akesson (1978) identified the potential deposit on a person standing anywhere from 0 to 165 feet from the treatment boundary to be less than 0.1 percent of the deposit under the plane when the spray is applied as herbicides are with D6-46-back nozzles and no whirlplate. D6-46-back or D6 angled have a drift potential of 2 percent. These data result in correction factors of 0.001 or 0.02, respectively.

8. Aerial application does not result in 8 hours nozzle time during an 8-hour working day. Flagmen in range application are exposed 1 to 10 hours/year and the typical exposure time is 3 hours/year; in forestry it is 0.1 to 0.2 hours/year; in rice it is 0.02 to 0.2 hours/year; and in ROW there is no exposure because flaggers are not used. Since these seasonal exposures could occur within the 45 day period essential for teratogenesis, they will be treated as 1 days exposure in the set of 45. The correction factor for typical range flagmen is 0.008; forestry, 0.0002; and rice, 0.0005.

We can set forth the modified assumptions as follows:

	Modified assumptions	Correction factor
1.	The exposed person is female, pregnant, in the second trimester, and weighs 60 kg.	--
2.	Finished spray: 30 lb/100 gal. (0.75)	--
3.	Rate of application is 2 lb/acre	0.5
4.	The person wears work clothes; long-sleeve shirt, buttoned up; long trousers, boots, wide brim hat, kepi.	0.1

5.	The airplane spray system uses D-6 angled nozzles with no whirlplates	(deferred)
6.	The person is a flagman to the side of the treatment (using the Caplan reduction factor)	0.1
7.	The person is exposed 3 hrs/year	0.008
8.	The dermal absorption of 2,4,5-T is 5% and for TCDD it is 10%	0.5 —
9.	The rate of dermal absorption is 1/2 that of oral exposure.	0.5

Cumulative correction factor:	2,4,5-T	TCDD
	1×10^{-5}	2×10^{-5}

The results of these two sets of assumptions are shown below. The assumptions used in the PD-1 resulted in no risk from TCDD, but the EPA concluded that there was an unreasonable risk (using the assumptions in PD-1) of a pregnant woman bearing a child with a birth defect. The assumptions in the modified scenario show exposure is much lower thus the calculated margin of safety is larger (table 28). In addition to these two sets of assumptions some simple alternatives are also shown. The Akesson drift figures are shown because the Caplan data are based on 109 µm drops, but 450-900 µm are used in herbicide applications.

THE FIFTH PRESUMPTION OF RISK - INHALATION/AERIAL APPLICATION

The following assumptions were stated or implied in the scenario describing the inhalation exposure of a person directly under a spray plane as in the previous presumption.
The set of assumptions used in the PD-1 appear to be as follows:

1. The exposed person is female, pregnant, in the first trimester, and weighs 60 kg.
2. The finished spray is 4 lb/10 gal or 40 lb/100 gal.
3. The rate of application is 4 lb/acre.
4. The person inhales 1.36 mg/day.

Table 28--Aerial application dermal exposure and margin of safety

	2,4,5-T		TCDD	
	Exposure mg/kg/day or season	Margin of safety	Exposure µg/kg/day or season	Margin of safety
No-adverse-effect-level[a]	20		0.03	
Calculated dose level PD-1[a]	0.051	392	$5x10^{-6}$	$6x10^{3}$
Modified assumptions for season	$5.1x10^{-7}$	$392x10^{5}$	$1x10^{-10}$	$3x10^{8}$
Use D6 angle (0.1 becomes 0.02)		$196x10^{7}$		$6x10^{10}$
Use D6 back (0.1 becomes 0.001)		$392x10^{8}$		$3x10^{11}$

a/ EPA (1978)

5. The lung absorption rate is 100%.

6. The plane is spraying a 109 μm VMD spray.

7. The solvent is Shell solvent No. 2 and medium diesel oil.

8. That the inhalation from a 2,4,5-T spray (450 to 900 μm VMD) would be 1/6 that from a malathion spray (109 μm VMD) and that a correction factor of 0.17 could be used.

9. The person inspires at a rate of 63.5 cubic feet per hour or 1 cu. ft/min.

10. The person is standing directly beneath the plane for 1 pass and remains there for two hours.

11. The person does this 4 times over an 8 hour period.

12. The person is so exposed daily for 45 days during the first trimester.

The assumptions which we feel need to be modified are as follows:

2. The finished spray should be 30 lb/100 gal. and has a correction factor of 0.75.

3. The rate of application is 2 lb/A and has a correction factor of 0.5. This factor cannot be used concurrently with that in assumption No. 2.

4&8. The person inhales 0.1 μg of 2,4,5-T per day. This is based on work by Akesson (1978) in which he computed that a person such as a flagger standing between 0 and 165 feet of a swath, and downwind from the swath (which is never done as the pilot cannot fly safely downwind from the last swath), would inhale 0.005 μg of pesticide per minute (a concentration 0.01 μg per ft^3) per 1.0 lb per acre of applied material when using a D-6 back nozzle, pointed with the airstream, no whirlplates, and using Nalcotrol. This is corrected to the rate of application and no use of a thickener such as Nalcotrol to 0.1 $\mu g/ft^3$ (still using a D6-back nozzle). For a D6-angled nozzle as is used in range brush control, the inhalation exposure would be corrected to 1.6 $\mu g/ft^3$. The PD-1 uses a concentration of 2.75 $\mu g/ft^3$. The corrections are 0.036 and 0.58, respectively.

6. The aircraft are using D6-back or D6-angled nozzles.

9. The inspiration rate of 1.8 m^3/hr (1 ft^3/min) is for more strenuous activity than is utilized in flagging. The appropriate rate is 0.5 ft^3/min. The correction factor is 0.5.

10. The seasonal exposure is as before: range, 3 hrs; forest, 0.1 hr; rice, 0.02 hr; and ROW, none. The correction factors are range, 0.008; forestry, 0.0002; and rice, 0.00005.

We can set forth the modified assumptions as follows:

Modified Assumptions	Correction factor
1. The exposed person is female, pregnant, in the second trimester and weighs 60 kg.	--
2. The finished spray is 30 lb/100 gal.	--
3. The rate of application is 2 lb/acre	0.50
4. The person inhales 1.6 $\mu g/ft^3$	0.58
5. The lung absorption rate is 100% for 2,4,5-T and TCDD	--
6. The plane is using a D-6 nozzle with no whirlplate aligned with the airstream (see assumption no. 4)	--
7. The person is a flagman standing 40 feet upwind of the last swath (see assumption no. 4)	--
8. The person receives 3 hrs exposure per season	0.008
9. The inspiration rate is 0.5 ft^3/min	0.5

Cumulative correction factor:	2,4,5-T	TCDD
	1.2×10^{-3}	1.2×10^{-3}

Based on these assumptions (and only under these conditions) the margins of safety we calculated from PD-1 and the modified scenarios are in table 29. The EPA concluded that the 2,4,5-T exposure level did not provide an ample margin of safety, thus it constitutes an unreasonable risk for a pregnant woman. The margin of safety calculated from the exposures we developed from the modified assumptions is much larger.

Citizens interested in applying margins of safety to their own circumstances may not be familar with the use of safety margins and be uncertain as to their usual magnitude. The example of caffein may clarify this. It has a minimum detectable effect level (MDEL) for teratogenic effects of 75 mg/kg/day (Shepard 1976). A single ounce cup of coffee per day provides a dose level of 2 mg/kg/day of caffein for a 60 kg person, or a safety margin with respect to the MDEL of 37. However, since no-averse-effect-levels are usually one-half to one-tenth of minimum detectable effect levels, the safety margin corresponding to those used in the PD-1 would be lower, probably between 4 and 18.

THE SIXTH PRESUMPTION OF RISK - ORAL, DERMAL AND INHALATION EXPOSURE

The sixth scenario is an analysis of the combined oral, dermal, and inhalation routes of exposure in three situations. According to PD-1 four presumptions of risk occur (out of a possible six - 3 of 3 for 2,4,5-T and 1 of 3 for TCDD). This cumulate exposure analysis merely repeats and cumulates the errors of the previous analyses.

One conceptual error exists in the analysis of oral exposure. The amount of 2,4,5-T entering the human diet from beef and dairy animals which had been on a 300 ppm 2,4,5-T diet for two weeks prior to taking samples was calculated. It was recognized in PD-1 that this was a very unrealistic assumption, but made the point that even under that extreme situation a presumption of risk did not arise. However, if such unrealistic values are then added to other sources of exposure which are in themselves near the acceptable safety margin, the unrealistic values function as the extra weight needed and the safety margin limits will be exceeded.

Table 29—Aerial application inhalation exposure and margin of safety

	2,4,5-T		TCDD	
	Exposure mg/kg/day or season	Margin of safety	Exposure µg/kg/day or season	Margin of safety
No-adverse-effect-level, PD-1[a/]	20		0.03	
Calculated dose level (daily), PD-1[a/]	$2.3x10^{-2}$	$8.7x10^{2}$	$2x10^{-6}$	$15x10^{3}$
Modified assumptions (seasonal)	$2.8x10^{-5}$	$7.2x10^{5}$	$2.4x10^{-9}$	$12.5x10^{6}$

a/ EPA (1978)

ESTIMATION OF EXPOSURE BY THE ABSOLUTE METHOD

The absolute method of estimating exposure uses a combination of assumptions and direct measurements. The assumptions are geared to particular applicator exposure situations as described in the section on "Exposure of Applicators According to Use Pattern" in Part 5 of Chapter 5.

These assumptions and direct measurements have been applied to exposure situations as they exist in the field. Clothing described are the kinds actually used. Estimates of skin area exposed are believed to be accurate for the types of clothing described.

The direct measurements involve data from two experiments: (1) a 2,4,5-T dermal absorption experiment involving four human volunteers in a laboratory experiment (Newton 1978) and (2) a field experiment in which 2,4,5-T deposition (and absorption) was measured during operational application by helicopter (5 individuals), tractor sprayer (5 individuals), and backpack sprayer (12 individuals) (Lavy 1978a&b).

In the first part of this section the various assumptions are used with the data from the laboratory experiment to calculate maximum absorption (exposure) levels for particular exposure situations. The absorption (exposure) levels from the field experiment are used to calculate exposure as it occurs during actual use. In the second part of this section, exposure levels from both sources are presented in narrative form for each method of 2,4,5-T application in each of the four commodity groups.

EXPOSURE CALCULATED FROM A LABORATORY EXPERIMENT

Assumption Sets

The likelihood of an applicator or observer in spray operations being exposed to a given level of 2,4,5-T depends on the physical circumstances during exposure. A series of sets of assumptions have been developed which describe the nature and extent of the exposure of applicators involved with particular types of application. Each set of assumptions closely approximates the actual conditions in which the chemical is used, based on experience of Assessment Team members and users in Oregon, Texas, Arkansas, California, Indiana, and Pennsylvania (Norris et al. 1979). Table 30 identifies the type of application (or situation) associated with each assumption set, and some of its conditions.

There are five sets of assumptions for ground spray workers and five for aerial spray workers. The various situations are those typical for backpack sprayer operators, tractor sprayer operators, tree injection personnel, aircraft mixer-loaders, and flaggers. Conditions for pilots were not described because they are protected more than the other workers. Each set embodies different assumptions relating to the concentration of spray mixture, protective clothing, skin exposed, and skin absorption. In addition there are 2 sets of assumptions from PD-1. In general, the assumptions in sets 1 through 10 are different from those used in PD-1 (EPA 1978). An explanation for the choices used follows.

Concentration of Spray Material

Concentrations of 2,4,5-T greater than 16 lb acid equivalent per hundred gallons (aehg) are seldom used in ground equipment. The higher cost for higher concentrations which do not substantially increase effectiveness precludes widespread use. None of the widely used products recommends higher than 6 aehg in water for general use; 2 to 4 aehg is more widely used. The rates of 8 to 16 aehg used here are in the upper range for oil sprays, but they are used with sufficient frequency to warrant calculations as upper limits of ordinary exposure. Higher concentrations are limited to mist blowers and aircraft.

Table 30--Typical job descriptions of workers exposed under assumption sets listed in Tables 31 and 32

Assumption set	Job description
1	Tractor mounted boom sprayer on rice levees or range and pasture lands
2	Backpack or handgun operator in right-of-way or rangeland basal spray operation, with gloves and long-sleeve shirt
3	Backpack, handgun or mistblower operator in forest or power line basal spray operation, short-sleeve shirt, no gloves
4	Same as 3, with long-sleeve shirt and gloves
5	Hypo-hatchet tree injector operator, 2,4,5-T amine, long-sleeved shirt, gloves
PD-1 a	Backpack spray operator without protection as described in PD-1
6	Helicopter mechanic-mixer, light (common) dose, gloves and long-sleeved shirt
7	Helicopter mechanic-mixer maximum concentration, wearing gloves and long-sleeved shirt
8	Flag person, 1 lb/A 2,4,5-T in 3 gpa, wearing broad-brim hat, long-sleeved shirt
	Exposure is derived as follows: flagger fails to move out of spray swath once for each 10 passes of the spray plane, or 4 times per hour. This gives an exposure of 1.042 mg 2,4,5-T.
9	Flag person, 2 lb/A 2,4,5-T in 5 gpa, wearing broad-brim hat, long-sleeved shirt.
	Exposure is as the same basis as in assumption 8, but adjusted by a factor of 2 for the higher rate of application. This gives an exposure of 2.084 mg 2,4,5-T.
10	Flag person, 2 lb/A 2,4,5-T in 5 gpa without protective clothing
	Exposure is as the same basis as in assumption 8, but adjusted by a factor of 2 for the higher rate of application and a factor of 8 for the greater degree of absorbtion due to less clothing.
PD-1 b	Flag person described in PD-1, with both dermal and inhalation exposure

Protective Clothing

Protective clothing of some kind is normally worn by all pesticide applicators. Long-sleeved shirts alone reduce exposure substantially below that of a tee shirt. Use of gloves and a long-sleeved shirt reduces skin exposure to 12.3 percent of that received when the applicator wears a short-sleeved shirt and no gloves (Wolfe et al. 1974). Addition of a wide-brim hat to long-sleeved shirt and gloves reduces exposure to 8.8 percent. Assumption sets 2, 4, and 5 for ground application and 6 and 7 for aerial application provide for long-sleeved shirts and gloves as protective clothing. This reduces exposure to 12.3 percent of the two square feet of skin surface estimated to be exposed to spray mixtures when a short-sleeved shirt and no gloves are used (assumption sets 1, 3 and PD-1a). Assumption sets 8 and 9 for flaggers involved with aerial applications include broad-brim hard hats, long-sleeved shirts, and gloves.

Dermal Absorption

In a previous section (The Factorial Method) the inappropriate use of the 10 percent 2,4,5-T absorption figure in PD-1 was discussed and a factorial correction factor developed. Unfortunately there are very limited data on which human exposure (via dermal absorption) to 2,4,5-T can be estimated. In this section we use data from a preliminary experiment involving humans as a basis for calculating 2,4,5-T absorption from dermal exposure (Newton 1978). In this experiment, four human volunteers were exposed to one of four spray solutions containing 2,4,5-T at concentrations of 2, 4, 16, or 32 aehg. The exposure involved placing a 144 square inch denim cloth soked with 40 ml of the appropriate spray mixture on the sking of one upper thigh. The cloth was covered and bound tightly in place with plastic wrap to insure good contact with the skin and to prevent drying. The skin was wet to saturation throughout the 2-hour exposure period. The assumption is this type of exposure results in maximum dermal uptake because the skin is as wet as it can be without the spray running off and the soaked cloth provides a reservoir of chemical to replace any that is removed by dermal absorption. At the end of the 2 hour exposure period, the cloth was removed and the treated area washed with alcohol and wiped dry. Urine was then collected for 5-24 hour periods. 2,4,5-T excretion beyond 5 days was estimated by extension of the excretion curves to zero (to 15 days for the 16 and 32 aehg material and to 8 days for the 2 and 4 aehg material) and integration. The assumption is that all the 2,4,5-T absorbed was excreted in this time period. A reasonable correlation was observed between the concentration of 2,4,5-T in spray mixtures kept moist on skin and the amount of 2,4,5-T appearing in the urine during five days post-treatment period, although it was not strictly proportional (table 31).

Net absorption of 2,4,5-T per hour per square foot of skin exposed was estimated from data in table 31.

Concentration of spray material aehg	2,4,5-T absorbed (dermal) (mg/sq ft/hr)
2	0.220
4	0.419
16	0.570
32	1.125

It is emphasized these are maximum possible values because the skin was saturated throughout the exposure period. In actual practice these levels will not normally be attained. The assumptions outlined above and the dermal absorption data in table 31 (Newton 1978) were used to calculate maximum applicator exposure for each of the 5 assumption sets involving ground application (table 32) and the 5 sets involving aerial application (table 33). These calculations indicate lightly clad backpack sprayer, handgun sprayer, and backpack mistblower operators will receive the greatest exposure. Addition of a hat, gloves, and long-sleeved shirt will markedly reduce exposure.

Table 31--Absorption and excretion of 2,4,5-T by humans after dermal exposure [a/]

Concentration of spray mixture[b/]	2,4,5-T recovered in urine					Estimated 2,4,5-T excretion in urine beyond the 5th day	Estimated 2,4,5-T absorbed[c/]
	Day						
	1	2	3	4	5		
lb/100 gal	----mg----					----mg----	----mg----
2	0.073	0.142	0.107	0.025	0.034	0.062	0.441
4	0.218	0.250	0.134	0.079	0.037	0.125	0.843
16	0.116	0.222	0.124	0.107	0.095	0.500	1.164
32	0.276	0.358	0.250	0.210	0.196	1.000	2.380

a/ Exposure involved 144 square inch denim patches soaked with 40 ml of 2,4,5-T spray solution of the appropriate concentration and applied to the upper thigh. The patches were covered with plastic wrap to prevent drying and were bound snugly to insure good contact with the skin. The skin was wet with the spray mixture throughout the exposure period. Patches were removed after 2 hours, the skin washed with alcohol and dried, and urine collected for 5-24 hour periods. 2,4,5-T excretion in urine beyond the 5th day was estimated by extention of the excretion curves (to 15 days for the two highest concentrations and to 8 days for the two lowest concentration) and integration. (Newton 1978).

b/ Acid equivalent per 100 gallon (aehg).

c/ Estimated 2,4,5-T absorbed is the sum of 2,4,5-T excreted in five days and estimated excretion beyond 5 days.

Table 32--Sets of assumptions for exposure of applicators using 2,4,5-T with ground equipment. Maximum levels of exposure are listed for each assumption set because they assume constant wetness of exposed skin. Dosage based on 60 kg worker except for the applicator monitored data (80 and 110 kg).

Variable	Assumption set					
	1	2	3	4	5	PD-1a
Spray concentration, aehg	4	8	16	16	400	40
Fully clothed[a/]	No	Yes	No	Yes	Yes	No
Square feet of skin exposed	2	1/4	2	1/4	1/4	2+
Dermal absorption of 2,4,5-T mg/hr	0.838[b/]	0.11[b/]	1.14[b/]	0.142[b/]	0.15[c/]	51[d/]
2,4,5-T dosage, mg/kg/hr	0.014	0.0018	0.019	0.0024	0.0025	0.85
TCDD dosage[e/] µg/kg/hr	$8.4x10^{-7}$	$1.1x10^{-7}$	$1.14x10^{-6}$	$1.4x10^{-7}$	$1.5x10^{-7}$	$2.1x10^{-5}$
Applicator monitoring mg/kg/day 2,4,5-T			0.026 (for 8 aehg)		0.0025 (for 6 aehg)	

a/ Long-sleeved shirt and gloves reduces exposure 91 percent compared to short-sleeve shirt and no gloves (Wolfe et al. 1974).

b/ Newton (1978).

c/ Norris (1974) Based on absorption salts of organic arsenicals by injector operators using 6 lb/gal concentrate, maximum concentration of 1 ppm in urine with daily 6-hour exposure. The organic arsenicals as salts are better models for 2,4,5-T amine than is the 2,4,5-T ester used by Newton (1978).

d/ Value from PD-1 (EPA 1978).

e/ Based on $3x10^{-8}$ ppm TCDD in 2,4,5-T (Alford 1978) and an absorption rate for TCDD which is twice as great as for 2,4,5-T. Thus µg TCDD absorbed = mg 2,4,5-T absorbed x (6×10^{-5}).

Table 33—Sets of assumptions for exposure of applicators using 2,4,5-T with aerial equipment. Maximum levels of exposure are listed for each assumption set because they assume constant wetness of all exposed skin. Dosage based on 60 kg workers.

Variable	Assumption set 6	7	8	9	10	PD-1b
Spray concentration aehg	10	40	10	40	40	40
Fully clothed[a/]	Yes	Yes	Yes	Yes	No	No
Square feet of skin exposed	1/4	1/4	1/4	1/4	2	2+
Inhaled 2,4,5-T, mg/hr	0	0	2.5×10^{-5}[b/]	1×10^{-4}[b/]	1×10^{-4}[b/]	0.17[c/]
Skin deposit of 2,4,5-T, mg[d/]	-	-	1.042	2.084	16.86	-
Dermal absorption of 2,4,5-T mg/hr	0.125	0.371	0.052	0.104	0.834	0.75
Total exposure to 2,4,5-T, mg/hr	0.125	0.371	0.052	0.1041	0.8341	0.92
2,4,5-T dosage mg/kg/hr	0.002	0.006	8×10^{-4}	0.002	0.014	0.0103
TCDD dosage µg/kg/hr[e/]	1.2×10^{-7}	3.7×10^{-6}	5.2×10^{-8}	1×10^{-7}	8.3×10^{-7}	6.7×10^{-6}[c/]

a/ Long-sleeved shirt and gloves for assumption sets 6 & 7 reduces skin exposure 91 percent compared to short-sleeved shirt and no gloves. A broad brim hat is added for assumption sets 8 and 9 (Wolfe et al. 1974).

b/ Assumes inhalation rate of 0.1 µg/min per acre pound applied in adjacent swath when air movement carries fine droplets into flagmen's position (based on 20 min/day exposure between 0 and 165 feet downwind from spray swath, Akesson 1978).

c/ Value from PD-1 (EPA 1978)

d/ Value from table 30.

e/ Based on 3×10^{-8} ppm TCDD in 2,4,5-T (Alford 1978) and an absorption rate for TCDD which is twice as great as for 2,4,5-T. Thus µg TCDD absorbed = mg 2,4,5-T absorbed x (6×10^{-5}).

EXPOSURE MEASURED DURING OPERATIONAL APPLICATION

Lavy (1978b) monitored the deposition of 2,4,5-T on 22 applicators engaged in the operational application of herbicide by helicopter (5 applicators), tractor-mounted boom sprayer (1 applicator), tractor-mounted mistblower (4 applicators), and backpack sprayer (12 applicators). Workers were actively involved with the application for 1.93 hours (helicopter), 1.08 hours (tractor boom sprayer), 4.08 hours (tractor mistblower), or 3.0 hours (backpack sprayer). Patches (6 - 100 cm^2 patches for each worker) were attached to the clothing on the chest, back, both biceps, and both thighs. At the end of the spray period the patches were removed and analyzed for 2,4,5-T. The assumption is that the spray deposited on the six patches was representative of the spray deposited on exposed areas of skin.

Lavy (1978a) reported urine samples were collected from these same workers but a complete report of the data is not yet available (January 15, 1979). Lavy (1978b) indicates, however, that it appears approximately 4 percent of the 2,4,5-T estimated to be on the skin was recovered in urine. Lavy's (1978b) data, recalculated to show mg/kg/hour 2,4,5-T deposited on the skin and the amount of herbicide and TCDD absorbed (exposure), are in table 34.

The levels of exposure from an actual operational application (table 34) are substantially lower than those calculated from the laboratory experiment (tables 32 and 33). When calculated to be on a directly comparable basis in terms of concentration of spray and skin area exposed, the following values were obtained from the two experiments:

Table 34--Deposition and dermal absorption (exposure) of 2,4,5-T by humans during operational application.

