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FINAL DRAFT REPORT

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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.

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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	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 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:

	Margin of safety			
	2,4,5-T		TCDD	
Exposure scenario[a/]	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.

TABLE OF CONTENTS

CHAPTER 2: PART 2. ECONOMIC IMPLICATIONS OF 2,4,5-T USE ON PASTURE AND RANGELANDS.......... 2-55

CHAPTER 3. THE BIOLOGIC AND ECONOMIC ASSESSMENT OF 2,4,5-T USE IN THE MANAGEMENT OF RIGHTS-OF-WAY IN THE UNITED STATES........................ 3-1

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:

		Cumulative		
Section and end of year	Annual reduced timber growth	Increased management cost	Reduced timber harvest	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.

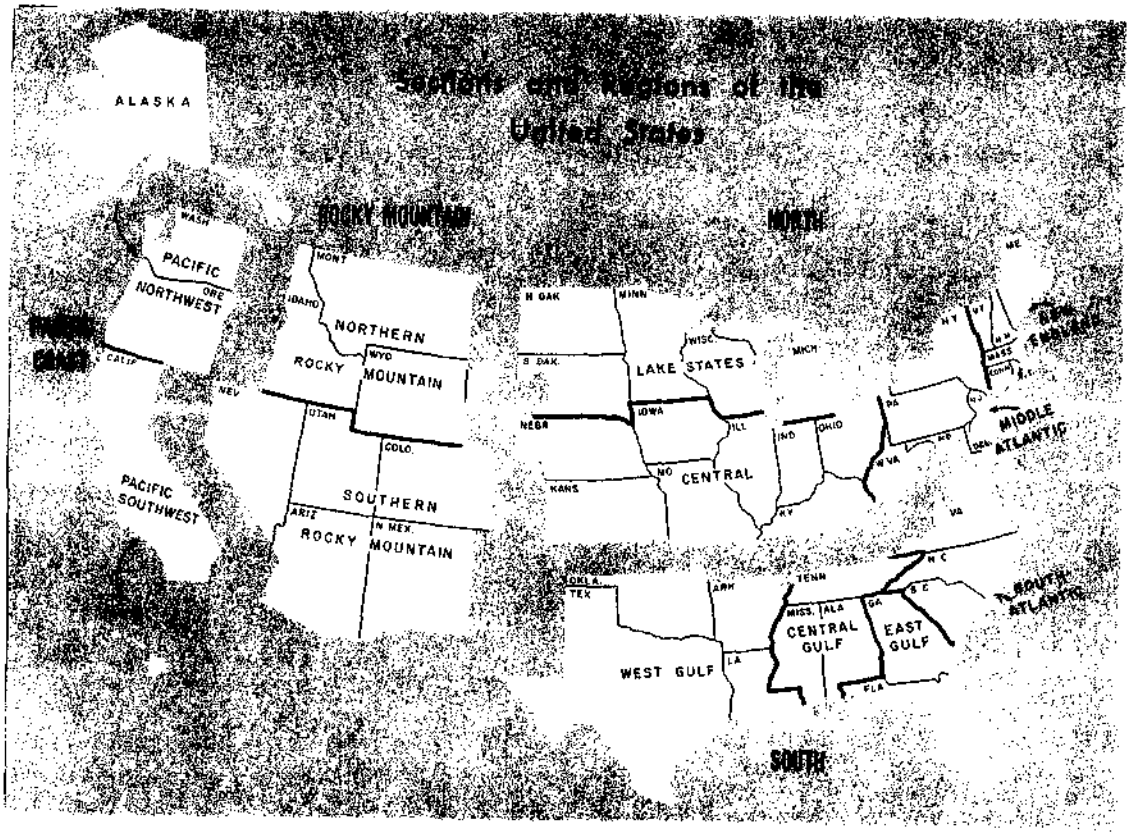

Figure 1. Sections and regions of the United States used in the timber commodity assessment.