Application method	Worker number	Skin exposed	Deposition of 2,4,5-T[a/]		Absorption of 2,4,5-T[b/]	Absorption of TCDD[c/]
		m^2	------------mg/kg/hr		------------	µg/kg/hr
Helicopter[d/]	1	0.294	0.0046		0.0002	1.2×10^{-8}
"	2	0.294	0.0072		0.0003	1.8×10^{-8}
"	3	0.173	0.0019		0.0001	6.0×10^{-9}
"	4	0.294	0.0070		0.0003	1.8×10^{-8}
"	5	0.294	0.0095		0.0004	2.4×10^{-8}
				Average	0.0003	1.6×10^{-8}
Tractor, boom[d/]	6	0.294	0.042		0.0017	1.0×10^{-7}
Tractor, mistblower[d/]	7	0.294	0.050		0.0020	1.2×10^{-7}
" "	8	0.173	0.035		0.0014	8.4×10^{-8}
" "	9	0.294	0.012		0.0005	3.0×10^{-8}
" "	10	0.173	0.026		0.0011	6.6×10^{-8}
				Average	0.0012	7.5×10^{-8}
Backpack[e/]	11	0.294	0.054		0.0021	1.3×10^{-7}
"	12	0.294	0.373		0.0149	8.9×10^{-7}
"	13	0.294	0.281		0.0112	6.7×10^{-7}
"	14	0.294	0.299		0.0120	7.2×10^{-7}
"	15	0.294	0.615		0.0246	1.4×10^{-6}
"	16	0.294	0.676		0.0271	1.6×10^{-6}
"	17	0.294	0.123		0.0049	2.9×10^{-7}
"	18	0.294	0.027		0.0011	6.6×10^{-8}
"	19	0.294	0.107		0.0043	2.6×10^{-7}
"	20	0.294	0.202		0.0081	4.9×10^{-7}
"	21	0.294	0.197		0.0079	4.7×10^{-7}
"	22	0.294	0.749		0.0300	1.8×10^{-6}
				Average	0.0123	7.4×10^{-7}

a/ Data from table 5 (Lavy 1978b) adjusted to per hour basis.

b/ 4 percent of deposit

c/ mg/kg/hr 2,4,5-T absorbed x (6×10^{-5}), see footnote e, table 32 in chapter 5 of this report.

d/ Concentration of 2,4,5-T in spray solution: 40 aehg

e/ Concentration of 2,4,5-T in spray solution: 20 aehg

Method of application	Concentration of spray	Exposure to 2,4,5-T[a/] Laboratory Experiment[b/]	Field Experiment[c/]
	------aehg------	---------mg/kg/hr---------	
Helicopter	40	0.076	0.0003
Tractor mistblower	40	0.076	0.0012
Backpack sprayer	20	0.038	0.0123

[a/] 0.294 m^2 exposed skin (3.28 ft^2)

[b/] From tables 32 and 33

[c/] From table 34

This illustrates the maximum nature of the exposure calculated using the data from the laboratory experiment where skin was soaked throughout the exposure period. In practice this level of exposure does not occur except in rare instances where abnormally high, accidental exposure occurs. There are two cases of this type of exposure noted in tables 32 and 33.

The two spray workers who received substantial exposure to 2,4,5-T were (1) one worker sprayed Texas mesquite with 8 aehg 2,4,5-T in diesel fuel 3 out of 5 days for 8 hours each day. Clothing was coveralls without gloves. (2) One worker in Oregon sprayed blackberry bushes with 6 aehg 2,4,5-T in water. The sprayer hose broke and soaked the trousers and leather boots. The trousers and boots were worn for 4 hours before washing up (Newton 1978).

The Texas worker did not use gloves and his hands came in contact with the solution and the concentrate. The 80 kg Texas applicator equilibrated at the level of 2.12 mg total absorption per 6 hour day, for a dosage of 0.026 mg/kg/day. This is half the predicted dosage encountered with one-hour exposure under assumption set 3, table 32, which most closely resembles his situation in the field but is based on 16 aehg spray mixture. This emphasizes the "maximum nature" of the estimates in tables 32 and 33 which were derived from data in table 31.

The Oregon applicator data in table 32 indicated an uptake of between 3 and 4 mg 2,4,5-T from an exposure surface of 2 sq ft over a 4-hour period (0.037-0.50 mg/sq ft/hr). Assuming partial drying and soaked skin for 2 hours, this exposure is estimated to be the equivalent of 2 square feet for 2 hours (0.075 mg/sq ft/hr). This is slightly higher than the rates shown for either the 4 or 16 aehg data in table 32. In addition to the spill, however, the Oregon applicator reported a 3-hour exposure the same day in which a leaky valve kept his spray-wand hand wet constantly. Under the circumstances, this observation was clearly an extreme example under assumption set 3, table 32, corrected to 6 aehg. Both the above observations suggest that the data in tables 32 and 33 give maximum estimates of exposure under the described conditions.

It is unfortunate there is not a more adequate data base currently available on dermal absorption of 2,4,5-T by applicators. Lavy (1978a) indicates data on 2,4,5-T and its relation to deposition on applicators will be available for inspection by March 1, 1979. There is another study of applicator exposure to 2,4,5-T that is being planned by the Cook College Agricultural Experiment Statment, Rutgers University, New Jersey. The study will be completely by June 1, 1980 (Norris et al. 1979).

EXPOSURE LEVELS IN THE FIELD

Personnel applying 2,4,5-T in the field are usually operating under conditions reasonably close to one of the assumption sets - job descriptions in table 30. The exposures for each type of application listed below were estimated for the first hour of operation from tables 32, 33, and 34.

The following discussion of exposure opportunities in the various commodity uses has been presented to show the level of exposure and area treated for each worker hour. These may be expanded according to the number of hours per day actual operator time. Generally 2 values are given; one is the normal operational level as predicted by the data in table 34 and the other is the maximum exposure expected under unusual circumstances based on data in tables 32 and 33. In all cases the data have been adjusted to a common base of 0.294 m^2 of skin exposed to spray unless otherwise stated.

The data are summarized in table 35 for each exposure situation. Generally four different exposure values are shown: (1) the operational exposure based on Lavy (1978b) with an exposed skin area of 0.294 m^2 (short-sleeved shirt), (2) reduced operational exposure based on Lavy (1978b) but with long-sleeved shirt and gloves added which reduces exposure 91 percent (Wolfe et al. 1974), (3) maximum exposure based on Newton (1978) with an exposed skin area of 0.294 m^2 (short-sleeve shirt), and (4) reduced maximum exposure based on Newton (1978) but with long-sleeved shirt and gloves added which reduces exposure 91 percent (Wolfe et al. 1974).

Exposures to TCDD are not included in this section but can be calculated as in tables 32, 33, and 34, assuming that TCDD is 3 x 10^{-8} ppm in 2,4,5-T (Alford 1978), and that it is absorbed twice as efficiently as 2,4,5-T. Thus the μg TCDD absorbed is equal to the mg 2,4,5-T absorbed x ($6x10^{-5}$).

Forest

The following descriptions and calculations of net exposure are for the specific types of 2,4,5-T application described in an earlier section "Exposure of applicators according to use patterns - forests" in this chapter.

Aerial Application

Based on Lavy's (1978b) data (table 34) aerial applicators may be exposed to 0.0003 mg/kg/hr 2,4,5-T under operational conditions. The mechanic-mixer is the person in an aerial spray operation likely to receive the largest exposure. This worker may receive maximum exposure up to 0.076 mg/kg/hr for each 60 acres treated (assumption set 7, table 33).[1/] Adding gloves and a long-sleeved shirt, the exposure would be reduced to 0.007 mg/kg/hr even for a worst case of exposure based on data of Wolfe et al. (1974) (table 35).

Ground Application with Tractor Mistblowers - Broadcast Treatment

Lavy (1978b) (table 34) reports tractor mistblower operators may be exposed to 0.0012 mg/kg/hr 2,4,5-T under operational conditions. A comparable assumption set for the worst case of exposure was not developed, but is likely to be similar to that for the backpack sprayer (table 35).

Ground Application with Backpack Mistblowers - Broadcast Treatment; and Backpack Sprayers and Tree Injectors - Individual Stem Treatment

No operational exposure data are available for workers using backpack mistblowers. The similarity to backpack sprayers suggests the use of those data. Lavy (1978b) (table 34) reports exposure for this group is 0.0123 mg/kg/hr 2,4,5-T under operational conditions. Worst case exposure is illustrated from assumption set 3, table 32. Performance rate of one acre per hour per applicator would lead to an exposure of 0.030 mg/kg/hr. If long-sleeved shirts and gloves are used (assumption set 4) exposure is reduced to 0.003 mg/kg/hr in covering one acre. Workers using injectors are described in assumption set 5, table 32. Based on one-half acre treated per hour, a worker receives a maximum dose of 0.032 mg/kg/hr (table 35).

1/ Sample calculation: 0.006 mg/kg/hg (assumption set 7, table 33) x 12.67 (to adjust exposed area from 0.25 square feet to 0.294 m^2) = 0.76 mg/kg/hr. The exposed area correction factor is 1.58 to adjust from 2 square feet to 0.294 m^2. Adding long-sleeved shirt and gloves reduces exposure 91 percent or 0.076 mg/kg/hr x 0.09 = 0.007 mg/kg/hr.

Table 35—Summary of hourly exposure to 2,4,5-T estimated by absolute method

Exposure situation	Area treated per hour	Time exposed per day	Operational exposure[a/]	Reduced operational exposure[b/]	Maximum exposure[c/]	Reduced maximum exposure[d/]
	acres	hours	mg/kg/hr			
Timber						
Aerial	60	4	0.0003	0.00003	0.076	0.007
Backpack	1	4	0.0123	0.0011	0.030	0.003
Injection	0.5	4	—	—	0.032	0.003
Tractor mist blower	6.5	4	0.0012	0.0001	0.030	0.003
Backpack mist blower	1	4	0.0123	0.0011	0.030	0.003
Range and pasture						
Aerial						
mechanic	100-300	4	0.0004	0.00004	0.095	0.009
flagger (2)	100-300	4	—	—	0.034[a/]	0.003[c/]
Backpack	1	6	0.0049	0.0004	0.016	0.001
Tractor Boom spray	20	4	0.0028	0.0003	0.007	0.0006
Rights of way						
Aerial-mixer	20	6	0.0003	0.00003	0.076	0.007
Backpack and handgun	0.25-1.25	6	0.0123	0.0011	0.030	0.003
Truck-mount	1-10	6	0.00003	0.000003	0.011	0.001
Backpack mistblower	0.25-1.25	6	0.0123	0.0011	0.037	0.003
Rice						
Aerial						
mixer-loader	80	1	0.0002	0.00002	0.063	0.006
flag person (2)	80	1	—	—	0.034[a/]	0.003[b/]
Tractor boom sprayer	5	1.3	0.0026	0.0002	0.007	0.006

a/ Calculated from Lavy (1978b) with 0.294 m^2 exposed skin area (short-sleeved shirt).

b/ Calculated from Newton (1978) adjusted to 0.294 m^2 exposed skin area.

c/ Calculated from Lavy (1978b). Long-sleeved shirt and gloves reduces exposure 91 percent (Wolfe et al. 1974).

d/ Calculated from Newton (1978). Long-sleeved shirt and gloves reduces exposure 91 percent (Wolfe et al. 1974).

Range and Pasture

The following descriptions and calculations of net exposure are for the specific types of 2,4,5-T applications described in an earlier section "Exposure of applicators according to use pattern - range brush and pasture weed control" in this chapter.

Aerial Application

Principal exposure is likely to involve the mechanic-loader. Lavy's (1978b) data (table 34) indicate exposure of 0.0003 mg/kg/hr 2,4,5-T for 40 aehg material; adjusted proportionally, this is equal to 0.0002 mg/kg/hr or 0.0004 mg/kg/hr for 25 and 50 aehg material respectively. The maximum exposure is derived from assumption set 7, table 33. The mechanic-mixer would be exposed at the rate of 0.095 mg/kg/hr (for 50 aehg) while accomplishing 100-300 acres of treatment. Adding a long-sleeved shirt and gloves reduces exposure to 0.009 mg/kg/hr. Flaggers involved with 2 lb/A applications (the maximum rate) would be exposed according to assumptions set 9, tables 30 and 33. Their exposures would be very brief and very minor. Flaggers would be exposed to 0.002 mg/kg/hr from inhalation and dermal sources for 100-300 acres maximum. Exposure would be less for flaggers working into the wind according to normal procedure. This exposure would occur once a year or less often (table 35). To estimate maximum exposure, Lavy (1978b) measured deposition on a human standing directly under a helicopter spray path. This would approximate the rare case when a flagger would fail to move and was directly sprayed. Data are available for only one individual. These shows deposition of 0.86 mg/kg 2,4,5-T on 0.294 m^2 exposed skin. Assuming 4 percent absorption, this equals an exposure of 0.034 mg/kg each time sprayed when dressed in a short-sleeved shirt. Adding a long-sleeved shirt and gloves reduces exposure to 0.003 mg/kg.

Ground Application - Backpack Sprayer

Lavy's (1978b) data (table 34) for backpack sprayers indicate an exposure of 0.0123 mg/kg/hr for 20 aehg material; adjusted proportionally to 8 aehg, this exposure is 0.0049 mg/kg/hr 2,4,5-T. Evaluation of maximum exposure uses assumption sets 2 and 3, table 32. For crews with short-sleeved shirts and no gloves, an 8 aehg treatment (assumption set 3, X 0.5 to correct for concentration) will produce a maximum exposure of 0.016 mg/kg/hr. If a long-sleeved shirt and gloves are worn (assumption set 2, x0.5 to correct for concentration) the exposure would be 0.001 mg/kg/hr to cover 1/4 to 1 acre (table 35). Basal spray treatments would produce twice this level, and pasture treatments half to three-fourths this level of dosage as adjusted for concentration used.

Ground Application - High Mounted Booms on Tractors

Lavy's (1978b) data (table 34) show an operational exposure (based on a single observation) of 0.017 mg/kg/hr 2,4,5-T for 40 aehg material. Adjusted proportionally for concentration, this is 0.0028 mg/kg/hr for 6.7 aehg material. Maximum exposure is derived from assumption set 1, table 32, for the tractor driver. The exposure would be adjusted according to the concentration used by a factor of 6.7/4. Thus, for a driver using 6.7 aehg spray at the rate of 20 acres per hour, exposure would be 0.037 mg/kg/hr. This assumes the driver is constantly wet with spray. Because the driver sits ahead of the boom, we multiply by 0.2 to allow for intermittent exposure. This gives an exposure of 0.007 mg/kg/hr. Adding a long-sleeved shirt and gloves reduces exposure to 0.0006 mg/kg/hr (table 35).

Rights-of-Way

The following descriptions and calculations of net exposure are for the specific types of 2,4,5-T applications described in an earlier section. "Exposure of applicators according to use pattern - Rights-of-way" in this chapter.

Aerial-Broadcast Foliar

Lavy's (1978b) data (table 34) indicate an operational exposure of 0.0003 mg/kg/hr 2,4,5-T. Maximum exposure is derived from assumption set 7, table 33. It shows the mixer-loader will be exposed to 0.076 mg/kg/hr for 20 acres of application. If a long-sleeved shirt and gloves are worn, maximum exposure decreases to 0.007 mg/kg/hr (table 35).

Ground Application - Selective Basal and Cut Stump Application

Lavy's (1978b) data (table 34) show operational exposure for backpack sprayers of 0.0123 mg/kg/hr 2,4,5-T. Worst case exposure is derived from assumption set 3, table 32. It indicates an exposure of 0.030 mg/kg/hr. If long-sleeved shirt and gloves are used, exposure is decreased to 0.0034 mg/kg/hr (table 35).

Ground Application - Broadcast Foliar (Spray Boom or Nozzles Mounted on Vehicle) and Selective Foliar (Hydraulic Sprayers with Hoses and Handguns)

Lavy's (1978b) data (table 34) for backpack sprayers are a reasonable approximation for these types of application if adjusted for concentration. Spray solutions of 4 aehg should result in exposure of 0.00003 mg/kg/hr 2,4,5-T. Maximum exposure is estimated according to assumption set 2, table 33. When adjusted to reflect the 4 aehg solution (correction factor 0.5), the net exposure is 0.011 mg/kg/hr. Addition of a long-sleeved shirt and gloves reduces maximum exposure to 0.001 mg/kg/hr (table 35).

Motorized backpack mistblower operators using 20 aehg mixtures would be exposed to 0.0123 mg/kg/hr 2,4,5-T based on Lavy's (1978b) data (table 34). In a worst case exposure, assumption set 3, table 32, (with a 25 percent upward ajustment for concentration) indicates an exposure of 0.0375 mg/kg/hr. If the operator wore a long-sleeved shirt and gloves, the exposure would decrease to 0.003 mg/kg/hour (table 35). Occasionally mistblowers are used with 80 aehg mixtures. Although this is beyond the data of Newton (1978) the trend of the data suggests the relation:

mg absorbed = 0.2 + 0.029 (concentration, aehg).

Following this relation, an 80 aehg mixture applied by mistblower as in assumption set 3, table 32, would result in a maximum applicator exposure of 0.132 mg/kg/hr, reduced to 0.012 mg/kg/hr if a long-sleeved shirt and gloves are worn.

Rice

The following descriptions and calculations of net exposure are for the specific types of 2,4,5-T applications described in an earlier section "Exposure of applicators according to use pattern - rice" in this chapter.

Aerial Application

Lavy's (1978b) data (table 34) indicate an exposure of 0.0002 mg/kg/hr 2,4,5-T adjusted for the 33 aehg mixture used on rice. The worst case example is derived from assumption set 7, table 33 and indicates an exposure of 0.063 mg/kg/hr. Addition of a long-sleeved shirt and gloves reduces maximum exposure to 0.006 mg/kg/hr (table 35).

Flaggers would be exposed according to assumption set 8, table 33. Their exposure would be brief and minor, and limited to their own farms. Flaggers would be exposed, as in range treatment, to minor inhalation and occasional "tails" from adjacent swaths. Net exposure would be 0.0008 mg/kg/hr for 80 acres (table 35).

Ground Application

Lavy's (1978b) data (table 34) indicate the tractor boom sprayer operator would be exposed to 0.017 mg/kg/hr for 40 aehg material, or 0.0026 mg/kg/hr for 6 aehg material used on rice. The worst case exposure is derived from assumption set 1, table 32. It indicates an exposure of 0.033 mg/kg/hr while covering 5 acres. This operator is exposed intermittently and the exposure should be adjusted by a factor of 0.2 to give 0.007 mg/kg/hr. Adding a long-sleeved shirt and gloves reduces exposure to 0.0006 mg/kg/hr (table 35).

RISKS OF ALTERNATIVE METHODS, SOME CONSIDERATIONS

The chemical alternatives to 2,4,5-T expose operators to potential intoxication in similar ways. An assessment of relative risk must take these into account. Chemical alternatives to 2,4,5-T will generally produce similar absorption patterns. The biochemical and toxicological properties of these materials are generally less well known, hence relative risks cannot be estimated as accurately as for 2,4,5-T.

Nonchemical alternatives also expose operators to chemical intoxication as well as physical accidents which are discussed later in this chapter. Exposure to chemical intoxicants occurs in both fires and in use of power saws. Recent data from Dow Chemical Company (DOW 1978a,b) suggest that both are significant sources of numerous dioxins, including TCDD. Fire produces numerous carcinogens as products of pyrolysis, as well as carbon monoxide and various organic volatiles of substantial acute and chronic toxicity. Chain saws produce hearing loss as well as potential chronic intoxication from hydrocarbons and lead. Peripheral nerve damage has recently been reported in Oregon and Washington loggers using chain saws in cold, wet weather.

Chain saws produce particularly noxious exhaust during brush clearing. Ordinary exhaust contains carbon monoxide and lead. Lead causes symptoms nearly identical to those described for 2,4,5-T chronic intoxication (EPA 1978). In addition, the two-cycle motors emit large amounts of unburned hydrocarbons and adjuvants in partially combusted oil smoke. Chain saw combustion products are particularly noxious during brush-clearing operations. Woody plant clearing is normally done in some protection from wind, leading to a tendency for exhaust fumes to build up near the operator. There is also a high percentage of idling and no-load time for the saws. This leads to inefficient oxidation of fuel and oil and excessive emissions. Intoxication from carbon monoxide and smoke inhalation is so common that most cases are not recorded. One member of the 2,4,5-T Assessment Team (Newton) with substantial experience operating a brush saw reported being mildly poisoned on several occasions (Norris et al. 1979).

On balance, control of woody vegetation with any of the acceptable practices entails some exposure to chemicals of known carcinogenic and teratogenic potential. The data for all the alternatives are far less precise than for 2,4,5-T, and no estimates of absolute exposure are possible except for other phenoxy herbicides. Smoke from fires and chain saws at this time would appear to offer the greatest potential for acute and chronic intoxication of any of the alternatives, including 2,4,5-T. The degree of intoxication, and its long term implications must remain speculative until these sources have undergone comparable examination.

PART 6: CONSEQUENCES OF EXPOSURE OF ANIMALS

This section reviews some acute and subacute toxicity data for 2,4,5-T in animals important to agriculture and some species of wildlife.

LIVESTOCK

Research data indicated that cattle were not affected when dosed (oral) 10 times at 100, 50 and 50 mg/kg with the propylene glycol butyl ether esters (Palmer and Radeleff 1969), the 2-ethylhexyl ester, and the triethylamine salt of 2,4,5-T, respectively (Palmer 1972). However, after 4 to 7 days, treatments of all three formulations at 250 mg/kg were lethal. At 100 mg/kg the 2-ethylhexyl ester and the triethylamine salt either had no effect or caused some weight loss.

Sheep tolerated 10 daily oral dose of 50, 25, and 25 mg/kg of the propylene glycol butyl ether esters (Palmer and Radeleff 1969), the 2-ethylhexyl ester and the triethylamine salt of 2,4,5-T, respectively (Palmer 1972). Higher dosages of each herbicide caused effects that ranged from minimal to lethal. The investigators (Palmer and Radeleff 1969, Palmer 1972) concluded from their studies that application rates of 2,4,5-T up to 5 kg/ha would not be hazardous for cattle, sheep or chickens.

Palmer and Radeleff (1969), and Palmer (1972) interpreted their data as follows: To relate the toxic dosages found for cattle, sheep, and chickens to the application rates recommended for each herbicide, the probable amounts that could be consumed daily from recently sprayed fields or pastures were calculated. In these calculations, neither the influence of environmental factors nor the decomposition rates of the herbicides were considered.

An arbitrary, although realistic, yield of 45 g of air-dry forage per 0.3 m of area was selected, which is the equivalent to approximately 4,480 kg/ha. This quantity would represent a high-quality, improved pasture (with adjustment for local conditions). A sparse cover of vegetation would allow more of the herbicide to reach the ground and be unavailable to animals, whereas a more lush cover would tend to hold more of the material available. In the latter case, however, less of the forage of the area would be consumed in any one day.

Further assumptions were: (1) that an animal would consume, as forage, three percent of its body weight each day, and (2) that all the chemical formulation applied would adhere to the vegetation. Although the latter is never actually the case, this assumption gives the maximum possible exposure.

An application of 454 g of chemical to 1 ha of land provides 11.6 mg for each square foot. We may simplify the whole calculation to a single statement that 1.12 kg/ha of herbicide provides a 7 mg/kg dosage to the animal under the conditions of their experiments.

In actual field experiments horses, cattle, sheep, pigs, and chickens were grazed on pastures immediately after spraying with 2,4-D and 2,4,5-T at two to four times the normal rate.

Grigsby and Farwell (1950) concluded that the use of these materials for pasture weed control was a reasonably safe procedure. The only detrimental effect was damage to legume forage plants. Goldstein and Long (1958) actually observed livestock (cattle, sheep, swine) grazing pastures sprayed with four times the recommended concentration of 2,4-D and 2,4,5-T. No harmful effects were noted.

POULTRY

Rowe and Hymas, (1954) indicated that the average LD_{50} for Hampshire Red chicks for the acid, isopropyl ester, and mixed butyl ester of 2,4-D was 541, 1,420 and 2,000 mg/kg, respectively. The LD_{50} for 2,4,5-T acid and the mixed butyl esters of silvex was 310 and 1,190 mg/kg. Chicks were considered more tolerant of 2,4-D than dogs and other animals.

Andersson et al. (1962) estimated contamination of animals drinking water from recommended treatments of 2,4-D, 2,4,5-T, dalapon, and amitrole could possible reach an upper concentration of 10 ppm. Data by Bovey et al. (1974) support this conclusion for 2,4,5-T and picloram. Andersson et al. (1962) found no harmful effect of 100 ppm of the herbicides in drinking water or in feed up to 510 ppm fed for 8 weeks to chicks, and concluded the contamination of water sources by these herbicides, under normal use, does not consititute a hazard to livestock.

The triethylamine salt of 2,4,5-T appeared more toxic to chickens than the propylene glycol butyl ether ester or 2-ethylhexyl ester (Palmer 1972). However, chickens were not affected when exposed to 100 mg/kg/day for 10 days of the ester formulations of 2,4,5-T or when 25 mg/kg of the triethylamine salt was used. Chickens also tolerated 50 mg/kg/day for 10 days without apparent effect when exposed to the propylene glycol butyl ether esters of silvex. At high dosages (500 mg/kg) most formulations of 2,4,5-T or silvex caused death of some birds.

Silvex amd 2,4,5-T were no more toxic than 2,4-D or MCPA. Palmer and Radeleff (1969) and Palmer (1972) concluded none of the phenoxy herbicides studied constituted a hazard to chickens when applied at recommended agricultural rates.

Erne and Björklund (1970) studied the nature of the renal change induced by 2,4-D or 2,4,5-T in poultry. Groups of day-old broiler chicks were fed 2,4-D or 2,4,5-T at 1,000 ppm in drinking water for up to 7 months. In another experiment, 2,4-D and 2,4,5-T were fed to 8-week-old broiler chickens. Some birds died at these high levels of herbicide and reduced mobility and decreased food and water intake were observed. In dead and killed animals, kidney enlargement was the predominant finding. It was appreciable after 14 days of exposure to 2,4-D or 2,4,5-T, increasing with exposure time. Histologically the kidney enlargement proved to be due to hypertrophy of the proximal tubular epithelium. Electron microscopy showed increased numbers of mitochondria in the tubular cells, with variations in mitochondria size, shape, and structure (Björklund and Erne 1971). The number of micro-bodies in the cytoplasm was increased and intranuclear bodies were observed. This information provides a better understanding of the mode-of-action of agricultural chemicals in animals, but such excessive doses will not be encountered in nature.

Whitehead and Pettigrew, (1972) found in subacute toxicity studies that chicks were able to tolerate large dietary doses of 2,4-D and 2,4,5-T for short periods. The only adverse affects were reductions in food consumption and growth rate. Chicks were able to tolerate 5,000 mg/kg of either 2,4-D or 2,4,5-T for up to 1 week, and resumed a normal growth rate when returned to uncontaminated food. The birds rejected contaminated (herbicide-treated) food when given a choice and grew at a normal rate.

Roberts and Rogers (1957) placed male turkeys, averaging about 6.8 kg each, in pens of alfalfa and bluegrass immediately after and three days after spraying the vegetation with a low-volatile ester of 2,4,5-T at 1.6 lb/A. The turkeys consumed most of the treated vegetation after three or four days and no harmful effect resulted when compared to birds in the control pen. In another experiment, birds received a ration containing the equivalent of 80 mg/kg of 2,4,5-T acid per day for 11 days. Weight of gain and feed consumption of the turkeys was not affected.

Foster (1974) recently reviewed over 230 scientific articles on the physiological and biological effects of pesticide residues in poultry. Foster found that lethal doses for most pesticides, including the phenoxy herbicides, are quite high and are not likely to be found except as a result of an accident. Residues of pesticides in eggs and meat rarely occurred under good management practices.

WILDLIFE

George (1963) summarized the various toxicities of commonly used pesticides in comparison to DDT. With DDT equal to 1, toxicity for 2,4,5-T and derivatives compared to DDT were 0.4, 0.2, 0.1, 0.2, and 0.1 for rats, bobwhite, pheasants, mallards, and bluegills, respectively. Data used to determine relative toxicities were based on amounts necessary to kill 50 percent of the test animals (LD_{50}) of acute toxicity for rats; chronic toxicity (10 to 100 days) for birds; and 96-hour tests for fish. Research currently in progress by the USDA Forest Service, Pacific Northwest Forest and Range Experiment Station and the USDI Fish and Wildlife Service indicates blacktail deer show no feeding preference either for sprayed or unsprayed forest vegetation in browse for food. This research will be completed in June 1979.

Somers et al. (1974) found no adverse effects of aqueous solutions of 2,4-D:picloram and 2,4-D:2,4,5-T mixtures when applied to fertile pheasant eggs preceding incubation at 10 times the normal field rate. No treatments caused any adverse effects on hatching success, incidence of malformed embryos, or subsequent chick mortality.

Recent work in Finland consisted of spraying pheasants with emulsions of 2,4,5-T or placing pheasants in enclosures sprayed with 2,4,5-T (Helminen and Raites 1969). No visible health effects were observed. No case of herbicide poisoning among wildlife species has been diagnosed in Finland. Herbicides may influence local game densities, however, by changing the density and composition of the vegetation.

AQUATICS

Pimentel (1971) prepared an extensive report of the effect of various agricultural chemicals on nontarget plants and animals. After review of available research, he concluded that various 2,4-D, 2,4,5-T and silvex formulations varied greatly in their toxicity to fish with the ester formulations being most toxic. Results vary between the same and different species of fish and also between investigators due to different conditions of the experiments. Fish tolerated high levels of the acid and salt formulations of 2,4-D, 2,4,5-T and silvex for long periods of time, but are more sensitive to the ester formulations, particularly the butyl ester of 2,4-D (<1 ppm). Earlier, it was indicated that the concentrations of 2,4-D or 2,4,5-T seldom exceeded 0.01 ppm in streams adjacent to forest spray operations in Oregon. The no-effect level for most fish is well above the 0.01 ppm concentration found in some water sources, even soon after application.

The concentration which is lethal to 50 percent of the test species (LC_{50}) or median tolerance limit (TLm) varies with formulation and species of fish. For example, after 48 hours exposure, the LC_{50} for bluegill for the dimethylamine salt, isooctyl ester, propylene glycol butyl ether ester, butoxyethanol ester of 2,4,5-T was 144, 31, 17, and 1.4 ppm, respectively (Hughes and Davis 1963).

As indicated by Hughes and Davis (1963), ester formulations are more toxic to fish than the acid or salts, probably due to more effective penetration. The same ester formulations from different sources (manufacturers) also vary in toxicity. Granular formulations of esters of 2,4-D, 2,4,5-T, and silvex were less toxic than liquid formulations (Hughes and Davis 1962). No-effect levels for 2,4,5-T have been established for some fish (table 36).

More recently, Kenaga (1974) reviewed the literature on the toxicity of 2,4,5-T to fish, shrimp, oysters, aquatic invertebrates, and marine and freshwater algae. Except for certain esters, 2,4,5-T is relatively low in toxicity to these organisms. Esters of 2,4,5-T, except in highly acidic waters, are usually hydrolyzed within a few days. Fish also hydrolyze the esters of 2,4,5-T. For these reasons, the more toxic esters of 2,4,5-T should not pose prolonged hazards to aquatic animals and algae under normal use conditions. Documented cases of fish mortality from operational uses of 2,4,5-T consistent with current registrations are not known.

Table 36--No effect levels of 2,4,5-T to fish

Formulation	Species	Exposure	Concentration	Source
Acid	Juvenile white mullet	48 hours	50 ppm	Butler, 1963
Isooctyl ester (liquid)	Bluegill	12 days	1 ppm	Hiltibran 1967
Isooctyl ester (granular)	Bluegill	12 days	10 ppm	Hiltibran 1967
Sodium salt	Bluegill	12 days	50 ppm	Hiltibran 1967

INSECTS

Moffet et al. (1972) found that various formulations (amine salts and esters) of 2,4-D, 2,4,5-T, silvex, and picloram were nontoxic to caged honey bees when the herbicide was applied in water carrier. Diesel oil alone showed considerable toxicity the first day after spraying. Diesel oil-water and diesel oil-water-DMSO combination carriers were less toxic than straight diesel oil, but more toxic than water alone. The authors concluded the phenoxy herbicides have relatively low toxicity to honeybees. Oil carriers are more toxic.

Morton et al. (1972) and Morton and Moffett (1972) fed herbicides to newly emerged worker honeybees in 60 percent sucrose syrup at concentrations of 0, 10, 100, and 1,000 ppm. At 1,000 ppm, ester and salt formulations of 2,4-D, 2,4,5-T, silvex, and 2,4-DB severely reduced or eliminated brood production. There was less effect at 100 ppm. At 10 ppm the phenoxy herbicides caused no adverse effect on brood development. The adverse effects of the phenoxy herbicides were temporary since once the herbicide was removed, normal brood development was resumed.

In other studies, Morton et al. (1974) placed apiaries where the bees' only source of water contained either paraquat or 2,4,5-T (triethylamine salt) at 1,000 ppm. When colonies were exposed to 2,4,5-T, large numbers of bees drowned because of the lower surface tension of the water. Production of the brood was reduced below that of check colonies during the period the treated water was used and for 3 months thereafter; however, in the subsequent 9 months, production returned to normal. Concentrations of 2,4,5-T in bees using water containing 2,4,5-T were as high as 149 ppm, but dropped to about 5 ppm as soon as bees used untreated water. Honey contained 2,4,5-T as high as 50 ppm, but dropped to 5 ppm within 1 week after bees began using untreated water. Trace amounts of 2,4,5-T could be detected in bees and honey after more than a year from time of exposure. The occurrence of 2,4,5-T phenoxy herbicide at this high dosage (1,000 ppm) after normal use is very unlikely.

Way (1969) indicated the hazard to bees and possibly other nectar feeding insects from applications of phenoxy herbicides was also a hazard to plants in flower (apparently from toxicity of the nectar or loss of nectar from herbicide treatment). Otherwise, there appears to be little hazard to insects from direct toxicity of the compound at normal agricultural rates of application.

PART 7: ECOLOGICAL EFFECTS

The principal thrust of most concerns about the use of 2,4,5-T has centered on direct toxic effects on animals. The previous sections in this chapter have reviewed some data in this perspective. Recognizing, however, that 2,4,5-T is most highly active biologically on plants, it is more likely that this chemical will have its greatest effect through modification of plant communities of all types. This section gives only a brief overview of this subject. Some additional discussions are also in Chapters 1, 2, 3, and 4.

SOIL ENVIRONMENT (MICROBES)

As early as 1947 (Newman 1947), it was recognized from research by several investigators that the disappearance of 2,4-D and 2,4,5-T from soil was due largely to microbial action. Certain groups of soil microorganisms, as determined by carbon dioxide evolution, nitrification plate counts, and growth of fungi were injured more readily than others. However, the workers concluded the quantity of phenoxy herbicides reaching the soil from weed control would probably not have a serious effect on most soil microorganisms.

Initial 2,4,5-T residues commonly found in soil from normal application practices are far below levels causing inhibition of soil microbes. Studies showing massive rates of 2,4-D and 2,4,5-T stimulate growth of certain microbes and suggest the herbicides are used as a carbon source.

There are some microorganisms that are susceptible to phenoxy herbicides (2,4-D and 2,4,5-T) at concentrations of about 50 ppm (100 lb/A in top 6" of soil) (Bollen 1961). However, most microorganisms are resistant to high concentrations. Shennan and Fletcher (1965) subjected 38 species of soil bacteria, fungi, and actinomycetes to 2,4-D and 2,4,5-T at concentrations up to 10,000 ppm; twenty-four organisms required 10,000 ppm 2,4,5-T for growth restriction to occur. Stojanovic et al. (1972) added a mixture of 2,4-D and 2,4,5-T to soil at a concentration of 5,000 ppm. The bacteria and actinomycetes were inhibited but the total number of fungi increased during a 56-day incubation period.

Fletcher (1956) investigated the effect of the sodium salts of 2,4-D, MCPA, 2,4,5-T, 2,4-DB, and MCPB on the growth of Rhizobium trifolii. Since growth was not affected at concentrations of 25 ppm by any phenoxy studied, it was assumed that concentrations used in agriculture of 1 lb/A (2 to 2.5 ppm) in soil would have no adverse effect on growth of Rhizobium trifolii, a nodule-forming organism of clover.

Large doses (25-250 ppm) of 2,4-D, 2,4,5-T, and silvex were required to cause inhibition of growth and inhibition of oxygen evolution by 50 percent (EC_{50}) in four species of unicellular algae (Walsh 1972). Silvex was more inhibitory to growth than 2,4-D or 2,4,5-T. The acid formulation of 2,4-D was more inhibitory than the butoxyethanol ester of 2,4-D.

Poorman (1973) indicated 50 and 100 ppm of 2,4-D and 2,4,5-T, respectively, was required to inhibit growth of Euglena gracilis cultures. Cells were morphologically altered by the herbicides, but recovered rapidly and completely when transferred to an herbicide-free medium. 2,4-D stimulated growth of the soil amoeba Acanthamoeba castellanii at 0.1 to 1 ppm, but stimulation was less pronounced at 10 to 100 ppm (Prescott and Olson 1974). The investigators indicated Acanthamoeba may be able to degrade 2,4-D and use it as an energy source.

Under field conditions, some workers have found that phenoxy herbicides have little or no effect on microbial populations (McCurdy and Molberg 1974, Chulakov and Zharasov 1973), while others have shown both depression and stimulation of numbers and growth of some soil organisms (Audus 1964).

Microbial studies by Stark et al. (1975) have shown that the application of 2,4-D and 2,4,5-T at massive rates (5,000-40,000 ppm) did not sterilize the soil, but stimulated the growth of certain microflora. These bacteria, actinomycetes, and fungi proliferated to such an extent that they are probably using the herbicide and TCDD as carbon source which contributes to their degradation.

Spraying big sagebrush with 2,4-D reduced the rate of soil moisture withdrawal (Tubler 1968). About 75 percent of the difference in total moisture depletion occured within the 3 to 5 foot soil depth. The opposite effect occurred in the 1-2 foot depth indicating an increase in grass herbage production. Total evapotranspiration losses from the 0 to 5 foot soil profile were reduced about 14 percent over the 4-month growing period the second year after spraying. Similar data would be obtained with 2,4,5-T on sagebrush and many other brush species.

Herbicide-induced changes in the composition and density of higher plant communities will alter moisture, nutrient, and carbon levels, cycles and relationships in the soil. These effects will cause changes in the density and composition of microfoil populations.

AQUATIC ENVIRONMENT

Young et al. (1975) studied the effect of massive doses of 2,4-D and 2,4,5-T sprayed from 1962 through 1970 on an aquatic environment (Test Area C-52A) at Eglin Air Force Base, Florida. The aquatic area was immediately adjacent to the sprayed area and was drained by five streams. A total of 22 species of fish was collected from 1969 to 1974. The results indicated no significant change had occurred in the ichthyofauna of either the test or the control streams during this period.

As part of a National Academy of Sciences program to assess the effects of defoliants on the plant and animal life of Vietnam, mollusks, which are extemely diverse and sensitive to environmental change, were surveyed in the Rung Sat Special Zone where defoliation by agents Orange (n-butyl ester of 2,4-D + 2,4,5-T, 1:1) and White (2,4-D + picloram, 4:1) had turned mangrove forest into barren mud flats (Davis 1973). More than 40 species of living mollusks were found between this area and the control Vung Tau, and 50 percent of the species were found in both areas. Fields of grass, new mangrove growth, and old trees provided habitat for large numbers of snails. No abnormalities were found in the snails. No molluscan species could be considered endangered. Shellfish, which depend on the nutrients from the mangrove areas, were being produced at a normal rate. Full recovery of the mangroves will occur within 10 years based on evidence of reseeding.

HIGHER PLANT COMMUNITIES

Controlling undesirable plants and causing ecological shifts in plant communities to favor desirable species are the main reasons for using the phenoxy herbicides. Broadleaved plants, in general, are much more susceptible to 2,4,5-T than grasses and conifers. The herbicide is used to suppress sensitive species growing among resistant species. A large volume of data concerning the response of common weeds of crops and pastureland are available from most State Agricultural Experiment Stations, USDA, or private industry relative to 2,4,5-T use. It is beyond the scope of this report to attempt to list the numerous uses and recommended practices; however, a few examples will be cited relative to their effect on various plant species.

Marker (1974) reported that 2,4,5-T caused a weak reduction in the number of species, but a great decrease in the frequency and vitality of the herbs. Tomkins and Grant (1974) found dicots were more susceptible than nonocots to 2,4-D, picloram, picloram + 2,4-D, and 2,4-D + 2,4,5-T. However, grasses growing in disturbed areas (immature) were more susceptible to the auxin type herbicides than mature communities. Hammerton (1966) showed that susceptibility of a weed species to a particular herbicide is not a constant property of that species. Variations in susceptibility may be due to environmental factors or to intrinsic or plant factors (ecotypes, stage of growth, etc.) or both. Norris (1967) reviewed the physiologic bases for selective herbicide action.

Young et al. (1975) assessed vegetation changes after repeated and massive applications of the n-butyl esters of 2,4-D + 2,4,5-T at Eglin Air Force Base. Treated areas continue to revegetate but the invading species are different than those on the control area.

Research has shown pasture and rangeland improvement with herbicides by controlling brush (Barrons 1969, Scifres and Haas 1974) and establishment of shrub communities on rights-of-way (Pierce 1958, Bramble and Byrnes 1972). The use of herbicides, such as 2,4,5-T and silvex has been proposed by Decker (1959) to maintain trails and control poison ivy in a nature sanctuary in New York. Herbicides may be the only effective means of controlling some weed populations since other methods, such as grazing or plowing, may not be satisfactory (Batranoff and Burrows 1973).

WILDLIFE HABITAT

Martin (1965), however, found areas of post oak and blackjack oak forest sprayed with 2,4,5-T provided significantly more suitable habitat for pairs of the eastern bluebird, eastern meadowlark, mockingbird, mourning dove, and bobwhite. The eastern woody pewee, blue gray gnatcatcher, and brown-headed cowbird had higher populations in the treated area than in the control area. The investigator concluded that there was no marked adverse effect upon any nesting species of birds and 2,4,5-T actually improved the habitat for a few species.

Kenaga (1975) recently reviewed the literature on the effect of 2,4,5-T on bird populations under recommended field practices. He concluded that birds in treated areas should not be affected acutely or chronically in the egg, chick, or adult stages of life since dietary levels of 2,4,5-T causing no effect in laboratory tests are high enough so that they normally exceed the residues expected in food of birds in the treated areas.

Newton and Norris (1968) studied blacktail deer on the Oregon Coast Range after treatment with 2,4,5-T and atrazine, and concluded the deer do not leave the treated area, do not accumulate 2,4,5-T or atrazine, that detectable levels of herbicide in deer was rare, and that the ruminant was able to degrade the herbicides almost completely soon after ingestion.

Data from Germany indicated herbicides (including phenoxys) had no harmful effects on deer, wild pigs, hare, rabbit, pheasant, and wood pigeon (Madel 1970). A decline in the population of partridge has been ascertained due to removal of weed seed, protective hedges, and pheasant competition. Giban (1972) concluded phenoxy herbicides and other herbicides used in forestry posed no appreciable risk to game animals since only a small fraction of the land was treated and at extended intervals.

2,4,5-T has been used to maintain or improve wildlife habitat in the north central United States. Bramble and Byrnes (1972) report the use of 2,4,5-T (and other herbicides) have enhanced wildife habitat on power line rights-of-way.

CHAPTER 6

ACCIDENTS DUE TO APPLICATION OF HERBICIDES AND THE USE OF MECHANICAL HAND LABOR AND BURNING FOR BRUSH CONTROL ON RANGELANDS, IN FORESTS, AND ON RIGHTS OF WAY.

SUMMARY

During approximately 1.4 million man-hours (includes air and ground workers) of aerial application of herbicides to brush in Texas, one accident occurred in which a flagger lost sight in one eye. The injury was diagnosed as being caused by diesel oil in the eye. During 75,000 hours of chemical application by ground equipment, no accidents occurred. The accident rate for air and ground application of herbicides to rangeland in Texas was 0.07 and 0 per 100,000 man hours respectively. During nearly 2 million man-hours of mechanical operation, it was estimated 201 accidents occurred or 6.7 accidents per 100,000 man-hours.

Two studies were conducted on control of brush by chain saws or manual clearing of brush in Oregon. Where chain saws were used, one accident per every 130 man-hours was reported or 769 accidents per 100,000 man-hours. In the other study, one accident per every 245.6 man-hours or 407 accidents per 100,000 man-hours was reported.

Thirty-five states separate Workmen's Compensation rates into two categories-- (1) tree trimming and brush cutting and (2) chemical spray. The average Workmen's Compensation rates are 8.14 for tree trimming and brush cutting and 2.65 for chemical spray.

The briefs of accidents involving aerial application operations for 1976 from the National Transportation Safety Board were used to estimate accident rate for aerial application of herbicides on rangelands, rights of way, forests, and rice. The estimated annual numbers of accidents for spraying rangeland, rights of way, forests, and rice are 2.42, 1.73, 1.59, and 0.63, respectively. The estimated numbers of annual fatalities for these same groups are 0.24, 0.16, 0.16, and 0.06, respectively.

A comparison of accidents per 100,000 man-hours shows that the accident rate for aerial and ground application of herbicides on rangeland in Texas is the lowest followed by mechanical control, all aerial application operation accidents, and clearing of brush in forests with a chain saw.

INTRODUCTION

The purpose of this section is to compare the accidents that happened during the application of 2,4,5-T by air or ground equipment compared to those accidents occurring as a result of mechanical-brush control, clearing brush by hand labor, or burning. Data in the report consist of the following:

1. A report of accidents from controlling range weeds and brush in Texas.
2. Two reports from Oregon on control of brush on cutover land.
3. Workmen's Compensation rates for tree trimming and brush cutting versus chemical spray.
4. The 1976 report of the National Transportation Safety Board briefs of accidents involving aerial-application operations.

RANGE WEEDS AND BRUSH

The information from Texas (table 1) for herbicide application by air on range weeds and brush represents nearly 1.4 million man-hours over the period operators have been in business, which was an average of 14.4 years. This includes all man-hours, air and ground.

There was one eye injury due to aerial application of 2,4,5-T. This happened to a flagger who continued to look up as the plane passed overhead and did not move out of the line of flight. The injury was diagnosed as eye injury from the diesel oil component of the spray mixture and not from the 2,4,5-T (Hardcastle 1974). This person lost sight in one eye. There were 0.07 accidents per 100,000 man-hours for aerial application of herbicides to weeds and brush in Texas. No accidents were reported for 75,000 man-hours of ground application of herbicides to range and brush in Texas (Hoffman 1978e, Hardcastle 1978).

Over a 32-year period, a contractor operating mechanical equipment for nearly 1 million man-hours (table 1) reported one accident resulting in

Table 1--Estimated man hours and accidents from controlling range weeds and brush in Texas

Method of control	Man-hours	Death	Disability	Other	Time lost
Chemical					
Air a/ (78) b/	1,393,776	None	None	eye loss	Did not re-employ
Ground (6) b/	75,300	None	None	None	None
Mechanical c/					
(1) b/	998,400	None	None	1 (Bruise)	20 hrs.
(200) b/	1,996,800	None	None	200	4,000 hrs.
Burning 10 years at Texas A&M University - No injury					
Hand labor - Not enough done to get data					

a/ Texas Aerial Applicators Association.

b/ Number of applicators or contractors.

c/ Contractors belonging to Texas Conservation Contractors Association.

20 hours lost from the job. There are 200 other contractors belonging to the Texas Conservation Contractors Association. It was estimated that these contractors operated a total of nearly 2 million man-hours with 200 accidents for a total loss of 4,000 hours of worktime. The accident rate was estimated as 6.7 per 100,000 man hours for mechanical control of brush.

There were no injuries as a result of burning up to 2,500 acres annually by the Texas A&M University personnel over a 10-year period. There is not enough hand labor done on controlling brush on rangelands to obtain data.

BRUSH ON CUTOVER LAND

In 1977, the Josephine County Forestry Department in Oregon conducted studies on the use of a chain saw to control brush on cutover land that was not replanted and was overgrown with brush. Brush was defined as shrubs and shrub-size hardwoods. These studies were conducted in three areas consisting of 10.26 acres, 15.49 acres, and 4.61 acres in size. Data were reported on injuries requiring first-aid, medical attention, or deemed serious enough to warrant the filling out of an accident report by a foreman. Injuries were measured in terms of man-days. The control period was from November 1976 to March 1977 and consisted of precommercial thinning in the forest (Bernstein 1977). The brush-control study was conducted in late April and early May in 1977.