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.

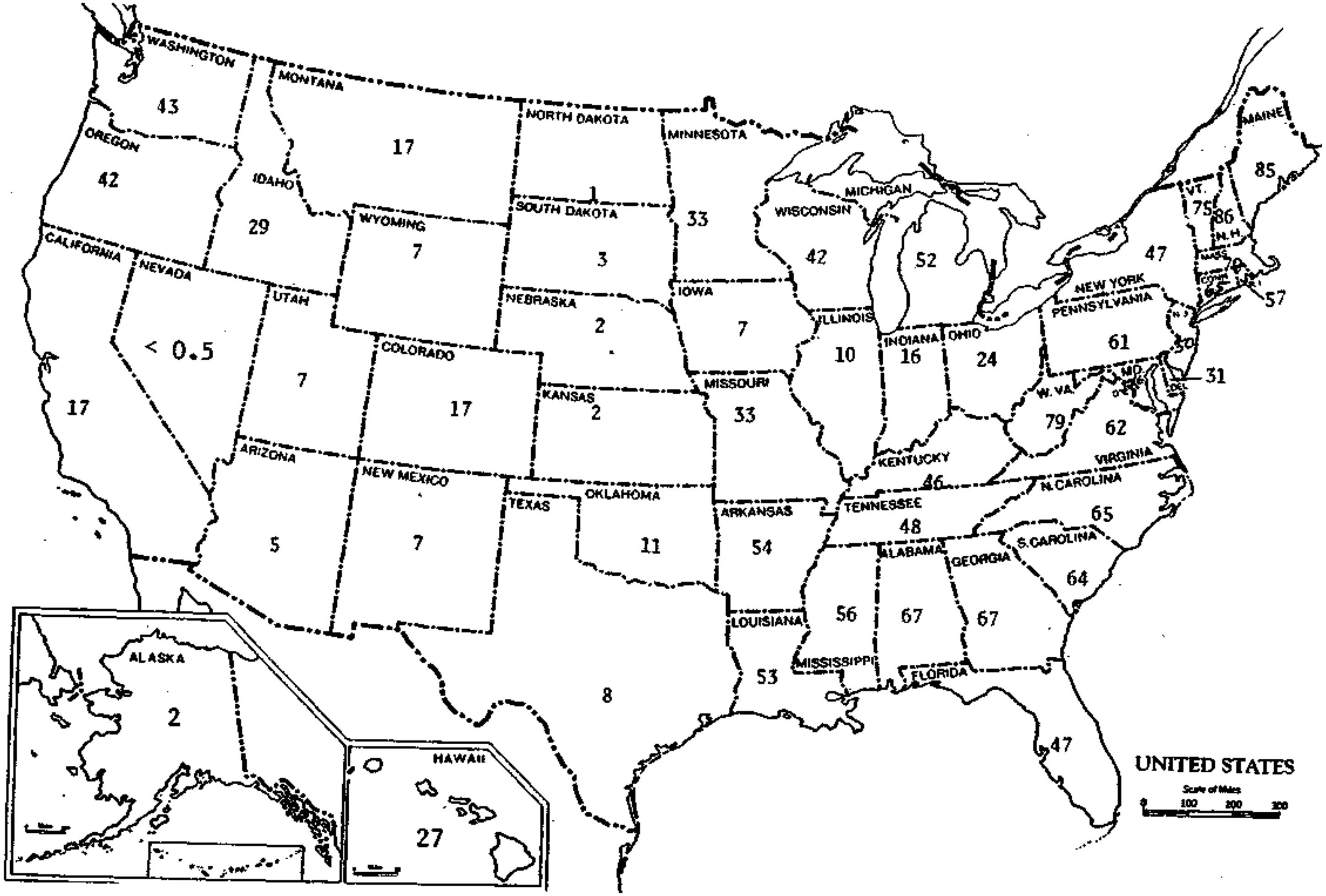

Figure 2. Commercial forest land by State as a percentage of total land area.