The accident rate during the brush-control study period was one injury for every 13 man-days, based on a 10-hour day. There were 769 accidents per 100,000 man-hours which was about twice the accident rate for the precommercial thinning work.

In another study, the State of Oregon, Forestry Department, documented some statistics for accident rates associated with manual clearing of brush. In 1977, hand clearing was performed on 168 acres of brush. The work required 2,455 man-hours for an average of 14.6 hours per acre.

Ten accidents were reported including three bee stings, two poked eyes, one laceration from a saw, one laceration with a machete, one infection from a thorn, one short stub in knee, and a tooth injury. This is one accident per 30.7 man-days or 407 accidents per 100,000 man-hours (Greaves 1978).

WORKMEN'S COMPENSATION RATES

Workmen's Compensation rates were compiled by the Asplundh Tree Expert Company on (1) tree trimming and brush cutting, and (2) chemical spray for all States from which the data were available (Asplundh Tree Expert Company 1978). These rates were effective August 1, 1978. The data in table 2 represent the percent of total labor cost spent on Workmen's Compensation. There were no data available from four states, Nevada, North Dakota, South Dakota, and Wyoming. Nine states, Arizona, Colorado, Georgia, Idaho, Kansas, Missouri, Montana, New Mexico, and Utah did not separate tree trimming and brush cutting from chemical spray rates. Of those states that did separate the two categories, 32 had average Workmen's Compensation rates for chemical spray much lower than for tree trimming or brush cutting. However, three of the states had the rates equal for both categories. The average Workmen's Compensation rates for the 35 states that separated the two categories are 8.14 for tree trimming and brush cutting and 2.65 for chemical spray (Asplundh Tree Expert Company 1978). These data definitely show that the accident rate to persons performing chemical spraying is less than for tree trimming or brush cutting.

AERIAL APPLICATION

The National Transportation Safety Board annually publishes briefs of accidents involving aerial application operations. There were 17.3 accidents per 100,000 hours flown to apply insecticides, herbicides, etc., in 1976 (US General Aviation 1976). The fatal accident rate was 1.56 per 100,000 hours flown (table 3). The total number of accidents and fatalities involved with treating of rangeland, rights of way, forests, and rice by aircraft were computed on the basis of these rates

Table 2--Workmen's Compensation rates a/ effective 8-1-78

State	Tree trimming brush cutting	Chemical spray
Alabama	4.00	1.14
Arizona	23.35	
Arkansas	6.84	1.46
California	16.74	5.05
Colorado	7.39	
Connecticut	6.41	1.70
Delaware	7.61	2.35
Florida	9.32	3.81
Georgia	5.78	
Idaho	8.00	
Illinois	5.26	1.48
Indiana	3.18	.94
Iowa	5.08	2.32
Kansas	5.41	
Kentucky	10.10	3.34
Louisiana	10.08	1.77
Maine	13.31	2.72
Maryland	6.59	1.70
Massachusetts	5.36	1.77
Michigan	8.19	3.45
Minnesota	26.75	3.91
Mississippi	6.29	1.18
Missouri	4.85	
Montana	6.52	
Nebraska	4.33	.90
Nevada		
New Hampshire	12.67	3.14
New Jersey	5.34	2.60
New Mexico	5.68	
New York	12.36	2.50
North Carolina	3.66	.76
North Dakota		
Ohio	7.50	7.50
Oklahoma	7.68	2.82
Oregon	14.75	5.21
Pennsylvania	7.20	2.30
Rhode Island	8.97	2.15
South Carolina	5.63	1.12
South Dakota		
Tennessee	4.73	1.17
Texas	8.48	3.63

continued

Table 2--Workmen's Compensation rates a/ effective 8-1-78 (continued)

State	Tree trimming brush cutting	Chemical spray
Utah	7.50	
Vermont	5.48	1.48
Virginia	6.06	1.12
Washington	6.50	6.50
West Virginia	6.36	6.36
Wisconsin	5.63	1.48
Wyoming		
Average b/	8.14	2.65

a/ Percent of total labor costs spent on Workmen's Compenstion. (Asplundh Tree Expert Company, 1978)

b/ Average of figures from States that separated tree trimming and brush cutting rates from chemical spray rates.

Table 3--Aerial application operation accidents reported by U.S. General Aviation 1976

Aerial application hours flown	Total accidents	Total accident rate a/	Fatal accidents	Fatal accident rate	Fatalities
2,498,600	433	17.3	39	1.56	43

a/ Accident rates per 100,000 hours flown during aerial application of insecticides, herbicides, etc.

for the estimated acres treated annually for each commodity group (table 4). An estimated 3,412,950 acres are treated each year for these four commodity groups. A total of 47,635 hours in the air is required to treat these acres.

These estimates give some idea of the number of accidents and fatalities resulting from the use of aircraft in treating these commodity groups. However, the accident rate in treating rangelands and forests may actually be lower than that for general agricultural spraying and therefore lower than indicated (table 3) because fewer obstructions such as powerlines, and buildings are present. The data from spraying rangeland in Texas bear this out (table 1). The estimated annual number of accidents for spraying rangeland, rights of way, forests, and rice are 2.42, 1.73, 1.59, and 0.63, respectively (table 4). The estimated annual numbers of fatalities for the same commodity groups are 0.24, 0.16, 0.16, and 0.06, respectively (table 4). It must be recognized also that flight personnel are not the only ones at risk. Ground crews and other support personnel are subject to accidents although presumably at a lesser rate.

Table 4--The estimated acres treated annually by aircraft with 2,4,5-T for each commodity group and the total annual accidents and fatalities for each estimated on the basis of data available from the National Transportation Safety Board 1976

Commodity group	Acres treated	Average acres treated per hour	Total number of hours required	Total accidents	Fatalities
Rangeland	2,321,000[a/]	166	13,990	2.42	0.24
Rights of Way	249,950[b/]	25	9,998	1.73	0.16
Forests	550,000[c/]	60	9,166	1.59	0.16
Rice	292,000[d/]	80	3,650	.63	0.06
Total	3,412,950		47,635	8.25	0.82

a/ Acreage treated annually with 2,4,5-T by air in Texas, New Mexico, Oklahoma, Arkansas, and Missouri. Estimated by Garlyn O. Hoffman 2,4,5-T Assessment Team.

b/ Acreage treated annually with 2,4,5-T by air in the United States. Estimated by Harvey A. Holt, 2,4,5-T Assessment Team.

c/ Acreage treated with 2,4,5-T in forests in the United States in 1976 estimated by Robert W. Pearl, 2,4,5-T Assessment Team.

d/ Acreage treated annually with 2,4,5-T by aircraft from 2,4,5-T assessment report, Chapter 4.

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APPENDIX I

FORESTRY-RELATED IMPACTS OF 2,4,5-T IN OREGON

by

Walter H. Knapp, Robert D. Greaves,
and Jerome J. Chetock

January 30, 1979

This Report was done as a cooperative effort between the U.S. Forest Service, Region 6, and the Oregon State Department of Froestry.

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ABSTRACT

This report is designed to estimate current and potential use levels of 2,4,5-T for silvicultural operations; determine alternatives to 2,4,5-T; evaluate impacts on future timber supply if 2,4,5-T is unavailable; compare the economic efficiency of using versus not using 2,4,5-T for forest management; indicate the potential changes in silviculture budgets; and estimate employment impacts if 2,4,5-T is unavailable.

The general approach to assessing alternative management practices and their cost and yield impacts was based primarily on a survey of experienced silviculturists within each of four vegetative subregions in Oregon. These subregions included northwestern Oregon (salmonberry-alder type); southwestern Oregon (tanoak-madrone and tanoak-chinquapin types); Cascade Range (vine maple-ceanothus type); and eastern Oregon (ceanothus and manzanita types).

During 1976 and 1977, 2,4,5-T was used on about 88,000 acres each year for forestry purposes in Oregon, roughly one-third of the potential level.

If 2,4,5-T is unavailable for forestry use in Oregon, a wide range of substitute practices would be used in the four major areas of the State. These practices generally result in increased silvicultural costs ranging from -3 percent to +67 percent of present levels. They are less efficient economically than the use of 2,4,5-T on potential use areas.

The economic impact of managing Oregon's forests without 2,4,5-T would be felt now and in the future in terms of both increased management costs and decreased revenues (i.e. yields). The state-wide impact in perpetuity of these consequences can be measured as the difference in the present net worth of the land when managed with and without 2,4,5-T. Management of Oregon's forests with 2,4,5-T could provide from $383 million (at current application rates) to $1.10 billion (at potential rates) greater present net worth than management without 2,4,5-T.

Furthermore, use of these alternatives could potentially result in an 11 percent reduction in timber yield--a current annual loss of 936 million board feet. The employment impacts of this reduction are estimated to be about 20,000 jobs, including both primary and secondary employment.

These impacts would be most heavily felt in western Oregon. In this area, not only are vegetative types more dependent upon the use of herbicides, but timber supplies are also critically short (Beuter et al. 1976). If 2,4,5-T is not available, projections in this study indicate that current harvest levels in this area and the State as a whole cannot be maintained.

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FORESTRY-RELATED IMPACTS
OF 2,4,5-T IN OREGON

by

Walter H. Knapp, Robert D. Greaves,
and Jerome J. Chetock[1/]

INTRODUCTION

This report assesses the effects of management with and without the herbicide 2,4,5-T on timber production, economic efficiency, employment, and related aspects for the State of Oregon. The assessment focuses on the four major geographic areas in Oregon: northwestern, southwestern, Cascade Range, and eastern. A more detailed case study for southwestern Oregon compares the economic efficiency among alternatives within this area (Appendix A).

Recent timber supply projections for western Oregon forecast a 22 percent decline in timber harvest by the year 2000 unless the

[1/] Respectively, Silviculturist, USDA Forest Service, Region 6, Portland, Oregon; Forest Resource Analyst, and Silviculturist, Oregon State Dept. of Forestry, Salem, Oregon

intensity of forest management is increased (Beuter et al. 1976). Herbicides have been an integral part of intensive forest management. In particular, the herbicide 2,4,5-T has been regarded as an effective tool for vegetation management within many forest types in Oregon.

The toxicity of 2,4,5-T and the hazards associated with its use have been studied with increasing intensity. In reviewing the chemical for reregistration, the United States Environmental Protection Agency (EPA) found that products containing this chemical exceeded the risk criteria relating to toxic effects specified in federal regulations. Thus, the EPA initiated a review process, a Rebuttable Presumption Against Registration (RPAR), to determine the relative risks and benefits derived from using this chemical.

This assessment in Oregon was undertaken to provide detailed information regarding the benefits of using 2,4,5-T in a key forestry state. This effort was conducted by representatives from the United States Forest Service, the Oregon State Department of Forestry, forest industry, and the Oregon State University School of Forestry.

The assessment was designed to:

* Estimate current and potential use levels of 2,4,5-T for silvicultural operations in Oregon.

* Determine alternatives to 2,4,5-T.

* Evaluate impacts on future timber supply projections if 2,4,5-T is not available for use.

* Compare the economic efficiency of forest management with and without 2,4,5-T.

* Indicate the potential changes in silviculture budgets.

* Estimate employment impacts if 2,4,5-T is not available for use.

PROCEDURE

The assessment of alternatives to the use of 2,4,5-T, including their cost and yield impacts, was based primarily on a survey of experienced silviculturists within each of four vegetative subregions in Oregon. The basic study procedure is shown in figure 1; additional details for the key steps follow.

GEOGRAPHIC AREAS

The herbicide 2,4,5-T has been used throughout the State in a wide variety of plant communities. To simplify the analysis, Oregon was divided into four general areas (figure 2) where alternatives to 2,4,5-T vary significantly because of major vegetative differences.[1/] The areas are northwestern (salmonberry-alder type); southwestern (tanoak-madrone and tanoak-chinquapin types); Cascade Range (vine maple-ceanothus type); and eastern (ceanothus and manzanita types). Divisions for analysis were based on political boundaries that approximated these vegetative zones in order to correlate with other data sources.

[1/] Approach based on similar technique developed by the U.S. Forest Service for their 1978 Herbicide Environmental Statement. (USDA FS 1978)

SURVEY

Within each geographic area a survey of selected silviculturists was taken, representing a cross-section of owner classes and experiences. The following information was derived through the initial survey and followup:

* Potential use of 2,4,5-T for silvicultural purposes.

* Alternative vegetation control methods.

* Yield impacts of alternatives.

SELECTION OF ALTERNATIVES

To evaluate the economic and silvicultural impacts of not having 2,4,5-T for management, a representative set of management practices with 2,4,5-T was defined for comparison within each region. Typical practices for site preparation and rehabilitation were based on "Suggested Site Preparation Methods" in Stewart (1978).

To simplify analysis, only one set of representative management practices was selected for all owner classes. Many industrial forest owners will manage their lands more intensively and many small woodland owners less intensively than the selected typical management level.

2,4,5-T MODEL DEVELOPMENT
FLOW DIAGRAM

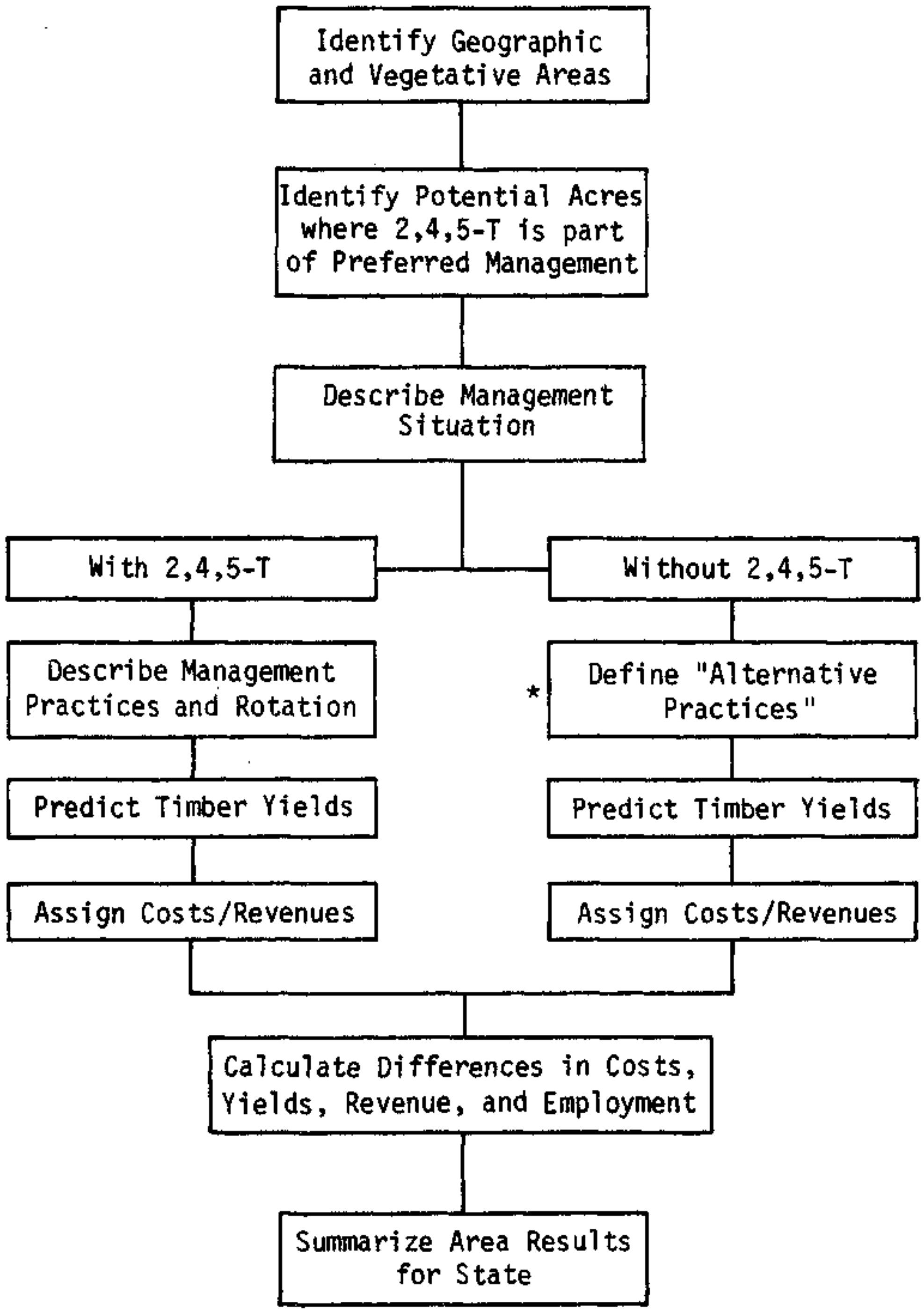

Figure 1--Flow diagram for assessing forestry-related impacts of 2,4,5-T in Oregon.

*Information derived from survey of silviculturists.

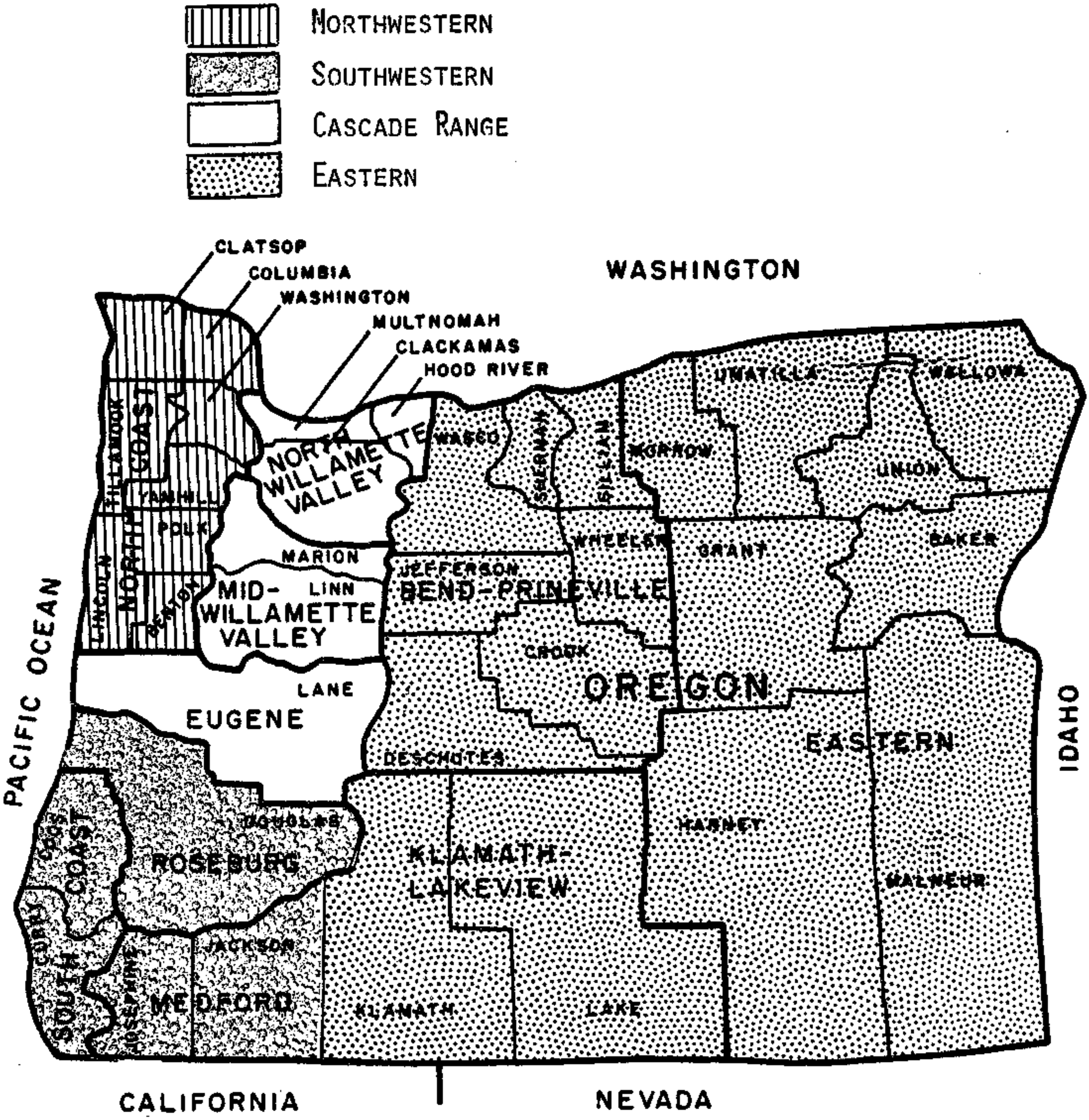

FIGURE 2. MAP OF OREGON SHOWING FOUR MAJOR GEOGRAPHIC AREAS.

The most prevalent alternatives to 2,4,5-T for silvicultural purposes were derived from survey results. Alternatives were not restricted by cost or yield assumptions, but tend to reflect the next choice management practices and the area to which these practices apply. Alternative chemicals were considered if registered and applicable for use.

Effect of Owner Class on Selection of Alternatives

Management intensity and selection of alternative treatments will vary among and within owner classes. Evaluating these differences within the model was beyond the scope of this project. Thus, differences in cost (silvicultural budget), yield, and subsequent projections for timber supply and employment represent an average approximation of the overall impact of losing 2,4,5-T as a silvicultural tool.

Actual impacts among and within owner classes may be higher or lower depending on owner objectives, individual management or funding constraints, productive quality of forest land, and management intensity. For example, forest industry lands in western Oregon are predominantly medium site or high site class (41 and 47 percent of total in owner class, respectively)(Beuter et al. 1976). Brush problems on these lands will generally be more severe than on low site class lands. When coupled with the fact that industry manages its lands on shorter rotations than other owner classes, selection of alternatives to 2,4,5-T that are less effective for brush control will cause a relatively larger decrease in yield on industry land. In most cases, industry managers will choose the most economically efficient alternative available. Some industry owners may choose not to manage their lands when economically viable alternatives are not available.

Small nonindustrial private forest owners manage their lands for a variety of objectives--not all economically motivated. Those who do manage for commercial timber would tend to have funding constraints that limit the application of more costly alternatives to 2,4,5-T. Losing 2,4,5-T in this owner class may result in changes in ownership or objectives (e.g., conversion to nonforest or noncommodity uses).

State and federal public agencies may have labor-intensive alternatives available on some lands where alternatives such as slashing or hand-clearing of brush are effective. The major limitations to increased use of manual brush control are the high treatment costs, lack of manpower, predominance of resprouting species, and safety considerations.

In all cases, choice of an effective alternative to 2,4,5-T depends on: ground cover, physical factors such as topography and soil type, site preparation or release requirements, available manpower and equipment, external constraints such as regulations and objectives, environmental impacts, and cost (Stewart 1978). Each owner or land manager has a unique combination of these variables for each site that needs treatment. The impact of losing 2,4,5-T as a silvicultural tool will depend on these variables and ultimately on the alternative(s) selected.

If 2,4,5-T were unavailable for forestry use in Oregon, that portion of site preparation, rehabilitation, and release currently requiring 2,4,5-T would have to be accomplished by different means. The most likely silvicultural substitutes for 2,4,5-T are identified in Tables 3, 6, 8, and 10. Although no presently registered herbicide can fully substitute for 2,4,5-T as a broad spectrum silvicultural tool, other chemicals would be utilized on some sites in the absence of 2,4,5-T.

Substitute herbicides for site preparation, rehabilitation, and release in Oregon include 2,4-D, Silvex, Amitrole, glyphosate (Roundup), and Fosamine ammonium (Krenite). In addition, 2,4-DP (Dichlorprop), Tordon 101 (Picloram and 2,4-D), Dicamba, and Dinoseb are partial substitutes for site preparation and rehabilitation. The degree of actual replacement for 2,4,5-T varies with the specific herbicide and vegetative species (Stewart 1978, USDA ARS, Undated, and Newton, unpublished). 1/ No single presently registered herbicide can fully substitute for 2,4,5-T as a broad spectrum silvicultural tool.

PREDICTION OF TIMBER YIELDS

With 2,4,5-T

Potential timber production with 2,4,5-T was predicted in western Oregon from DFIT (Douglas-fir Interim Tables) computer simulations (Bruce et al. 1977) using the average site productivity summarized from U.S. Forest Service survey data.[2/] These simulations reflect the anticipated development of an average future stand of timber managed as described in the alternatives for each region. Timber yields for an average site in eastern Oregon had been developed in an earlier analysis (Sassaman et al. 1977). Stand age for each silvicultural operation was based on standard practices within each region without regard to ownership variations. The assumed rotation ages were: northwestern, 65 years; southwestern, 85 years; Cascade Range, 75 years; and eastern, 120 years. Rotation ages were based on averages for industry and federal lands, given an assumed level of management.

1/Newton, M. 1978. Chart on susceptibility of forest species to herbicides. Unpublished data on file at Oregon State Univ. Forest Research Laboratory, Corvallis, Oregon.

2/Data on file, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Without 2,4,5-T

Potential yield decreases without 2,4,5-T were estimated by survey respondents. DFIT computer simulations for western Oregon were modified to be consistent with these estimates. Eastern Oregon yield predictions were also reduced consistent with the estimates from the survey of silviculturists. These yield impacts were calculated using weighted averages. A sample derivation of overall yield effects is displayed in Appendix B.

ECONOMICS

Costs

The cost for each management practice was derived from recent reports (OSDF 1977, USDA FS 1978; Bernstein and Brown 1977). Costs reflect statewide averages for all owner classes.

Revenues

Revenues for commercial thinnings and final harvests for western Oregon start at the U.S. Forest Service's 1980 Resources Planning Act Timber Assessment stumpage value of $124 per cunit[1/]. Eastern Oregon revenues were reduced by 33 percent to reflect recent stumpage value differences. Thinning revenues were reduced to 75 percent of the final harvest stumpage value.

Economic Efficiency

The economic efficiency of management with and without 2,4,5-T was evaluated using MULTIPLOY (Row 1976), a computer-assisted economic analysis. Present net worth and benefit-cost ratios were calculated from cost and yield data for the alternatives. Treatment costs were

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[1/] A cunit equals 100 cubic feet or approximately 500 board feet for the assessment area.

assumed to be constant in real terms, and timber values were increased at 2.5 percent annually in real terms, based on trend analysis. Because real prices are used in the analysis, the most relevant interest rate for interpreting the results is a real rate which is below the current market rate. In this report an alternative investment rate of 6 5/8 percent was used as presently recommended by the Water Resources Council (WRC) for long-term investments on federal lands. Rates of 4, 8, and 10 percent are also analyzed for comparison.

Employment

Changes in yield will affect both direct and indirect forest industry employment.[1/] Multipliers of 7.51 jobs per million board feet of timber processed for direct employment and 15.02 jobs per million board feet for indirect (secondary) employment were based on recent averages for the State of Oregon.[2/] Employment increases resulting from alternatives to 2,4,5-T that require more intensive labor were not considered. For a discussion of these effects, refer to the Final Environmental Statement for Vegetation Management With Herbicides for Region 6 of the U.S. Forest Service (USDA FS 1978).

CURRENT AND POTENTIAL USE OF 2,4,5-T

Intensive forest management is an integrated series of practices designed to establish, maintain, and utilize stands of commercial tree species in an efficient and economical manner. Site preparation, conifer release, and rehabilitation of underproductive lands are

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[1/] Direct employment includes those jobs that are specifically a part of timber harvesting and processing. Indirect employment includes those additional jobs resulting from direct employment, from shops, restaurants, and the like. Synonyms: Primary employment and secondary employment.

[2/] Western Environmental Trade Association, Oregon TREE project, phase 1 data, October 1976, on file.

practices within this series which are commonly accomplished, at least in part, with 2,4,5-T. For a variety of reasons, not all commercial forest lands are presently managed according to their potential for timber production. Nevertheless, the potential use of 2,4,5-T was defined as that level of usage which would accompany intensive management on commercial forest land where 2,4,5-T would normally be a part of the preferred management. For example, survey respondents estimated that 2,4,5-T is part of preferred management on 75 percent of the commercial forest lands in northwestern Oregon. The potential use of 2,4,5-T for all silvicultural purposes is shown in table 1. In 1976 and 1977, 2,4,5-T was used on approximately 88,000 acres per year, roughly one-third of the potential level. Details are included in Appendix C.

DESCRIPTION OF ALTERNATIVES

Vegetation management is frequently accomplished with silvicultural tools other than 2,4,5-T, or by combining another method with 2,4,5-T. Mechanical methods, fire, other herbicides, and hand slashing of vegetation are viable alternatives to 2,4,5-T in some specific situations. Although alternatives are available and are used where appropriate, 2,4,5-T currently remains the preferred treatment on a significant part of the commercial forest in Oregon.

Table 2 shows the potential use of 2,4,5-T for rehabilitation of forest lands presently nonstocked or understocked with conifers. Unless these areas are treated, they are not likely to produce satisfactory stands of commercial species within a reasonable time span.

NORTHWESTERN OREGON

The typical management for northwestern Oregon involves the use of 2,4,5-T on 75 percent of the commercial forest land. Thirty percent of site preparation in this area is done with 2,4,5-T in combination with a slash disposal fire. Rehabilitation of underproductive forest lands uses 2,4,5-T in combination with fire and hand slashing on 50

Table 1--Potential use of 2,4,5-T for silvicultural practices in Oregon

Silvicultural Practice	Geographic Area				
	Northwestern	Southwestern	Cascades	Eastern	State Total
	--Thousands of acres (percent of CFL 1/ in geographic area)--				
Rehabilitation and Release With 2,4,5-T 2/	255(9%)	129(2%)	199(4%)	incidental	583(2%)
Site Preparation and Release With 2,4,5-T 2/	569(20%)	894(15%)	319(7%)	incidental	1,782(8%)
Release Only With 2,4,5-T	1,329(46%)	3,574(58%)	1,808(39%)	1,944(19%)	8,655(36%)
Subtotal: All 2,4,5-T	2,153(75%)	4,597(75%)	2,326(50%)	1,944(19%)	11,020(46%)
No 2,4,5-T	718(25%)	1,532(25%)	2,325(50%)	8,287(81%)	12,862(54%)
TOTAL	2,871(100%)	6,129(100%)	4,651(100%)	10,231(100%)	23,882(100%)

1/CFL = commercial forest land.
2/Areas that require 2,4,5-T for site preparation or rehabilitation also require 2,4,5-T for release.

Table 2--Potential use of 2,4,5-T for rehabilitation in western Oregon[1/]

Treatment Description	Geographic Area		
	Northwestern	Southwestern	Cascades
	---Thousands of acres (percent of CFL in geographic area)---		
Rehabilitation with 2,4,5-T	255 (50%)	129 (45%)	199 (30%)
Rehabilitation without 2,4,5-T	255 (50%)	157 (55%)	463 (70%)
Total Rehabilitation	510 (100%)	286 (100%)	662 (100%)

[1/]The use of 2,4,5-T for rehabilitation in eastern Oregon is minor and is not included.

percent of this underproductive area. Two release operations are generally applied to forest plantations in northwestern Oregon, with 2,4,5-T being the preferred treatment on 75 percent of the area.

If 2,4,5-T were unavailable for forestry use in northwestern Oregon, the practices of site preparation, rehabilitation, and release would have to be accomplished by different means. The range of alternative treatments available include mechanical, other chemical, fire, hand slashing, no management, and combinations of these methods. The silvicultural alternatives to 2,4,5-T identified by survey respondents in northwestern Oregon are listed in table 3. The resulting alternative management is contrasted to the typical management in table 4. Note that the silvicultural cost--the sum of anticipated stand investments--is slightly lower without 2,4,5-T in northwestern Oregon. This decrease in costs occurs because (1) 15 percent of the time no release is done because no cost effective alternatives are available, and (2) alternatives to 2,4,5-T, though less effective, are only slightly more expensive.

Although these substitute practices decrease costs, they also directly impact timber yield. The analysis indicates that in northwestern Oregon, 39 cubic feet per acre per year would be lost if 2,4,5-T were unavailable--a reduction of 19 percent on areas that would normally use 2,4,5-T (table 11).

SOUTHWESTERN OREGON

Typical management for southwestern Oregon involves the use of 2,4,5-T on 75 percent of the commercial forest land. Twenty percent of site preparation in this area uses 2,4,5-T in conjunction with a slash disposal fire. Forty-five percent of the rehabilitation of nonmerchantable multistoried hardwood stands on steep slopes, prevalent in this area, involves combining 2,4,5-T with hand slashing and fire. Seventy-five percent of the forest plantations in southwestern Oregon are expected to require two release operations, both typically done with 2,4,5-T.

Table 3--Silvicultural substitutes for 2,4,5-T in northwestern Oregon

Silvicultural Substitutes for 2,4,5-T	Percent Replacement for 2,4,5-T	Percent 1/ Yield
Site Preparation		
Fire	30% 3/	90%
Other Chemical	15%	100%
Other Chemical and Fire	35%	100%
Clean Log Only 2/	20%	70%
Rehabilitation		
Other Chemical	35%	85%
Hand Slash, Other Chem., and Fire	50%	100%
No Rehabilitation	15%	10%
Release		
Other Chemical	85%	90%
No Release	15%	55%

1/Percentage of full yield obtainable with 2,4,5-T under typical management regime.
2/"Clean log only" refers to more intensive harvest operations that would leave more ground exposed. It may include yarding of unmerchantable material or some other form of slash removal.
3/The use of fire as a substitute may be limited by state and federal smoke management regulations.

Table 4. Management with and without 2,4,5-T in northwestern Oregon

	Stand Age		Revenue or Cost (-) 2/		Volume	
	With 1/	W/O 1/	With	W/O	With	W/O
	yrs.	yrs.	$/acre	$/acre	cunits/acre	
Site Prep	0	0	-60	-45 3/		
Planting Operations	0	0	-130	-130		
Rehabilitation	0	0	-200	-200 3/		
Release	2	2	-30	-28 3/		
Release	4	4	-30	-28 3/		
Precommercial Thin	12	12	-95 4/	-95		
Commercial Thin	30	--	1,144	None	12.3	None
Commercial Thin	35	35	884	1,209	9.5	13.0
Commercial Thin	45	45	1,144	1,311	12.3	14.1
Harvest	65	65	11,668	9,399	94.1	75.8
Slash Disposal	65	65	-110	-110		

1/ "With" refers to "with 2,4,5-T," i.e., the typical management practices. "W/O" refers to "without 2,4,5-T," i.e., the alternative management practices.
2/ Revenues and costs are for a single rotation, current dollars.
3/ Weighted average cost of substitute treatments for 2,4,5-T identified in Table 3; see Appendix B for method.
4/ Because of initial stocking levels and anticipated early stand development, precommercial thinning is estimated to be needed on only 25 percent of the land area. This proportional treatment was used in the economic analysis.

The unavailability of 2,4,5-T for forestry uses would require alternative practices for those situations described above. These alternative practices are listed in table 5. The resulting alternative management is contrasted to typical management in table 6.

In southwestern Oregon, a reduction of 31 cubic feet per acre per year (a loss of 23 percent) is expected if 2,4,5-T is not available (table 11).

A more detailed case study for southwestern Oregon is found in Appendix A.

OREGON CASCADES

Typical management in the Oregon Cascades involves the use of 2,4,5-T on 50 percent of the commercial forest land. Fifty percent of the release operations, 30 percent of the rehabilitation projects, and 15 percent of the site preparation activities occurring on forest lands in this area typically use 2,4,5-T.

Alternatives to these silvicultural uses of 2,4,5-T in the Oregon Cascades are listed in table 7. The management resulting from the use of these substitutes is contrasted with typical management in table 8.

If 2,4,5-T is not available for forestry use a loss of 24 cubic feet per acre per year is predicted--a reduction of 16 percent (table 11).

EASTERN OREGON

The use of 2,4,5-T for site preparation and rehabilitation of underproductive forest lands is incidental and is not included in this analysis. Release is the only silvicultural practice significantly dependent on 2,4,5-T. Approximately 19 percent of the forest land base could potentially benefit from a release spray containing

Table 5--Silvicultural substitutes for 2,4,5-T in southwestern Oregon

Silvicultural Substitutes for 2,4,5-T	Percent Replacement for 2,4,5-T	Percent 1/ Yield
Site Preparation		
Clean Log Only 2/	60%	60%
Hand Slash, Other Chem., and Fire 3/	25%	100%
Fire	15%	95%
Rehabilitation		
Hand Slash, Other Chem., and Fire 3/	60%	100%
No Rehabilitation	25%	20%
Other Chemical	15%	85%
Release		
Other Chemical	50%	95%
No Release	35%	60%
Hand Slashing	15%	85%

1/Percentage of full yield obtainable with 2,4,5-T under typical management regime.
2/"Clean log only" refers to more intensive harvest operations that would leave more ground exposed. It may include yarding of unmerchantable material or some other form of slash removal.
3/The use of fire as a substitute may be limited by state and federal smoke management regulations.

Table 6--Management with and without 2,4,5-T in southwestern Oregon

Practice	Stand Age		Revenue or Cost (-) 2/		Volume	
	With 1/	W/O 1/	With	W/O	With	W/O
	yrs.	yrs.	$/acre	$/acre	cunits/acre	
Site Prep	0	0	- 60	- 78 3/		
Planting Operations	0	0	-130	-130		
Rehabilitation	0	0	-200	-211 3/		
Release	4	4	-30	-150 3/		
Release	6	6	-30	-150 3/		
Release	--	9	--	-376 3/ 4/		
Precommercial Thin	15	15	-95 5/	- 95		
Commercial Thin	40		1,247	none	13.4	none
Commercial Thin	50	45	1,153	1,116	12.4	12.0
Commercial Thin	65	60	1,088	1,163	11.7	12.5
Harvest	85	85	9,511	7,775	76.7	62.7
Slash Disposal	85	85	-110	-110		

1/"With" refers to "with 2,4,5-T," i.e., the typical management practices. "W/O" refers to "without 2,4,5-T," i.e., the alternative management practices.
2/Revenues and costs are for a single rotation, current dollars.
3/Weighted average cost of substitute treatments for 2,4,5-T identified in Table 5; see Appendix C for method.
4/All release operations in this alternative in southwestern Oregon include manual release on 15 percent of the area. Costs are mid-range values from RPAR timber assessments.
5/Because of initial stocking levels and anticipated early stand development, precommercial thinning is estimated to be needed on only 40 percent of the land area. This proportional treatment was used in the economic analysis.

Table 7--Silvicultural substitutes for 2,4,5-T in the Oregon Cascades

Silvicultural Substitutes for 2,4,5-T	Percent Replacement for 2,4,5-T	Percent 1/ Yield
Site Preparation		
Clean Log Only 2/	90%	80%
Other Chemical	10%	100%
Rehabilitation		
Other Chemical	35%	100%
No Rehabilitation	25%	50%
Hand Slash, Other Chem., and Fire	20%	115%
Mechanical	20%	110%
Release		
Other Chemical	50%	100%
No Release	50%	75%

1/Percentage of full yield obtainable with 2,4,5-T under typical management regime.
2/"Clean log only" refers to more intensive harvest operations that would leave more ground exposed. It may include yarding of unmerchantable material or some other form of slash removal.

Table 8--Management with and without 2,4,5-T in the Oregon Cascades

Practice	Stand Age With 1/	Stand Age W/O 1/	Revenue or Cost (-) 2/ With	Revenue or Cost (-) 2/ W/O	Volume With	Volume W/O
	yrs.	yrs.	$/acre	$/acre	cunits/acre	
Site Prep	0	0	-60	-9 3/		
Planting Operations	0	0	-130	-130		
Rehabilitation	0	0	-200	-180 3/		
Release	5	5	-30	-45 3/		
Precommercial Thin	13	13	-95 4/	-95		
Commercial Thin	35	--	1,125	none	12.1	none
Commercial Thin	45	40	1,200	1,200	12.9	12.9
Commercial Thin	60	50	1,247	1,088	13.4	11.7
Harvest	75	75	9,412	8,940	75.9	72.1
Slash Disposal	75	75	-110	-110		

1/"With" refers to "with 2,4,5-T," i.e., the typical management practices. "W/O" refers to "without 2,4,5-T," i.e., the alternative management practices.

2/Revenues and costs are for a single rotation, current dollars.

3/Weighted average cost of substitute treatments for 2,4,5-T identified in Table 7; see Appendix B for method.

4/Because of initial stocking levels and anticipated early stand development, precommercial thinning is estimated to be needed on only 90 percent of the land area. This proportional treatment was used in the economic analysis.

2,4,5-T. The alternatives to using 2,4,5-T for release are listed in table 9. Management resulting from the use of substitutes is contrasted with typical management in table 10.

If 2,4,5-T is not available for use in eastern Oregon, a reduction of 12 cubic feet per acre per year (a loss of 23 percent) is expected on areas needing 2,4,5-T for release. This represents a large proportionate impact on yield, but because of the lower productivity of typical eastern Oregon sites and the comparatively small area which would use 2,4,5-T, the total yield reduction is less than in other areas.

ECONOMIC EFFICIENCY

In all areas of the State where 2,4,5-T is part of the preferred treatment, management with 2,4,5-T is economically more efficient than management without 2,4,5-T (tables 12 and 13). The greatest difference in management efficiency is found in southwestern Oregon. Here management with 2,4,5-T results in a return of $3.80 per acre for every dollar invested, compared with a return of $1.68 without 2,4,5-T (table 12, WRC rates).

On a Statewide basis, management with 2,4,5-T results in $288 per acre greater present net worth than management without 2,4,5-T. Since 2,4,5-T has the potential for use on 11 million acres (table 1), or 253,000 acres annually, management with 2,4,5-T could provide as much as $1.1 billion greater present net worth from these lands than management without 2,4,5-T. In other terms, the benefit-cost ratio with 2,4,5-T indicates a return of $4.13 for every dollar invested in management, dropping to $2.43 in the absence of 2,4,5-T.

In eastern Oregon, lower timber production makes management less profitable than in other areas. The analysis shows that management with 2,4,5-T is efficient at approximately the 6 percent discount level or less. It must be understood, however, that only timber values are included in this assessment. Inclusion of other commodities could result in substantial changes.

SILVICULTURE COSTS

Proportional changes in silvicultural costs and yields with and without 2,4,5-T are shown in Figure 3. These values compare the average undiscounted management costs of alternatives on potential use areas. They could be viewed as likely changes in silvicultural budgets if 2,4,5-T is not available.

If 2,4,5-T becomes unavailable, costs are expected to decrease slightly in northwestern Oregon, but yields will also be reduced. Anticipated budget costs of alternatives increase in all other areas, reaching a maximum in southwestern Oregon. The likely management alternatives in this area would require a 67 percent increase in silviculture budgets, but even with these added expenditures, yields would be reduced by 23 percent. Similar comparisons can be made for each geographic area.

STATE IMPACTS

TIMBER SUPPLY IMPACTS

Reductions in timber yield without 2,4,5-T have been expressed only in terms of loss on areas that would potentially use 2,4,5-T for one or more silvicultural operations. However, these areas represent only a portion of the total commercial forest land area (table 1). To assess the net change in wood volume production with and without 2,4,5-T, the entire commercial forest land area must be evaluated. To simplify this analysis, changes in wood production on areas using 2,4,5-T are expressed as a proportion of change in production on all commercial forest lands in each region (table 14).[1/] This analysis assumes

1/Procedural details are shown in Appendix B.

Table 9--Silvicultural substitutes for 2,4,5-T in eastern Oregon

Silvicultural Substitutes for 2,4,5-T	Percent Replacement for 2,4,5-T	Percent 1/ Yield
Release		
No Release	39%	66%
Mechanical	33%	80%
Other Chemical	28%	90%

1/Percentage of full yield obtainable with 2,4,5-T under typical management regime.

Table 10--Management with and without 2,4,5-T in eastern Oregon

Practice	Stand Age With 1/	Stand Age W/O 1/	Revenue or Cost (-) 2/ With	Revenue or Cost (-) 2/ W/O	Volume With	Volume W/O
	yrs.	yrs.	$/acre	$/acre	cunits/acre	
Planting Operations	0	0	-130	-130		
Release	6	6	-60	-144 3/		
Precommercial Thin	13	20	-85 4/	-85		
Commercial Thin	40	--	249	none	4.0	none
Commercial Thin	60	60	461	548	7.4	8.8
Commercial Thin	80	80	498	386	8.0	6.2
Harvest	120	120	3,340	2,575	40.2	31.0
Slash Disposal	120	120	-110	-110		

1/"With" refers to "with 2,4,5-T," i.e., the typical management practices. "W/O" refers to "without 2,4,5-T," i.e., the alternative management practices.

2/Revenues and costs are for a single rotation, current dollars.

3/Weighted average cost of substitute treatments for 2,4,5-T identified in Table 9; see Appendix B for method.

4/Because of initial stocking levels and anticipated early stand development, precommercial thinning is estimated to be needed on only 35 percent of the land area. This proportional treatment was used in the economic analysis.

Table 11--Potential productivity with and without 2,4,5-T for areas which would use 2,4,5-T for vegetation management

Geographic Area	Potential Productivity Mean Annual Increment with 2,4,5-T cu. ft./ acre/year)	without 2,4,5-T cu. ft./ acre/year)	Difference 1/ cu.ft./ acre/year	percent
Northwestern	197	158	-39	-19%
Southwestern	134	103	-31	-23%
Cascade Range	152	128	-24	-16%
Eastern	50	38	-12	-23%

1/ Compared with potential productivity with 2,4,5-T. Percentages are adjusted to compensate for rounding differences in DFIT simulations.

Table 12--Benefit-cost ratios for management with and without 2,4,5-T in Oregon

Geographic Area	Management Alternative	Benefit-cost Ratio at Discount Rate of: 4%	6-5/8%	8%	10%
Northwestern	With 2,4,5-T	24.98	6.73	3.58	1.54
	Without 2,4,5-T	20.37	5.21	2.66	1.06
Southwestern	With 2,4,5-T	19.27	3.80	1.79	.67
	Without 2,4,5-T	9.12	1.68	.76	.26
Cascades	With 2,4,5-T	19.32	4.55	2.29	.92
	Without 2,4,5-T	16.82	3.74	1.81	.68
Eastern	With 2,4,5-T	5.24	.74	.33	.13
	Without 2,4,5-T	2.98	.36	.14	.04
State	With 2,4,5-T		4.13		
	Without 2,4,5-T		2.43		

TABLE 13--Present net worth per acre for management with and without 2,4,5-T in Oregon

Geographic Area	Management Alternative	Present Net Worth at Discount Rate of: 4%	6-5/8%	8%	10%
Northwestern	With 2,4,5-T	6,413	1,349	591	121
	Without 2,4,5-T	5,023	962	368	13
	Difference	1,390	387	223	108
Southwestern	With 2,4,5-T	4,201	578	158	-65
	Without 2,4,5-T	2,955	218	-74	-212
	Difference	1,246	360	232	147
Cascades	With 2,4,5-T	4,801	805	280	-16
	Without 2,4,5-T	4,014	598	168	-64
	Difference	787	207	112	48
Eastern	With 2,4,5-T	841	-48	-119	-151
	Without 2,4,5-T	515	-152	-195	-207
	Difference	326	104	76	56
State	With 2,4,5-T		666		
	Without 2,4,5-T		378		
	Difference		288		
State (Total)[1/]	Potential Level (253,000 acres treated annually)		$1.10 billion		
	Current Level (88,000 acres treated annually)		$383 million		

[1/] The equation for a perpetual series of annual payments was used to estimate present net worth loss without 2,4,5-T.

$V_o = \frac{a}{i}$ Where V_o = present net worth;
a = periodic payment (i.e. net revenue or cost; or difference in per acre value); and
i = annual interest rate (i.e. 6 5/8 percent).

$$\text{e.g.} \quad V_o = \frac{(\$288/\text{acre})(253{,}000 \text{ acres})}{0.06625}$$

that the 2,4,5-T acres are of average productivity. In fact, 2,4,5-T acres tend to be more productive, thereby supporting more competing vegetation that must be controlled. Thus, the weighted average yield impact in each region tends to be a conservative estimate.