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

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[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

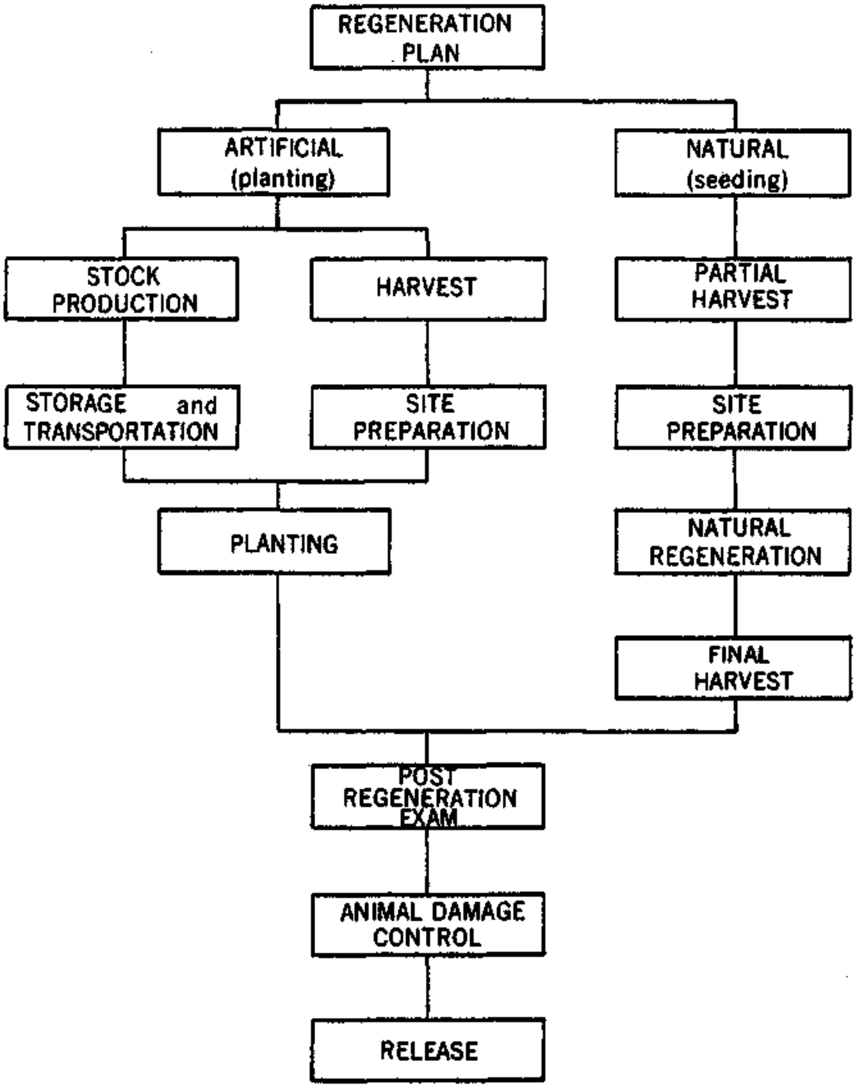


Figure 3. Sequence of steps before and after harvest operation to obtain either natural or artificial regeneration (from Cleary and Greaves 1974).

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

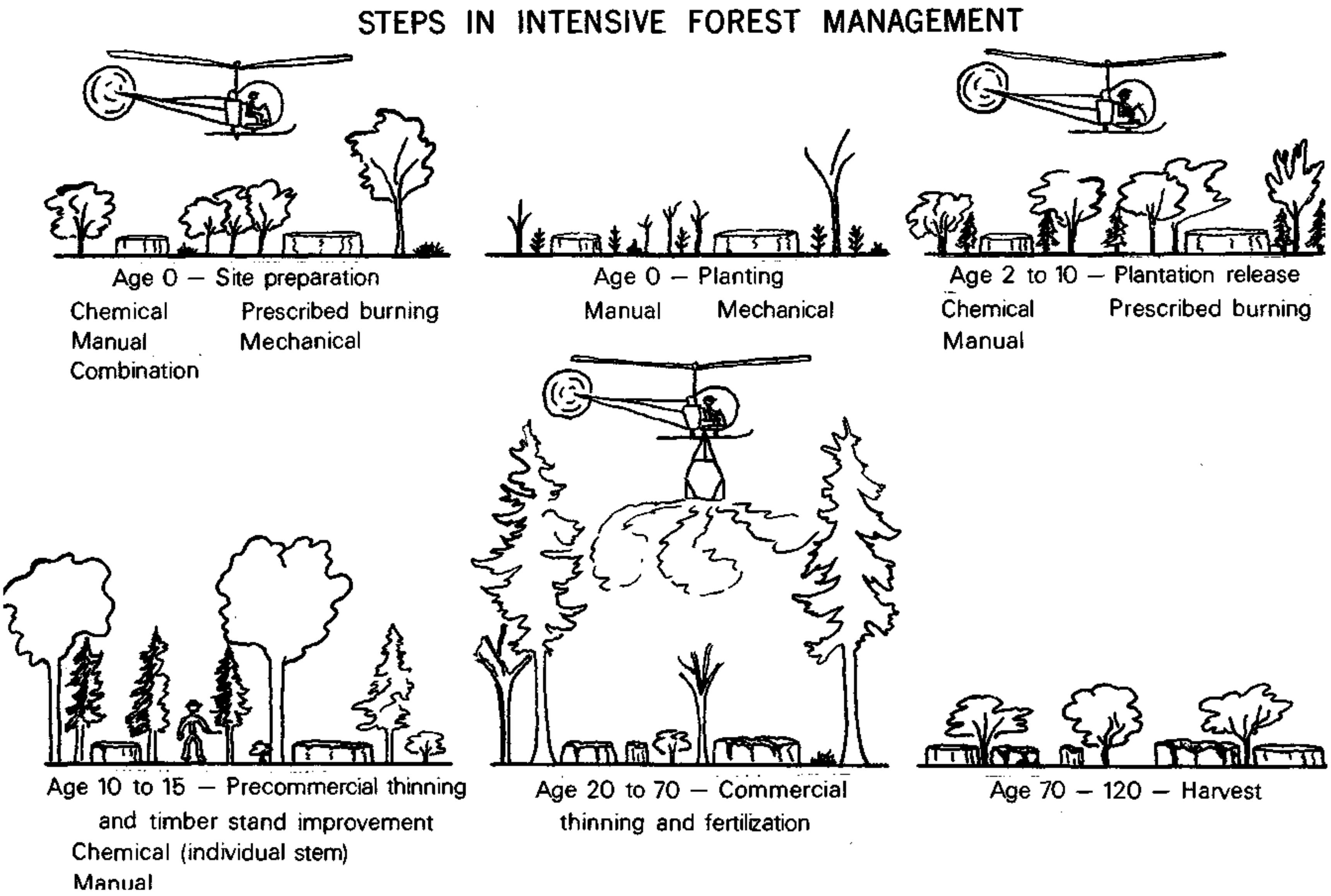


Figure 4. Steps in intensive forest management--not all steps may be necessary on every acre.