These yield impacts were applied to long-term projections of timber supply in order to estimate total volume reduction within each region.[1/] This expansion of results is based on the assumption that per-acre changes in productivity from this 2,4,5-T assessment are directly proportional to changes in productivity for the area as a whole. The results are shown in figures 4-8. The intensity of management now being practiced in Oregon is approximated by the "A-1" level (Beuter et al. 1976). Management at this level would result in a timber supply decline in western Oregon by the year 2000. The curves reflecting a higher level of management, labeled "FPFO", are based on maintaining future harvest levels at or above the current harvest levels (OSDF 1977). [2/]

1/The general form of the projection is given by the equation:

$$\text{supply at year } n \text{ without 2,4,5-T} = (1-a) + ay \quad S_n$$

Where: a = proportion of area using 2,4,5-T
y = proportion of full yield attainable without 2,4,5-T
S_n = projected supply at year n

2/Both projection studies cited used linear programing techniques which may give substantially different results from per-acre projections. However, in a comparison of both techniques on the Siskiyou National Forest in southwestern Oregon, the per-acre projection method gave approximately the same result as linear programing using Timber-RAM (Navon 1971). These results are on file with USDA Forest Service, Pacific Northwest Region, Portland, Oregon.

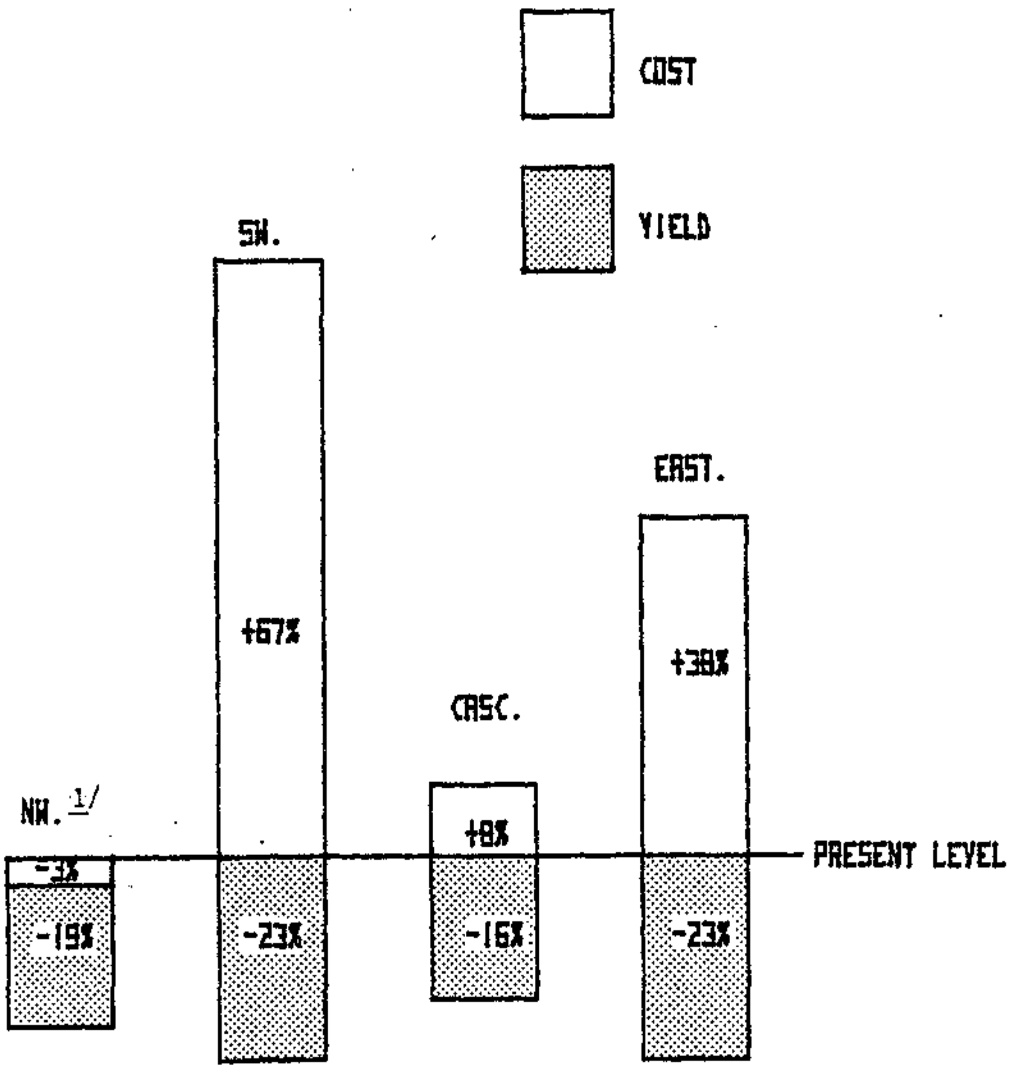

FIGURE 3. CHANGES IN SILVICULTURE COSTS AND TIMBER YIELDS ON POTENTIAL USE AREAS IF 2,4,5-T IS UNAVAILABLE.

1/This decrease in silvicultural costs in northwestern Oregon occurs because alternatives to 2,4,5-T, though less effective, are only slightly more expensive in this region, and 15 percent of the time no release is done (and no expense incurred). The combined impact is a slight reduction in silvicultural cost.

Table 14--Summary of yield effects for management without 2,4,5-T

Region	Yield on 2,4,5-T Areas	Overall Yield 1/
Northwestern	81%	86%
Southwestern	77%	83%
Cascades	84%	93%
Eastern	77%	96%
State	--	89%

1/Percentage of full yield obtainable with 2,4,5-T. Includes the yield from 2,4,5-T areas plus the areas not requiring 2,4,5-T. See equation, footnote 2, p. 30.

In northwestern Oregon, for example, yield without 2,4,5-T is 86 percent of the potential yield with 2,4,5-T. Total harvest would decline about 14 percent from the projected 300 million cubic feet per year[1/] through the year 2000--a loss of 42 million cubic feet (206 million board feet) annually. Thereafter, as the full yield potential with 2,4,5-T rose, potential impacts would increase, culminating in losses of over 45 million cubic feet (220 million board feet) per year by the year 2070 if 2,4,5-T were unavailable and no new substitutes were introduced.

EMPLOYMENT IMPACTS

One of the most critical social and economic changes resulting from a reduction of timber supplies is loss of employment. About 20,000 jobs will potentially by lost if 2,4,5-T is unavailable (table 15, figure 9), based on timber supply projections for the first three decades. The economic impact of this job loss is additional to the loss of stumpage revenue.

SUMMARY

If 2,4,5-T is unavailable for forestry use in Oregon, a range of substitute practices would be used in the four major areas of the State. In some situations, no suitable substitutes are available. These practices generally result in increased silvicultural costs ranging from -3 percent to +67 percent of present levels. They are less efficient economically than the use of 2,4,5-T on potential use areas. Furthermore, use of these alternatives could potentially result in a loss of more than $1.1 billion in present net worth and an 11 percent reduction in timber yield--a current annual loss of 936 million board feet. The employment impacts of this reduction are estimated to be about 20,000 jobs, including both primary and secondary employment.

[1/] Beuter et al. 1976, A-1 level.

These impacts would be most heavily felt in western Oregon. In this area, not only are vegetative types more dependent upon the use of herbicides, but timber supplies are also critically short (Beuter et al. 1976). If 2,4,5-T is not available, projections in this study indicate that current harvest levels in this area and the State as a whole cannot be maintained.

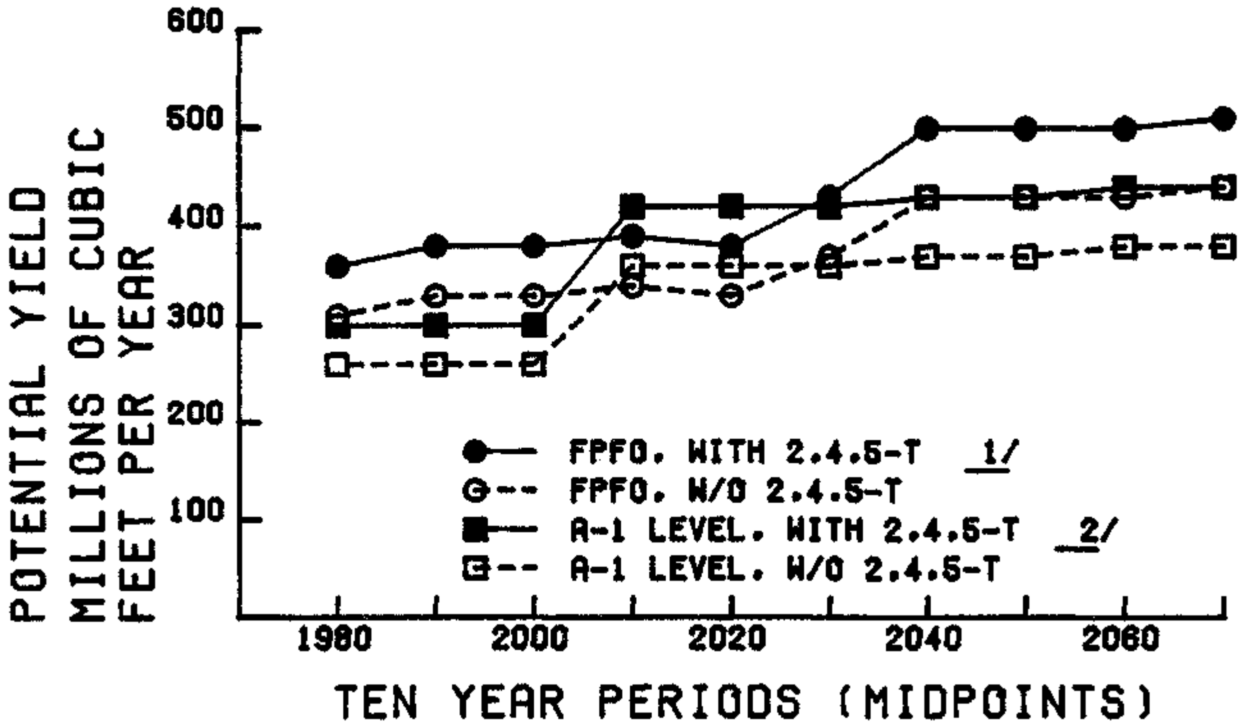

FIGURE 4. HARVEST PROJECTIONS FOR TWO MANAGEMENT INTENSITIES IN NORTHWEST OREGON, SHOWING ANTICIPATED LEVELS WITH AND WITHOUT 2,4,5-T.

1/ FPFO: Forestry Program for Oregon (OSDF 1977). The anticipated level of management needed to maintain future harvest levels at or above current levels. Projected yield without 2,4,5-T would fall 14 percent short of FPFO potential.

2/ A-1 level (Beuter et al. 1976). The harvest levels anticipated if current policies and resultant management intensities are projected into the future. Projected yield without 2,4,5-T would fall 14 percent short of A-1 level.

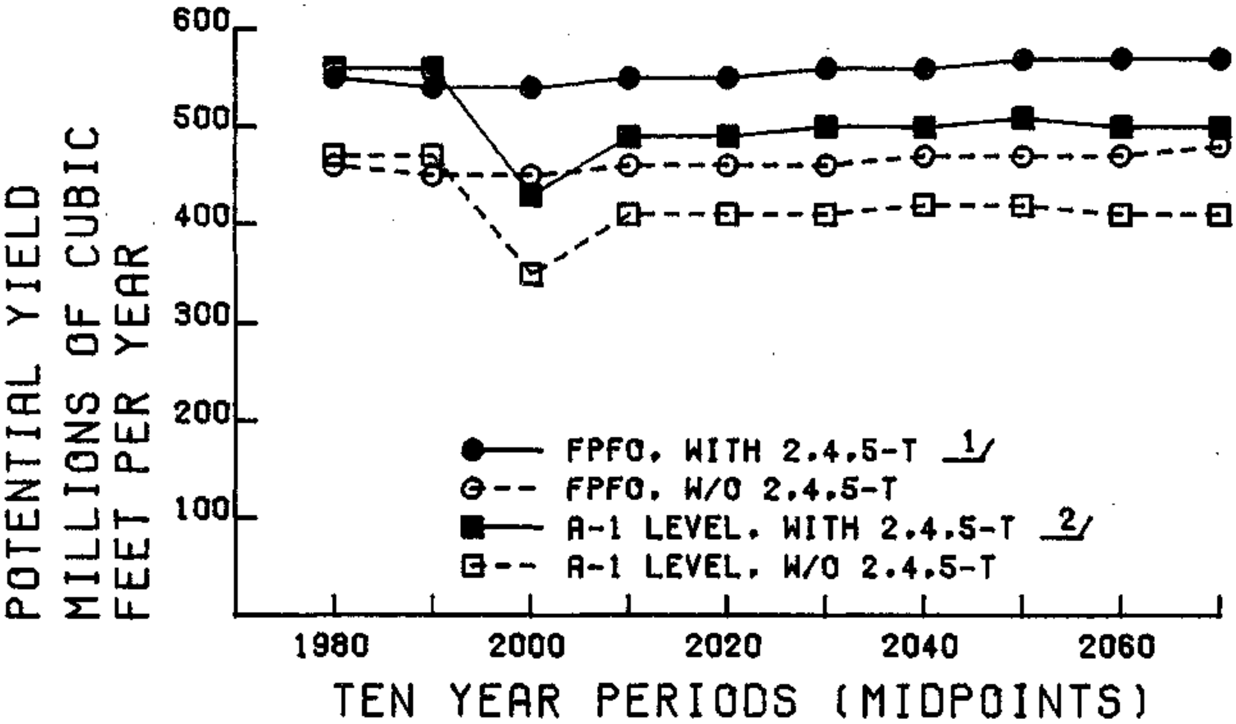

FIGURE 5. HARVEST PROJECTIONS FOR TWO MANAGEMENT INTENSITIES IN SOUTHWEST OREGON, SHOWING ANTICIPATED LEVELS WITH AND WITHOUT 2,4,5-T

1/FPFO: Forestry Program for Oregon (OSDF 1977). The anticipated level of management needed to maintain future harvest levels at or above current levels. Projected yield without 2,4,5-T would fall 17 percent short of FPFO potential.

2/A-1 level (Beuter et al. 1976). The harvest levels anticipated if current policies and resultant management intensities are projected into the future. Projected yield without 2,4,5-T would fall 17 percent short of A-1 level.

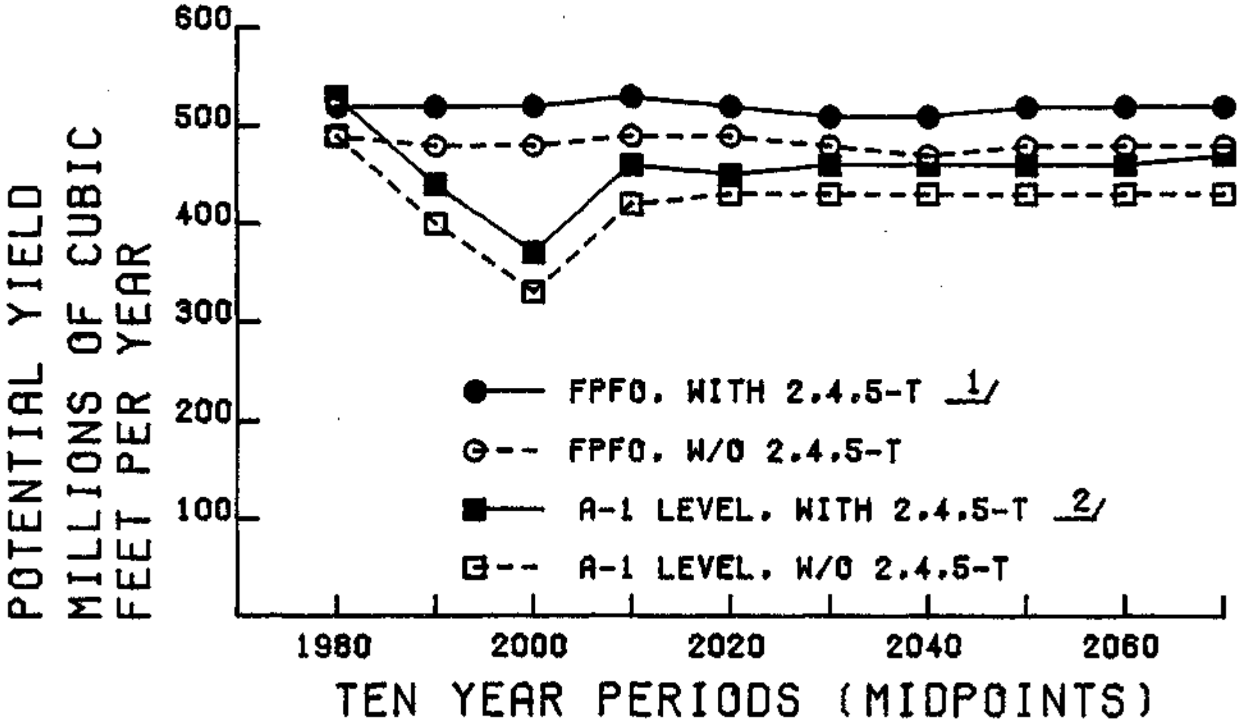

FIGURE 6. HARVEST PROJECTIONS FOR TWO MANAGEMENT INTENSITIES IN CASCADES OF OREGON, SHOWING ANTICIPATED LEVELS WITH AND WITHOUT 2,4,5-T

1/ FPFO: Forestry Program for Oregon (OSDF 1977). The anticipated level of management needed to maintain future harvest levels at or above current levels. Projected yield without 2,4,5-T would fall 7 percent short of FPFO potential.

2/ A-1 level (Beuter et al. 1976). The harvest levels anticipated if current policies and resultant management intensities are projected into the future. Projected yield without 2,4,5-T would fall 7 percent short of A-1 level.

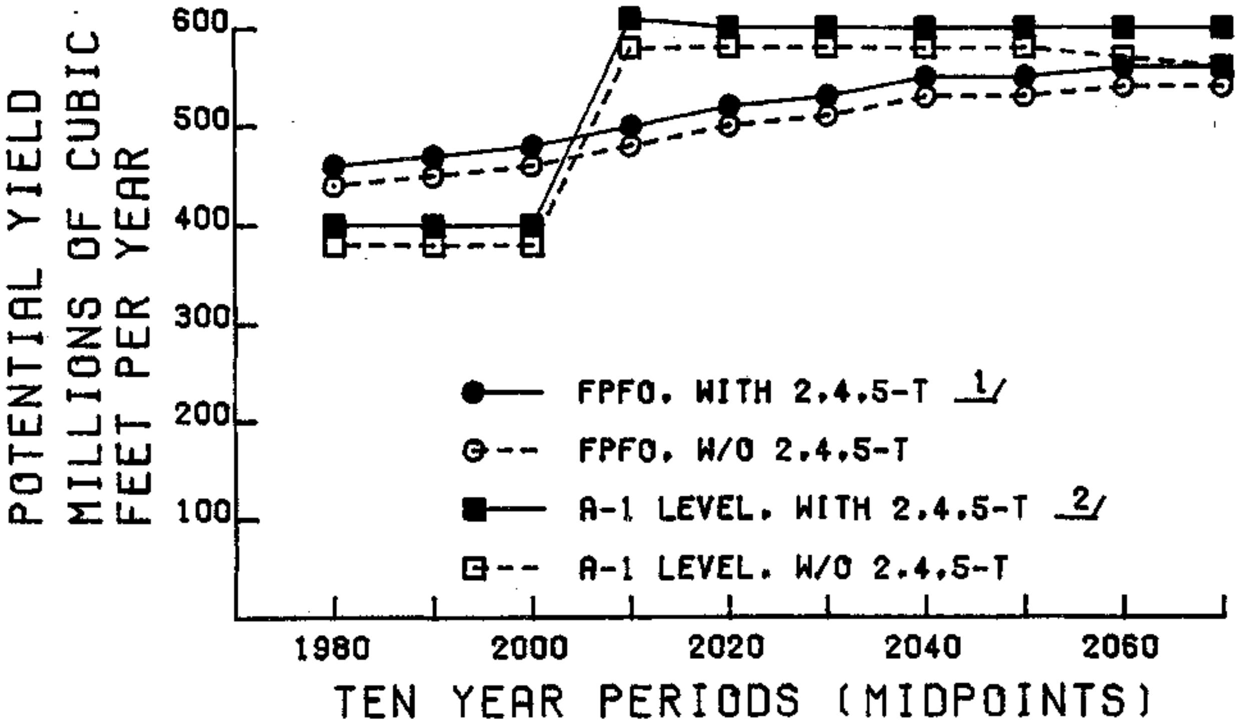

FIGURE 7. HARVEST PROJECTIONS FOR TWO MANAGEMENT INTENSITIES IN EASTERN OREGON, SHOWING ANTICIPATED LEVELS WITH AND WITHOUT 2,4,5-T

1/ FPFO: Forestry Program for Oregon (OSDF 1977). The anticipated level of management needed to maintain future harvest levels at or above current levels. Projected yield without 2,4,5-T would fall 4 percent short of FPFO potential.

2/ A-1 level (Beuter et al. 1976). The harvest levels anticipated if current policies and resultant management intensities are projected into the future. Projected yield without 2,4,5-T would fall 4 percent short of A-1 level.

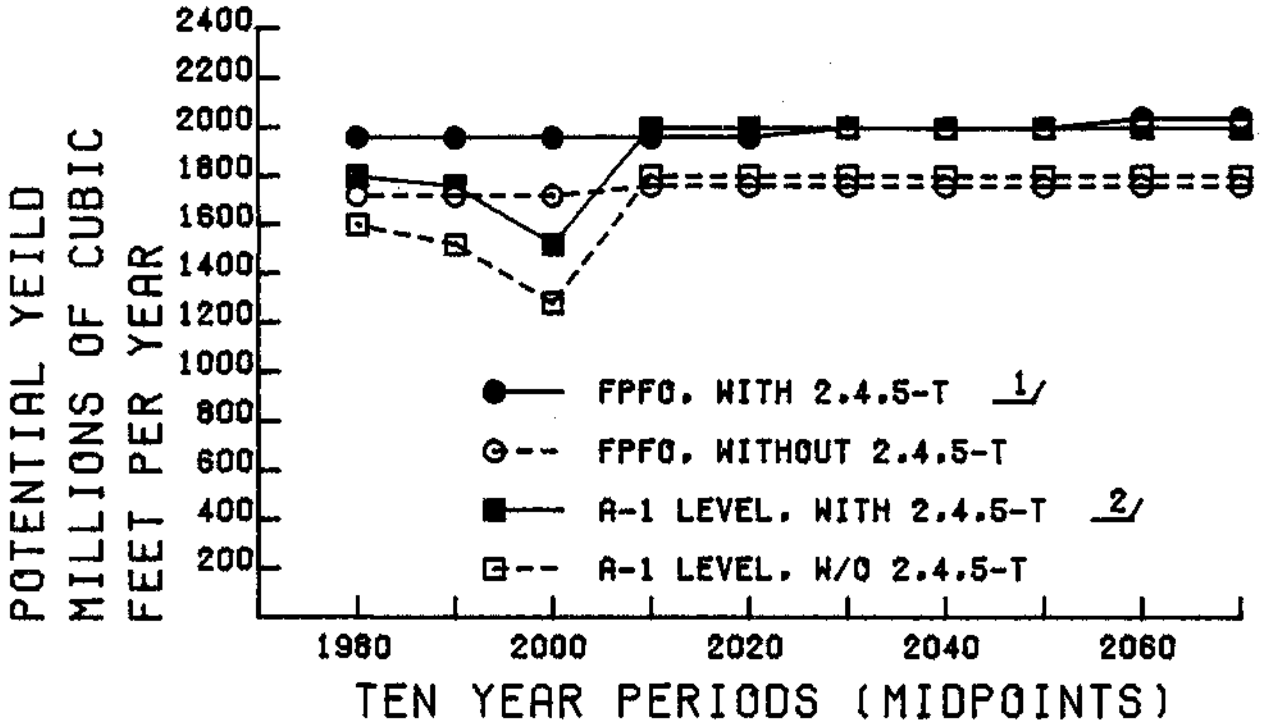

FIGURE 8. HARVEST PROJECTIONS FOR TWO MANAGEMENT INTENSITIES IN STATE OF OREGON, SHOWING ANTICIPATED LEVELS WITH AND WITHOUT 2,4,5-T

[1] FPFO: Forest Program for Oregon (OSDF 1977). The anticipated level of management needed to maintain future harvest levels at or above current levels. Projected yield without 2,4,5-T would fall 11 percent short of FPFO potential.

[2] A-1 level (Beuter et al. 1976). The harvest levels anticipated if current policies and resultant management intensities are projected into the future. Projected yield without 2,4,5-T would fall 11 percent short of A-1 level.

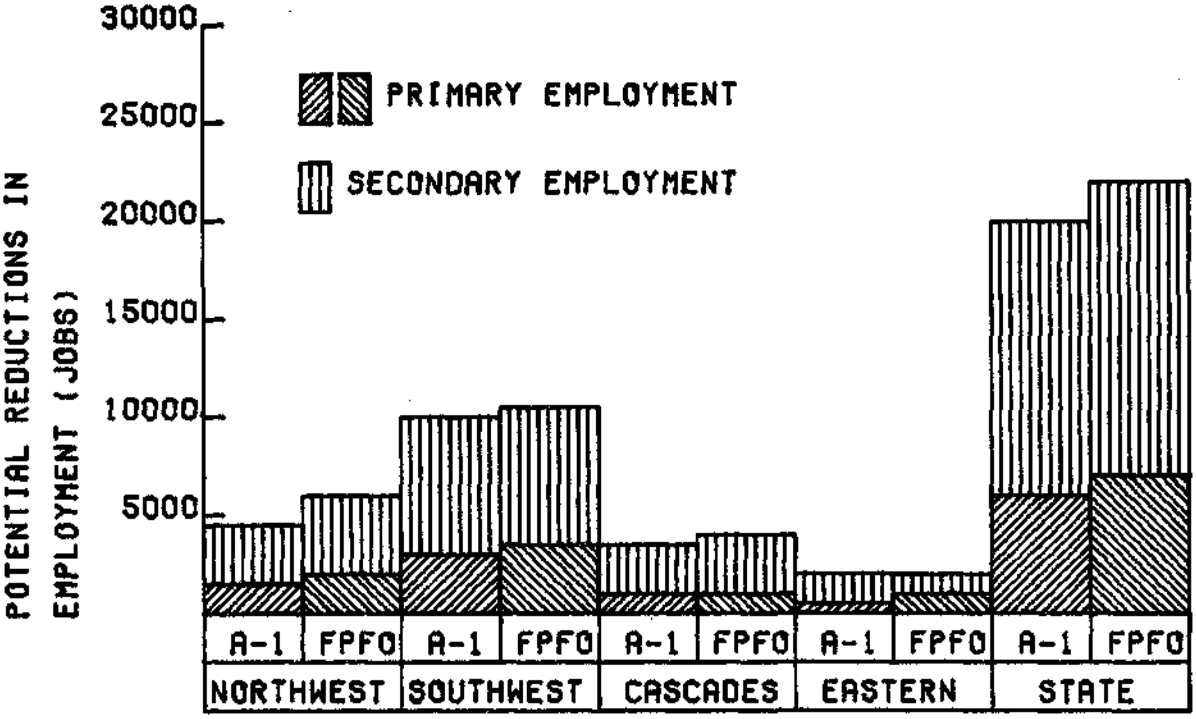

FIGURE 9. POTENTIAL REDUCTIONS IN TIMBER-RELATED EMPLOYMENT, 1980-2000, FROM LOSS OF 2,4,5-T

Table 15--Potential losses in yield and employment if 2,4,5-T is unavailable in Oregon 1/

	Geographic Area				
	Northwestern	Southwestern	Cascades	Eastern	State Total
	---Yield impacts, MMCF (percent)---				
Current Annual Yield	300	563	530	400	1,793
Reduction Without 2,4,5-T	-42(-14%)	-96(-17%)	-37(-7%)	-16(-4%)	-191(-11%)
Yield Without 2,4,5-T, MMCF	258	467	493	384	1,602
	---Yield impacts, MMBF---				
Current Annual Yield	1,470	2,759	2,597	1,960	8,786
Reduction Without 2,4,5-T	-206	-470	-181	-78	-936
Yield Without 2,4,5-T	1,264	2,289	2,416	1,882	7,850
	---Employment impacts, average job loss 1980-2000---				
Direct Employment Loss	1,546	3,235	1,145	589	6,515
Indirect Employment Loss	3,091	6,469	2,289	1,178	13,027
Total Employment Loss	4,637	9,704	3,434	1,767	19,542

1/Based on A-1 levels, representing current intensity of management. FPFO levels are approximately 13 percent greater.

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APPENDIX A

SOUTHWESTERN OREGON CASE ANALYSIS

In southwestern Oregon substitute vegetation management practices could be used on part of the commercial forest if 2,4,5-T were unavailable. These substitutes were discussed and analyzed within the body of the report using a composite approach (e.g., see tables 5 and 6).

The following discussion goes still further. It independently examines the effects of each of the major substitute methods by displaying likely yields and economic efficiencies. In essence, the discussion presents an expanded case analysis for a major timber producing area within Oregon.

RELEASE

The total area which would use 2,4,5-T was described in table 1. In southwestern Oregon, 58 percent of the commercial forest land would use 2,4,5-T just for release. Site preparation on these areas would result from logging and slash disposal from the previous rotation. Thus, the early stand development costs prior to release are the same for 2,4,5-T and its alternatives. It is only at the time of release treatment that differences between alternatives become apparent. From this point on, the cost and yield differences from the use of 2,4,5-T or its substitutes can be evaluated.

These effects are displayed in table A-1. It should be noted that if 2,4,5-T is unavailable, the next most efficient method may not be an alternative on a particular site. For example, although other chemical substitutes are economically more efficient than hand slashing or no release treatment, these chemicals will not effectively control many of the vegetative types in southwestern Oregon. This is why other chemical substitutes would be selected only about half the time (table 5).

Table A-1--The expected efficiency of alternative release methods on areas which would potentially use 2,4,5-T in southwestern Oregon 1/

Release Method	Percent Use 2/	Percent Timber Yield	Economic Efficiency 3/		
			Present Net Worth		Benefit-Cost Ratio
				Diff. From 2,4,5-T 4/	
2,4,5-T	--	100%	$612	--	4.23
Other Chemical	50%	95%	$518	-$94	3.51
No Release	35%	60%	$196	-$416	2.34
Hand Slashing	15%	85%	-$273	-$885	.70

1/Assumes site preparation was accomplished from logging and slash disposal in the previous rotation.
2/Percent of time the method would be used if 2,4,5-T were unavailable. From survey of silviculturists.
3/At Water Resources Council rate, 6-5/8 percent discount.
4/The expected difference in present net worth of the substitute method is used to replace 2,4,5-T.

Table A-2--The expected efficiency of alternative methods for site preparation, rehabilitation, and release in southwestern Oregon[1]

	Method of Release											
	2,4,5-T			Other Chemical			None			Hand Slash		
Method of Site Preparation	Yield % [2]	PNW $	B/C	Yield %	PNW $	B/C	Yield %	PNW $	B/C	Yield %	PNW $	B/C
2,4,5-T	100%	$534	3.14									
Clean Logging				54%	$114	1.59	33%	$10	1.07	52%	-$624	.31
Hand Slash-Other Chemical-Fire				90%	$130	1.26	55%	-$145	.68			
Fire				86%	$442	3.30	52%	$137	1.94			
Method of Rehabilitation												
2,4,5-T	100%	$364	2.01									
Other Chemical				76%	$81	1.18	47%	-$150	.62			
No Rehabilitation							11%	-$80	.45			
Hand Slash-Other Chemical-Fire				90%	$130	1.26	55%	-$145	.68	86%	-$564	.53

[1] Does not include areas which would use 2,4,5-T only for release.

[2] Yield is in comparison with use of 2,4,5-T.
PNW = Present Net Worth
B/C = Benefit-Cost Ratio

OTHER TREATMENTS

The herbicide 2,4,5-T is used for rehabilitation and release on 2 percent and for site preparation and release on 15 percent of the commercial forest land in southwestern Oregon. The most likely management substitutes for 2,4,5-T for site preparation, rehabilitation, and release combinations are shown in table A-2. These substitutes are contrasted with management with 2,4,5-T to show yield effects and economic efficiencies as in the previous case where release alone was examined. The analysis isolates the specific management practices rather than building a composite analysis such as that used in the main report.

APPENDIX B

SAMPLE DERIVATION OF YIELD IMPACTS

The following calculations show how the impact of cancelling forestry uses of 2,4,5-T was calculated for each silvicultural operation and how the weighted average impact for each region was derived. The Northwest Coast Range is used as an example.

STEP 1.

Selection of alternatives to 2,4,5-T. Based on the survey, the following alternative management practices were identified by one or more silviculturists for each operation. Those with an asterisk were, by consensus, the most prevalent. The proportion of use within the region for the most prevalent alternatives as derived from the survey is shown in the right-hand column. "Chemical" refers to the use of alternative chemicals that are currently registered for use.

Site Preparation Alternatives	Proportion of Use
*Chemical	0.15
*Fire	0.30
*Chemical and Fire	0.35
*No Management (clean log only)	0.20
Mechanical	--
Hand	--

Rehabilitation Alternatives	Proportion of Use
*Chemical	0.35
*Slash, Chemical, and Fire	0.50
*No Management	0.15
Chemical and Fire	--
Mechanical	--

Release Alternatives	Proportion of Use
*Chemical	0.85
*No Management	0.15
Hand	--

STEP 2.

Calculation of weighted average yield impact by silvicultural operation. Survey respondents estimated the yield impact (i.e., difference in yield attributable to using an alternative practice instead of a practice including 2,4,5-T). The average response of each alternative is shown below. The weighted average impact for each silvicultural operation overall was derived by multiplying the proportion of use by the yield impact for each alternative and summing the products.

Site Preparation

Alternative	Average Estimated Yield Impact*	Proportion of Use	Product (Yield x Use)
Fire	0.90	0.30	0.27
Chemical	1.00	0.15	0.15
Chemical and Fire	1.00	0.35	0.35
No Management (clean log)	0.70	0.20	0.14
Weighted Average			0.91

Rehabilitation

Alternative	Average Estimated Yield Impact*	Proportion of Use	Product (Yield x Use)
Chemical	0.85	0.35	0.30
Slash, Chemical, and Fire	1.00	0.50	0.50
No Management	0.10	0.15	0.015
Weighted Average			0.81

Release

Alternative	Average Estimated Yield Impact*	Proportion of Use	Product (Yield x Use)
Chemical	0.90	0.85	0.77
No Management	0.55	0.15	0.08
Weighted Average			0.85

*Estimated yield impacts are expressed as a proportion of yield obtainable with 2,4,5-T.

STEP 3.

Calculation of yield impact by not using 2,4,5-T in each region. A weighted average yield impact in each region was derived by multiplying the proportion of each silvicultural operation by its corresponding yield impact and adding the products. Survey results indicated that the number of acres needing 2,4,5-T for release equalled the total acres using 2,4,5-T for one or more silvicultural operations. It is assumed that 2,4,5-T is used for release on all the 2,4,5-T acres. In addition, it is also used for site preparation and rehabilitation on a portion of these areas. Thus, three combinations of silvicultural operations with 2,4,5-T had to be proportioned to derive a weighted yield impact; namely, site preparation and release, rehabilitation and release, and release alone. The example below shows how the operations were proportioned and the weighted average yield impact calculated.

	(Thousands of Acres)
a. Commercial forest land in N.W. Oregon[1/]	2,871.40
b. Total use of 2,4,5-T in region = 75 percent of a.[2/]	2,153.55
c. Total acres of rehabilitation[3/]	510.77
d. Rehabilitation with 2,4,5-T = 50 percent of c.[2/]	255.39
e. Remaining acres needing 2,4,5-T = 2,153.55 - 255.39 =	1,898.16
f. Site preparation with 2,4,5-T = 30 percent of e.[2/]	569.45
g. Release only with 2,4,5-T is e. - f. =	1,328.71

[1/] Data from Pacific Northwest Forest and Range Experiment Station.

[2/] Consensus estimate from survey.

[3/] Data from adding "nonstocked regeneration" and "conversion" acres from beginning inventory in Beuter et al., 1976.

Summary of Proportions of 2,4,5-T Operations in northwest Oregon

Operations	Thousands of Acres	Percent
Rehabilitation and Release	255.39	12
Site Preparation and Release	569.45	26
Release Only	1,328.71	62
TOTAL	2,153.55	100

h. Weighted yield impacts using proportions and yield impacts by operation (from Step 2):

	Yield Effects		Prop. of Area		Product
Rehabilitation and Release	0.81 x 0.85	x	0.12	=	0.08
Site Preparation and Release	0.91 x 0.85	x	0.26	=	0.20
Release Only	0.85	x	0.62	=	0.53
Weighted Average =					0.81

Thus, without 2,4,5-T there is a projected 19 percent growth or yield reduction in the northwest Oregon region compared to similar management intensity using 2,4,5-T on total 2,4,5-T acres.

To find the overall yield impact on all commercial forest land in the region, those acres not needing 2,4,5-T for any silvicultural operation must be taken into account:

Acres using 2,4,5-T	0.75 x 0.81 (from Step h.)	= 0.61
Acres not using 2,4,5-T	0.25 x 1.00 (full yield)	= 0.25
Weighted average overall yield impact		= 0.86

APPENDIX C

AMOUNT OF 2,4,5-T USED IN SILVICULTURAL OPERATIONS

CURRENT USE OF 2,4,5-T

The 1976-1977 use of 2,4,5-T for forestry operations in Oregon was determined by surveying commercial and private aerial applicators. 1/ Nineteen companies located in the Pacific Northwest were contacted. Of these, six companies had applied 2,4,5-T in Oregon for forestry purposes in either 1976 or 1977. State and federal land management agencies and most major private owners contracted with one or more of these six applicators to spray 2,4,5-T on their forest lands. These companies sprayed about 81,000 acres in calendar year 1976 and 95,000 acres in calendar year 1977, an average of 88,000 acres per year. Based on current trends, use appears to be increasing in Oregon.

Applicators and agency representatives estimated that figures supplied by these respondents accounted for over 85 percent of the aerial applications for forestry in Oregon during those years. A 100 percent survey was beyond the scope and limitations of this study. Details of the survey are on file.

CURRENT VERSUS POTENTIAL USE

Oregon has about 24 million acres of commercial forest land. Less than half of that acreage, about 11 million acres, has the type of ground cover that might require the application of 2,4,5-T to control undesirable plant species during commercial forest management. Silvicultural operations that require 2,4,5-T occur only during the early ages of a new stand of trees (i.e., 0 to 10 years); older stands in the state do not require the use of 2,4,5-T for effective forest management. Generally, 2,4,5-T is applied from one to three times on

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1/Over 98 percent of all 2,4,5-T for forestry in Oregon was applied aerially as estimated by the survey of silviculturists.

applicable acres during each rotation. Thus, only a small portion of the 11 million acres that might require 2,4,5-T would need treatment in any given year, as depicted in figure C-1, because the large majority of the forest would be older and established.

If all commercial forest lands in Oregon were managed at the intensity assumed in this report, an average of about 253,000 acres per year would require treatment with 2,4,5-T. This is the highest annual application rate which could be expected in the future. Not every commercial forest acre is presently managed this intensively, so the application rate in Oregon averages 88,000 acres per year.

For a variety of reasons that encompass landowner objectives as well as economic, political, and social constraints, the reasonable potential use level in Oregon is not likely to reach the maximum potential use. For example, some of the current constraints include the following:

* Small nonindustrial private lands generally are not managed as intensively as forest lands in other ownerships (because of other management objectives or constraints) and therefore use less 2,4,5-T than the assumed management at the potential level.

* Bureau of Land Management policy precludes the use of 2,4,5-T on forest lands in Oregon.

* National Forest lands include a large area of old growth timber that will not require 2,4,5-T until it is harvested and regenerated.

* Temporary management constraints have been imposed on the aerial application of 2,4,5-T on all forest lands through the Oregon

Forest Practices Act. These restrictions include a 200-foot buffer strip on each side of specified streams and roads and a 500-foot buffer around residences. 1/

This residence buffer has been extended to 1 mile on National Forest lands. Other restrictions have occurred, such as the 1977 court injunction against use of 2,4,5-T on the Siuslaw National Forest. This ban was extended to all National Forest lands in Washington and Oregon, but was lifted following completion of a revised environmental statement.

* Current management intensity for some owners and areas of the State is less than the maximum potential level of management. This is attributable to many reasons, including lack of awareness or knowledge, cash-flow problems, tax disincentives, owner objectives, funding constraints, environmental, political, or legal pressures from interest groups, and slow conversion from old growth to regulated forests.

1/The Oregon State Department of Forestry, in a recent unpublished study on its lands, estimated that 4 percent of the acreage in spray units could not be treated by aerial application of herbicides when buffer strips around streams were one swath width (50-75 feet); with 200-foot wide buffer strips, 18 percent of the acreage is left untreated.

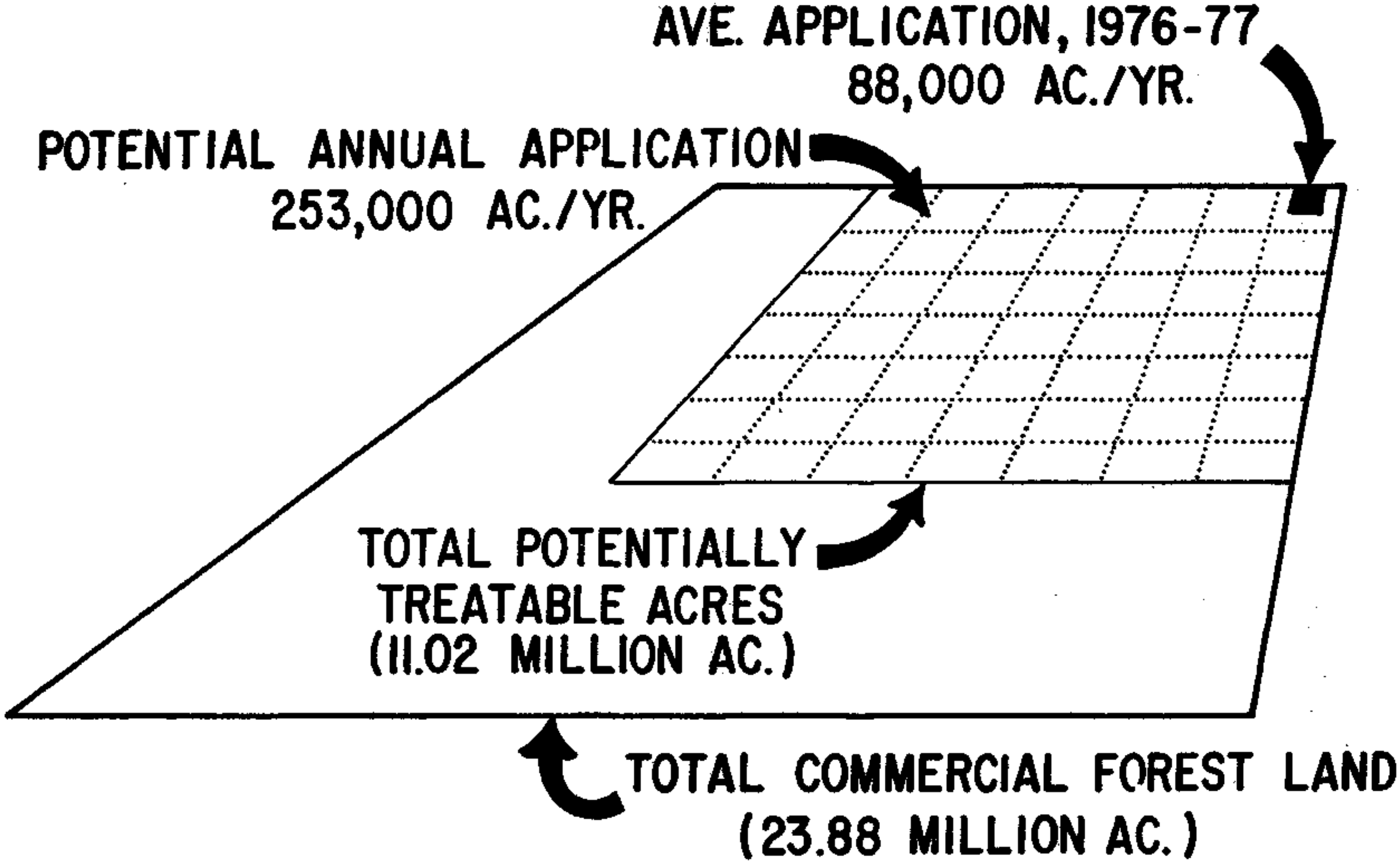

FIGURE C-1 HERBICIDE APPLICATION ON COMMERCIAL FOREST LAND IN OREGON.

APPENDIX 2

SUMMARY OF UNSOLICITED PUBLIC COMMENTS RECENTLY RECEIVED BY USDA ON THE USE OF 2,4,5-T

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The issue of public concern over the use of the herbicide 2,4,5-T is not simply stated. It is complicated and confused by many sub-issues. In the years since Rachel Carson wrote Silent Spring the public has become sensitized to the use of all pesticides. Although the initial focus of her book was on "broad spectrum insecticides," public attention has recently shifted more toward the vegetation-management chemicals--herbicides. Among these: 2,4,5-T now occupies center stage. This shift in attention appears to have resulted from:

1. Success in the regulation and restriction of the use of certain insecticides such as DDT, chlordane, heptachlor, aldrin, and dieldrin.

2. Use of a 2,4-D and 2,4,5-T formulation (Agent Orange) by the U.S. Armed Forces for military purposes in Vietnam and the general lack of support among young people for our involvement in that conflict.

3. Increasing uses of herbicides nationwide due to increasing food and fiber demands both domestic and abroad.

4. Adverse effects (from the growers' and users' points-of-view) of herbicides to destroy marijuana.

5. Presence of the toxic impurity 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) in 2,4,5-T.

6. Several recent chemical manufacturing plant accidents, industrial spills, and water-contamination incidents that are continuing to receive widespread media coverage.

These and similar considerations have changed public and scientific response to the use of herbicides from one of general indifference to one of considerable involvement in the decision-making process involving their use and regulation. Two major recent events have resulted in a considerable acceleration of public involvement; on April 11 the issuance of an RPAR on 2,4,5-T by EPA; and on April 27 the decision by the Assistant Secretary of Agriculture to personally review all proposals to use 2,4,5-T and related TCDD containing compounds on National Forest System lands. As a result, the U.S. Department of Agriculture (USDA) received, during March 1 to December 1, 1978, almost 1,000 unsolicited letters, mailgrams, and telegrams from persons concerned about the entire gamut of 2,4,5-T issues, including: registration, use, exposure, cost, alternatives, and policy on its use. A few of these were copies of information sent to EPA as a result of their issuance of the RPAR, but most were directed specifically to USDA.

The following paragraphs summarize the issues which received most attention in the correspondence.

HUMAN HEALTH

The area of human health hazard received a great amount of comment and is one of the most emotional issues relating to 2,4,5-T. Many citizens do not accept EPA registration as an adequate guarantee of safety. Instances of anecdotal information on adverse human health effects were presented in all forms of correspondence ranging from affidavits to appeals. Medical opinions supporting adverse effects due to 2,4,5-T exposure were presented in a few instances. Overwhelmingly, however, actual 2,4,5-T users reported no observed adverse human health effects. In fact, 134 users indicated a combined total of 2,650 person-years of experience with, and direct exposure to 2,4,5-T with no adverse effects. They strongly suggest that their ± 30 year record is the best evidence

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1. Success in the regulation and restriction of the use of certain insecticides such as DDT, chlordane, heptachlor, aldrin, and dieldrin.

2. Use of a 2,4-D and 2,4,5-T formulation (Agent Orange) by the U.S. Armed Forces for military purposes in Vietnam and the general lack of support among young people for our involvement in that conflict.

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4. Adverse effects (from the growers' and users' points-of-view) of herbicides to destroy marijuana.

5. Presence of the toxic impurity 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) in 2,4,5-T.

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COST/BENEFIT ANALYSIS OF 2,4,5-T

Major concerns were expressed in the correspondence about the cost of 2,4,5-T relative to the costs of alternatives, and the benefits of using manual labor to assist local economies by reducing unemployment. Most of these responses dealt with the use of the herbicide for forest vegetation management. Throughout the correspondence against the use of 2,4,5-T there was concern that the frequently quoted costs of its use were inordinately low as compared to costs of alternatives. Actual use figures presented in the correspondence were computed for the various vegetation management alternatives as follows:

Cost Comparison

Vegetation management alternative	Average cost/acre of treatment	Range of costs	Number of respondents
Aerial release with 2,4,5-T	$ 20.53	$ 10-35	41
Manual release (without herbicide)	249.13	94-500	24
Mechanical release	147.95	60-375	11
Manual release (with herbicide using ground equipment)	80.13	68-123	4
Aerial site preparation with 2,4,5-T	20.00	10-35	3
Manual site preparation with herbicide	150.00	100-200	2

These actual costs indicate that 2,4,5-T is very cost effective and that alternatives, although used, are 7 to 12 times more expensive.