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

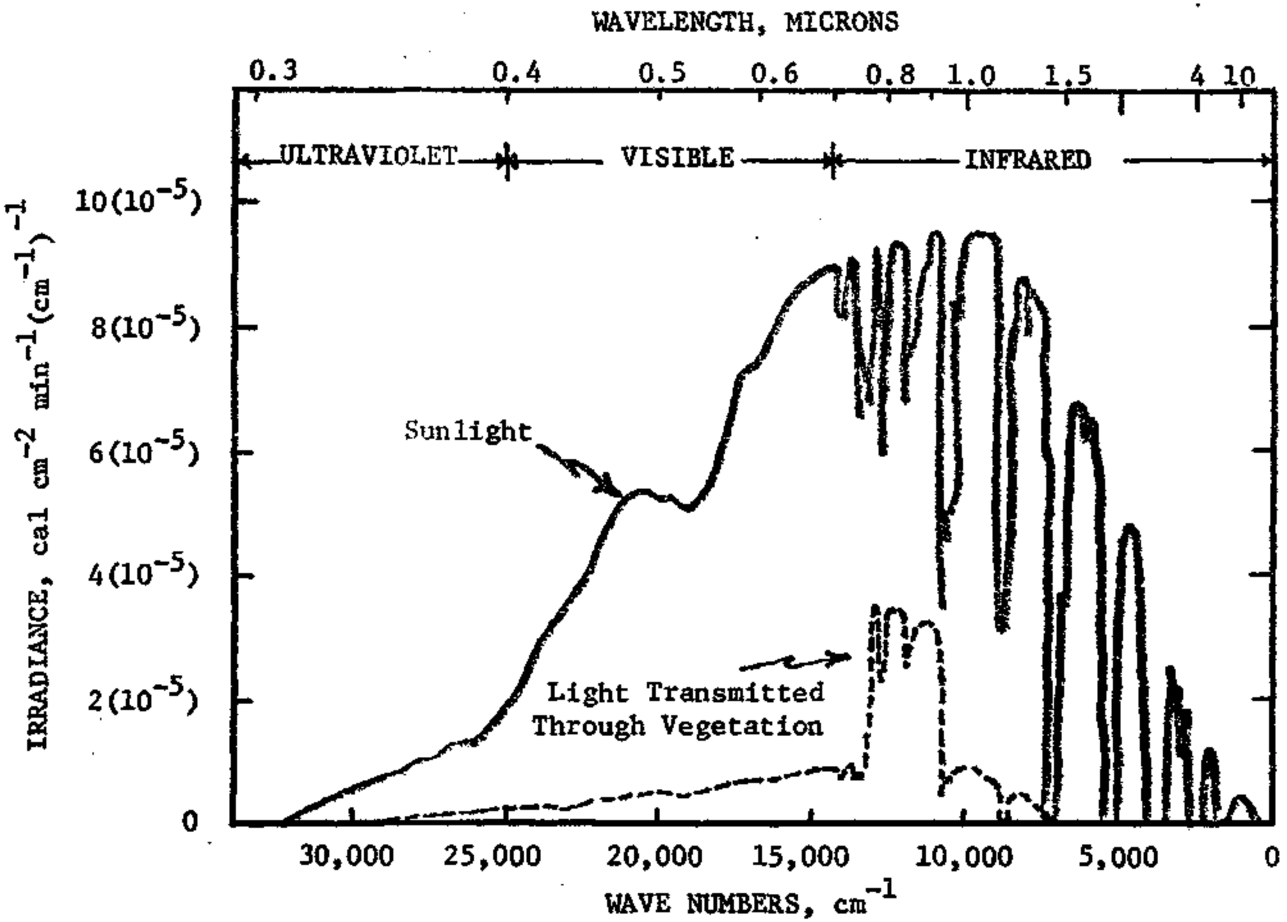
Studies of growth in fully stocked natural and intensively managed stands confirm that measures to insure prompt regeneration and use of intensive cultural practices on suitable highly productive sites can markedly increase future timber supplies. Control or modification of competing vegetation is an 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.