A related topic of discussion in the correspondence is the viewpoint that the use of manual labor could reduce local unemployment. This socio-economic counterbalance might thereby influence any decision where cost differential was being considered. In actual practice, however, the correspondence indicates that an available work force of manual laborers to do this kind of work simply does not exist in most areas.

ALTERNATIVES

There are a number of possible alternatives to the use of herbicides. However, their acceptability, as indicated in the correspondence, was highly dependent on the particular special interests of individual correspondents.

Manual control of vegetation was the most frequently proposed alternative to the use of herbicides. This method supposedly devoid of toxicological effects is seen as a highly desirable technique by many citizens. The major drawbacks of manual control expressed by those involved in vegetation management are those of cost, ineffectiveness necessitating repetitive treatments, lack of labor, human health hazard, and creation of excessive fire hazard through fuel concentration.

Mechanical control was suggested as a solution in some correspondence. Recognized by those involved in vegetation management as a viable alternative, mechanical control is dependent on gentle topography with well-drained soils and lack of large rocks or stumps. Soil compaction, erosion and nutrient leaching were discussed as frequently accompanying mechanical control operations.

Fire was also a frequently discussed alternative to herbicides. Although burning was preferred by some, it was recognized by those with actual use experience as having more dramatic ecological effects than herbicides.

The correspondence which involves over 3,100 pages of views, opinions, and factual data represents a broad cross-section of interests nationwide.

A content analysis of the correspondence indicates a ratio of 2.3:1 in favor of 2,4,5-T use in vegetation-management programs. This can be summarized as follows:

2,4,5-T USERS

	Number	Percent
Commercial (pest-control operators, industry representatives, consulting foresters, forest-products personnel, etc.)	186	20.2
Noncommercial (universities, weed-control districts, Government agencies, etc.)	5	.5
Private citizens (farmers, ranchers, homeowners, etc.)	86	9.3

NONUSERS

	Number	Percent		Number	Percent
Family of user	4	0.4	Governmental agency		
Forest resident	15	1.6	Federal	1	0.1
Woods worker	20	2.2	State	10	1.1
Recreationist	2	.2	Local	7	.7
Citizen	262	28.5	Organization/Assoc.	143	15.5
Elected Official	40	4.3	Industry Rep.	112	12.2
Academician	26	2.8	Other	1	0.1

Among 2,4,5-T users, commercial concerns represented primarily by professional or consulting foresters, accounted for the greatest number of responses (20.2%). Among non-2,4,5-T users, individual citizen response was the greatest, accounting for more than 28 percent of the total number of responses.

Correspondence from 277 persons expressed opposition to the use of 2,4,5-T in general, use of 2,4,5-T in Forest Service Regions 1 (Idaho), 5 (California), and 6 (Oregon and Washington) as outlined in their respective environmental statements, and use of chemical pesticides in general.

Opposition to the use of herbicides in the form of "Motions to Stay Decisions and Appeals" was received from 36 groups representing 1,221 persons as indicated by signed petitions, affidavits, and related appeal documentation.

Correspondence was received from 643 persons representing citizens, users, industry representatives, etc. supportive of the registration and use of 2,4,5-T. Herbicide-use support letters received from organizations and associations (e.g., National Cattleman's Association, American Farm Bureau, Society for Range Management, Western Environmental Trade Association, Society of American Foresters, Alaska Loggers Association, etc.) indicated a combined membership of more than 327,522 members in favor of continued use of 2,4,5-T.

In summary, it is apparent that in the future, the general public will expect persons involved in vegetation-management activities to fully examine all alternatives to the use of herbicides. The environmental consequences of both chemical and nonchemical alternatives may not be ecologically superior to the careful, safe use of currently registered herbicides documented by the many letters by actual users with long records of experience and exposure who strongly support the continued use of 2,4,5-T.

APPENDIX III

EXCERPTS FROM POSITION DOCUMENT - 1 (PD-1)

US EPA, 2,4,5-T WORKING GROUP

III. B. (3) Exposure Analysis

(a) Oral Exposure pages 102-104

For purposes of this analysis, the Working Group considered currently registered uses where the possibility of oral exposure to 2,4,5-T and/or TCDD existed. Treatment of range and pasture land could result in oral exposure through ingestion of meat and milk from animals grazing on the treated area. Since actual data on residues of 2,4,5-T in animals grazing on treated rangeland is unavailable, for purposes of the 2,4,5-T oral exposure analysis, the Working Group used residue information obtained in a feeding study (37) in which cattle were fed considerably higher amounts of 2,4,5-T than they would normally be exposed to in grazing on treated land. The following calculations are based on the average quantities of food eaten per day (1.5 kg), as reported by Lehman (144, 165).

To find the average daily intake of a single food item, multiply the average daily food intake by the percent of that item in the total diet: for milk, 1.5 kg X 19.6% = 0.294 kg; and for meat (beef), 1.5 kg X 4.6% = 0.069 kg.

The quantity of 2,4,5-T in the average daily diet equals the average daily intake of each food item multiplied by the level of 2,4,5-T in the food item: for milk, 0.294 kg X 0.103 ppm = 0.03 mg; and for meat (beef), 0.069 kg X 0.2 ppm = 0.014 mg.

The theoretical exposure of an average woman equals the amount of 2,4,5-T in the daily diet divided by the weight of the average woman: for milk, 0.03 mg / 60 kg = 0.0005 mg/kg; and for meat (beef), 0.014 mg / 60 kg = 0.0002 mg/kg; total exposure from milk and beef products could be 0.0007 mg/kg per day.

Existing data on TCDD residues in animals grazing on treated rangeland are too meager to use for an analysis of TCDD exposure to humans through ingestion of meat or milk from animals so exposed.

The Working Group considers that the difference between the no-adverse-effect level of 2,4,5-T for teratogenic effects (20 mg/kg) and the calculated oral exposure level for 2,4,5-T (0.0007 mg/kg per day) does constitute an

Table 25. 2,4,5-T Oral Exposure Analysis

	Whole Milk	Meat (Beef)
No-adverse-effect level for teratogenicity in mice	20 mg/kg	20 mg/kg
Average level of 2,4,5-T identified	0.103 ppm[a/]	0.2 ppm[a/]
% of food item in total human diet	19.6%	4.6%
Average amount of food eaten per day	1.5 kg	1.5 kg
Exposure to 2,4,5-T per day	0.0005 mg/kg	0.0002 mg/kg

a/ Animals were fed at 300 ppm 2,4,5-T in the diet for 2 to 3 weeks. This is a worst case assumption for cows grazing on freshly-treated pasture without a withdrawal period; all milk and meat was obtained from such cows. Meat (beef) includes muscle, fat, and liver tissues which constitute the major portion of edible meat.

ample margin of safety. Since this risk criterion for other chronic adverse effects has not been met or exceeded, a rebuttable presumption does not arise.

III. B. (3) Exposure Analysis
(b) Dermal
(i) Back Pack pages 105 - 108

For purposes of this analysis, the Working Group assumes the applicator to be a 60-kg woman of child-bearing age, and the site of application either a right-of-way or spot treatment of pasture or rangeland. The equipment is a back-pack sprayer (166). The following calculations of exposure are based on dilution for spraying of three pints of formulated product per 32 pints of water. Typical 2,4,5-T formulations, based on inspection of a large number of registered labels (164), range from 4 to 6 pounds active ingredient (acid equivalent) per gallon. The product used in this exposure analysis has an assumed concentration of 4 pounds 2,4,5-T per gallon. Label recommendations vary from a recommended dilution of 0.094 to 4 pounds acid equivalent per 32 pints of water. A dilution rate of 1.6 pounds per 32 pints has been selected as representative of a typically-used spray mixture.

Wolfe et al. (166) studied dermal exposure to fenthion during hand back-pack spraying for mosquitoes for ten situations. Exposure ranged from 0.1 to 6.3 mg/hr, with a mean value of 3.6 mg/hr (6 ml/hr). Method of application was a hand pressure sprayer, using a 0.06% spray. Workers wore short-sleeved, open-necked shirts with no gloves or hat. Based on Wolfe's data, CED (164) calculated a dermal exposure of approximately 0.177 pints per day. CED (164) also determined that approximately 10% of the 2,4,5-T and TCDD coming in contact with the skin of the applicators would be absorbed even after washing, based on absorption studies with other pesticides (145, 146, 163).

Table 26. Back-pack Sprayer Dermal Exposure Data

	2,4,5-T	TCDD
Use Dilution rate	3 pints (1.6 pounds 2,4,5-T) per 32 pints water	3 pints (0.00000016 pounds TCDD) per 32 pints water
Amount of diluted material gotten on skin daily	0.18 pint	0.18 pint
% Diluted material absorbed	10%	10%
Exposure level	409 mg	0.0409 ug
Dose level	6.8 mg/kg	0.0007 ug/kg
No-Adverse-Effect level for teratogenic effects	20 mg/kg	0.03 ug/kg

The following calculations (see Table 27 for mathematics) will give the daily dermal exposure for both 2,4,5-T and TCDD: 1) convert the dilution rate to grams; 2) multiply this figure by 1,000 (for 2,4,5-T) to convert to milligrams and by 1,000,000 (for TCDD) to convert to micrograms; 3) multiply this figure by the daily dermal dose of diluted material; 4) multiply this figure by the percent absorbed; and 5) divide this figure by the weight of the applicator for the daily exposure to 2,4,5-T or TCDD per 8-hour working day.

Table 27

2,4,5-T	TCDD
1) 1.6 pounds/32 pt X 454 g/-pound = 22.70 g/pt;	1) 0.00000016 pounds/-32 pt X 454 g/pound = 0.00000227 g/pt;
2) 22.70 g/pt X 1,000 mg/g = 22,700 mg/pt;	2) 0.00000227 g/pt X 1,000,000 ug/g = 2.27 ug/pt;
3) 22,700 mg/pt X 0.18 pt = 4,086 mg;	3) 2.27 ug/pt X 0.18 pt = 0.41 ug;
4) 4,086 mg X 10% = 408.6 mg	4) 0.41 ug X 10% = 0.041 ug;
5) 408.6 mg / 60 kg = 6.8 mg/kg per day	5) 0.041 ug / 60 kg = 0.0007 ug/kg per day

The Working Group considers that the difference between the no-adverse-effect level of 2,4,5-T for teratogenic effects (20 mg/kg) and this calculated dermal exposure level for 2,4,5-T (6.8 mg/kg), as well as the difference between the no-adverse-effect level of TCDD for teratogenic effects (0.03 ug/kg) and this calculated exposure level for TCDD (0.0007 ug/kg), do not constitute an ample margin of safety. The Working Group therefore recommends issuance of a rebuttable presumption against pesticide products containing 2,4,5-T and/or TCDD pursuant to 40 CFR Section 162.11(a)(3)(ii)(B).

III. B. (3) Exposure Analysis
(b) Dermal
(ii) Tractor Mounted pages 108 - 110

For the purpose of this analysis, the Working Group assumes the applicator to be a 60-kg female of child-bearing age clearing brush on either rangeland or rights-of-way. The same product cited above (2,4,5-T at 4 pounds/gal) is being used, and the dilution rate is 1.6 pounds of formulation to 32 pints of water (equal to 4 pounds of 2,4,5-T per 10 gallons of water). Based on exposure studies using similar equipment but a different herbicide (147), the Working Group determined that, during an eight-hour working day, the applicator would get 0.048 pints of diluted material on her skin. The Working Group determined that 10% of the pesticide on the skin would be absorbed (145, 146, 163).

Table 28. Dermal Exposure Data (Tractor Mounted Equipment)

	2,4,5-T	TCDD
Use Dilution rate	3 pints (1.6 pounds 2,4,5-T) per 32 pints water	3 pints (0.00000016 pounds TCDD) per 32 pints water
Amount of diluted material gotten on skin daily	0.048 pint	0.048 pint
% Diluted material absorbed	10%	10%
Exposure level	109 mg	0.0109 ug
Dose level	1.8 mg/kg	0.00018 ug/kg
No-Adverse-Effect level for terato-genic effects	20 mg/kg	0.03 ug/kg

The following calculations (see Table 29 for mathematics) will give the daily dermal exposure for both 2,4,5-T and TCDD: 1) convert the dilution rate to grams; 2) multiply this figure by 1,000 (for 2,4,5-T) to convert to milligrams and by 1,000,000 (for TCDD) to convert to micrograms; 3) multiply this figure by the daily dermal dose of diluted material; 4) multiply this figure by the percent absorbed; and 5) divide this figure by the weight of the applicator for the daily exposure to 2,4,5-T or TCDD per 8-hour working day.

Table 29

2,4,5-T	TCDD
1) 1.6 pounds/32 pt X 454 g/-pound = 22.70 g/pt;	1) 0.00000016 pounds/-32 pt X 454 g/pound = 0.00000227 g/pt;
2) 22.70 g/pt X 1,000 mg/g = 22,700 mg/pt;	2) 0.00000227 g/pt X 1,000,000 ug/g = 2.27 ug/pt;
3) 22,700 mg/pt X 0.048 pt = 1,089.6 mg;	3) 2.27 ug/pt X 0.048 pt = 0.109 ug;
4) 1,089.6 mg X 10% = 108.96 mg;	4) 0.109 ug X 10% = 0.011 ug;
5) 108.96 mg / 60 kg = 1.8 mg/kg per day	5) 0.011 ug / 60 kg = 0.00018 ug/kg per day

The Working Group considers that the difference between the no-adverse-effect level of 2,4,5-T for teratogenic effects (20 mg/kg) and this calculated dermal exposure level for 2,4,5-T (1.8 mg/kg), as well as the difference between the no-adverse-effect level of TCDD for teratogenic effects (0.03 ug/kg) and this calculated exposure level for TCDD (0.00018 ug/kg), do not constitute an ample margin of safety. The Working Group therefore recommends issuance of a rebuttable presumption against pesticide products containing 2,4,5-T and/or TCDD pursuant to 40 CFR Section 162.11(a)(3)(ii)(B).

III. B. (3) Exposure Analysis
(b) Dermal
(iii) Aerial Application pages 110 - 113

Caplan et al. (167), working with aerially applied malathion in oil sprays applied at 0.46 pounds per 0.76 gallons water/acre, determined a dermal exposure to persons directly beneath the spray plane for bare skin (head, neck, shoulders, forearms, hands, and thighs) of 3.556 mg/day. With these data, an equivalent dermal exposure for 2,4,5-T and TCDD, aerially applied at 4 pounds acid equivalent 2,4,5-T per 10 gallons water/acre, can be determined.

Table 30. Dermal Exposure Data (Aerial Application)

Dermal exposure to aerially applied malathion	3.556 mg/0.46 pounds malathion per acre	
	2,4,5-T	TCDD
Use Dilution rate	4 pounds 2,4,5-T per 10 gallons of water/acre	0.0000004 pounds TCDD per 10 gallons of water per acre
% Diluted material absorbed	10%	10%
Exposure level	3.1 mg	0.0003 ug
Dose level	0.051 mg/kg	5×10^{-6} ug/kg
No-Adverse-Effect level for teratogenic effects	20 mg/kg	0.03 ug/kg

The following calculations (see Table 31 for mathematics) will give the daily dermal exposure for both 2,4,5-T and TCDD: 1) divide the dermal exposure to malathion by the malathion application rate and multiply by the application rate of 2.4.5-T and TCDD to obtain the dermal exposure; for TCDD, multiply this figure by 1,000 to convert to micrograms; 2) multiply this figure by the percent absorbed; and 3) divide this figure by the weight of the applicator for the daily exposure to 2,4,5-T or TCDD per 8-hour working day.

Table 31

2,4,5-T	TCDD
1) 3.556 mg/0.46 pounds X 4 pounds = 31 mg;	1) 3.556 mg/0.46 pounds X 0.0000004 pounds = 0.000003 mg X 1,000 = 0.003 ug;
2) 31 mg X 10% = 3.1 mg;	2) 0.003 ug X 10% = 0.0003 ug;
3) 3.1 mg/ 60 kg = 0.051 mg/kg per day	3) 0.0003 ug / 60 kg = 5×10^{-6} ug/kg per day

The Working Group considers that the difference between the no-adverse-effect level of TCDD for teratogenic effects (0.03 ug/kg) and this calculated dermal exposure level for TCDD (5×10^{-6} ug/kg) does constitute an ample margin of safety. The Working Group also considers, however, that the difference between the no-adverse-effect level of 2,4,5-T for teratogenic effects (20 mg/kg) and this calculated dermal exposure level for 2,4,5-T (0.051 mg/kg) does not constitute an ample margin of safety. The Working Group therefore recommends issuance of a rebuttable presumption against pesticide products containing 2,4,5-T pursuant to 40 CFR Section 162.11(a)(3)(ii)(B).

There are no studies available on inhalation exposure of 2,4,5-T. There are, however, several studies on inhalation exposure to malathion (167, 168) which CED used as a model for this 2,4,5-T exposure analysis (164). Caplan et al. (167) determined an air concentration, for unprotected persons directly beneath the spray plane during application and for two hours afterward, of 0.067 mg malathion/m^3 from aerial application of 0.46 pounds AI/gallon per acre. The collection period spanned the course of the actual application time plus two hours thereafter. The authors considered the sampling technique to be equivalent to average inspiration through the nostrils. This inhalation exposure (amount available for inhalation) was 12% of the applied malathion. Caplan et al. further reported that the average median diameter (= volume median diameter, or vmd[16/]) was 109 microns. Based on work by Akesson and Yates (168), CED (164) estimated that the size of the malathion droplets which could be inhaled was under 60 microns. Since 2,4,5-T is typically applied as a medium or coarse spray, while malathion is applied as a fine spray, the percent of 2,4,5-T droplets small enough to be inhaled (under 60 microns) would be less than the percent of malathion droplets small enough to be inhaled. According to

16/ The vmd is that droplet size which divides the total volume of drops in half, i.e., 50% of the volume is in drops above the vmd size and 50% below it.

Akesson and Yates (168), 2% of 2,4,5-T spray droplets would be available for inhalation (or 1/6 the amount of malathion droplets available for inhalation), on a "worst case" basis.

Table 32. Inhalation Exposure Data (Aerial Application)

Air concentration of aerially applied malathion	0.067 mg/m^3 with application rate of 0.46 pounds malathion per gallon per acre	
	2,4,5-T	TCDD
Use Dilution rate	4 pounds 2,4,5-T per 10 gallons of water/acre	0.0000004 pounds TCDD per 10 gallons of water per acre
Lung Absorption Rate	100%	100%
Breathing Rate	1.8 m^3/hr	1.8 m^3/hr
Exposure level	0.34 mg per 2 hr	0.000032 ug per 2 hr
Dose level	0.023 mg/kg per 8 hr	2 X 10^{-6}ug/kg per 8 hr
No-Adverse-Effect level for teratogenic effects	20 mg/kg	0.03 ug/kg

The following calculations (see Table 33 for mathematics) will give the daily inhalation exposure for both 2,4,5-T and TCDD: 1) multiply the air concentration of malathion by the amount of 2,4,5-T and TCDD applied, then multiply this figure by 1/6 for the inhalation exposure to 2,4,5-T and TCDD; for TCDD, multiply this figure by 1,000 to convert to micrograms; 2) multiply this figure by the breathing rate; 3) multiply this figure by eight [8] to get the 8-hour exposure total; and 4) divide this figure by the weight of the applicator for the inhalation exposure to 2,4,5-T or TCDD per 8-hours exposure.

Table 33.

2,4,5-T	TCDD
1) 0.067 mg/cu m per 0.46 pounds X 4 pounds = 0.58 mg/cu m X 1/6 = 0.097 mg/cu m;	1) 0.067 mg/cu m per 0.46 pounds X 0.0000004 pounds = 0.000000058 mg/cu m X 1/6 = 0.000000009 mg/cu m X 1,000 = 0.000009 ug/cu m;
2) 0.097 mg/cu m X 1.8 cu m/-hr = 0.17 mg/hr;	2) 0.000009 ug/cu m X 1.8 cu m/hr = 0.000016 ug/hr;
3) 0.17 mg/hr X 8 = 1.36 mg;	3) 0.000016 ug/hr X 8 = 0.000128 ug;
4) 1.36 mg / 60 kg = 0.026 mg/kg exposure per day	4) 0.000128 / 60 kg = $2 X 10^{-6}$ ug/kg per day

The Working Group considers that the difference between the no-adverse-effect level of TCDD for teratogenic effects (0.03 ug/kg) and this calculated dermal exposure level for TCDD ($2 X 10^{-6}$ ug/kg) does constitute an ample margin of safety. The Working Group also considers,

however, that the difference between the no-adverse-effect level of 2,4,5-T for teratogenic effects (20 mg/kg) and this calculated dermal exposure level for 2,4,5-T (0.026 mg/kg[17/])

17/ Johnson (63) [see Section I.G.(3)], in a review article, calculated a daily inhalation exposure to phenoxy herbicides of 0.025 ug/kg for a 70-kg adult. The calculations were based on actual air monitoring data of air samples collected in two wheat-growing areas in the state of Washington during spring and summer and analyzed for phenoxy herbicides. The author did not specify how soon after application the samples were taken.

does not constitute an ample margin of safety. The Working Group therefore recommends issuance of a rebuttable presumption against pesticide products containing 2,4,5-T pursuant to 40 CFR Section 162.11(a)(3)(ii)(B).

III. B. (3) Exposure Analysis
(d) Cumulative pages 116 - 117

The Working Group has also considered the possibility of a single individual being exposed through two or more of the above routes. The results (derived from Tables 27, 29, and 31) are shown in Table 34. The Working Group also notes that possible cumulative exposure to several dioxin-containing pesticides could increase the total body burden and increase total risk from dioxin exposure.

The Working Group considers that the differences between the no-adverse-effect level of TCDD for teratogenic effects (0.03 ug/kg) and the calculated cumulative exposure levels for TCDD in Situations 2 and 3 (see Table 34) do constitute an ample margin of safety. The Working Group also considers, however, that the differences between the no-adverse-effect levels of 2,4,5-T and TCDD for teratogenic effects (20 mg/kg and 0.03 ug/kg, respectively) and the calculated cumulative exposure levels for 2,4,5-T in Situations 1, 2, and 3 and TCDD in Situation 1 (see Table 34) do not constitute an ample margin of safety. The Working Group therefore recommends issuance of a rebuttable presumption against pesticide products containing 2,4,5-T pursuant to 40 CFR Section 162.11(a)(3)(ii)(B).

Table 34. Cumulative Exposure to 2,4,5-T and TCDD

Situation #1: 2,4,5-T	Situation #1: TCDD
Oral- 0.0007 mg/kg	Oral- -----
Dermal- 6.8 mg/kg	Dermal- 0.0007 ug/kg
Inhal.- 0.2 mg/kg[a/]	Inhal.- negligible[a/]
Cum. = 7.0 mg/kg	Cum. = 0.0007 ug/kg
Situation #2: 2,4,5-T	**Situation #2: TCDD**
Oral- 0.0007 mg/kg	Oral- -----
Dermal- 1.8 mg/kg	Dermal- 0.00018 ug/kg
Inhal.- 0.05[a/]	Inhal.- negligible[a/]
Cum. = 1.85 mg/kg	Cum. = 0.00018 ug/kg
Situation #3: 2,4,5-T	**Situation #3: TCDD**
Oral- 0.0007 mg/kg	Oral- -----
Dermal- 0.051 mg/kg	Dermal- 5×10^{-6} ug/kg
Inhal.- 0.026 mg/kg	Inhal.- 2×10^{-6} ug/kg
Cum. = 0.0777 mg/kg	Cum. = 7×10^{-6} ug/kg

a/ Calculations were made on a worst-case basis as 3% of dermal exposure based on Wolfe (179) who states, "over 97% of the pesticide to which the body is subjected during most exposure situations, and especially to applicators of liquid sprays, is deposited on the skin." TCDD inhalation exposure values were negligible: Situation #1, 21×10^{-6} ug/kg; Situation #2, 54×10^{-7} ug/kg.