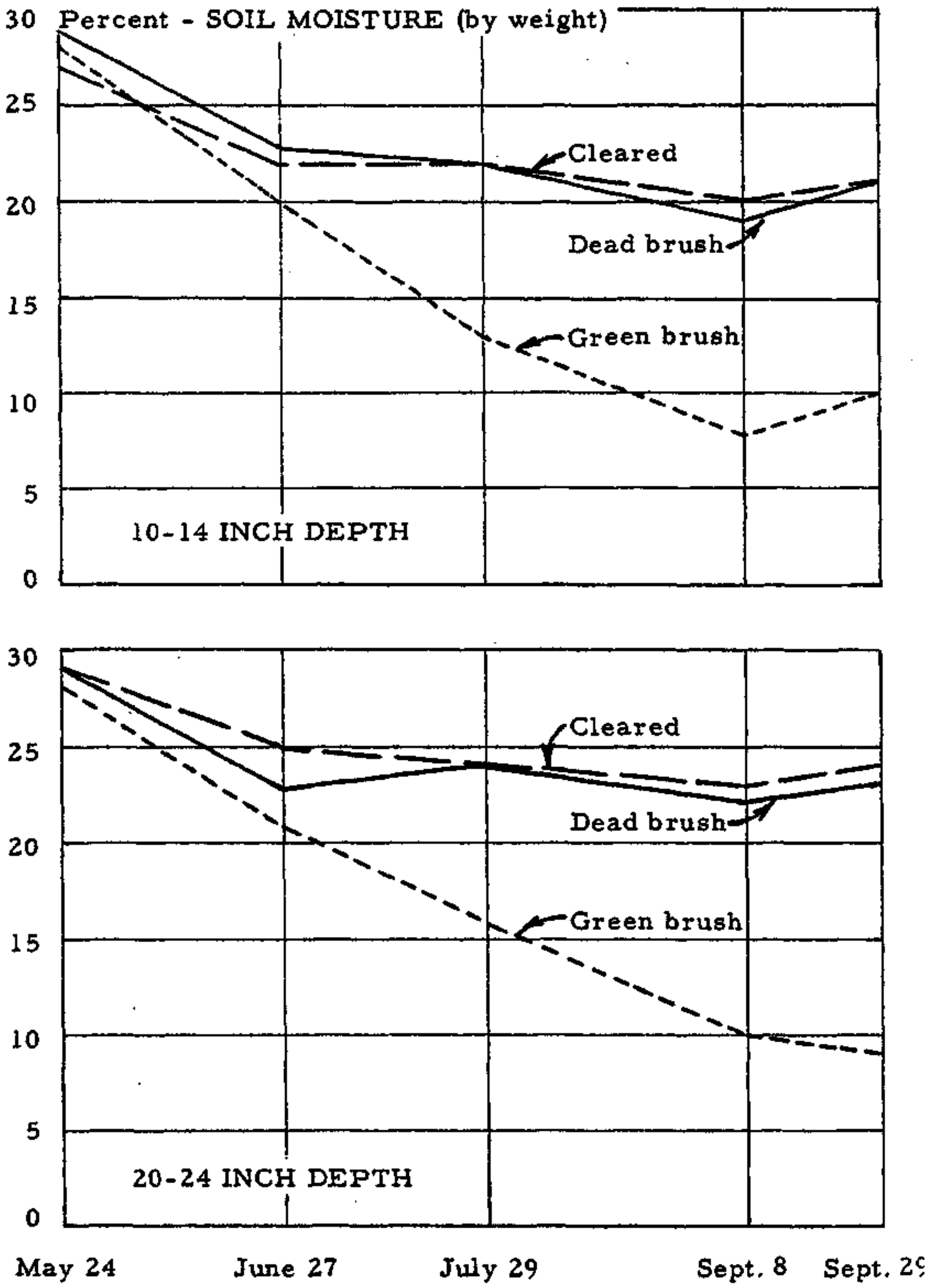


Figure 6. Trend of soil moisture at depths of 10 to 14 and 20 to 24 inches in cleared, sprayed and untreated greenleaf manzanita brushfields in central Oregon (from Tarrant 1957).

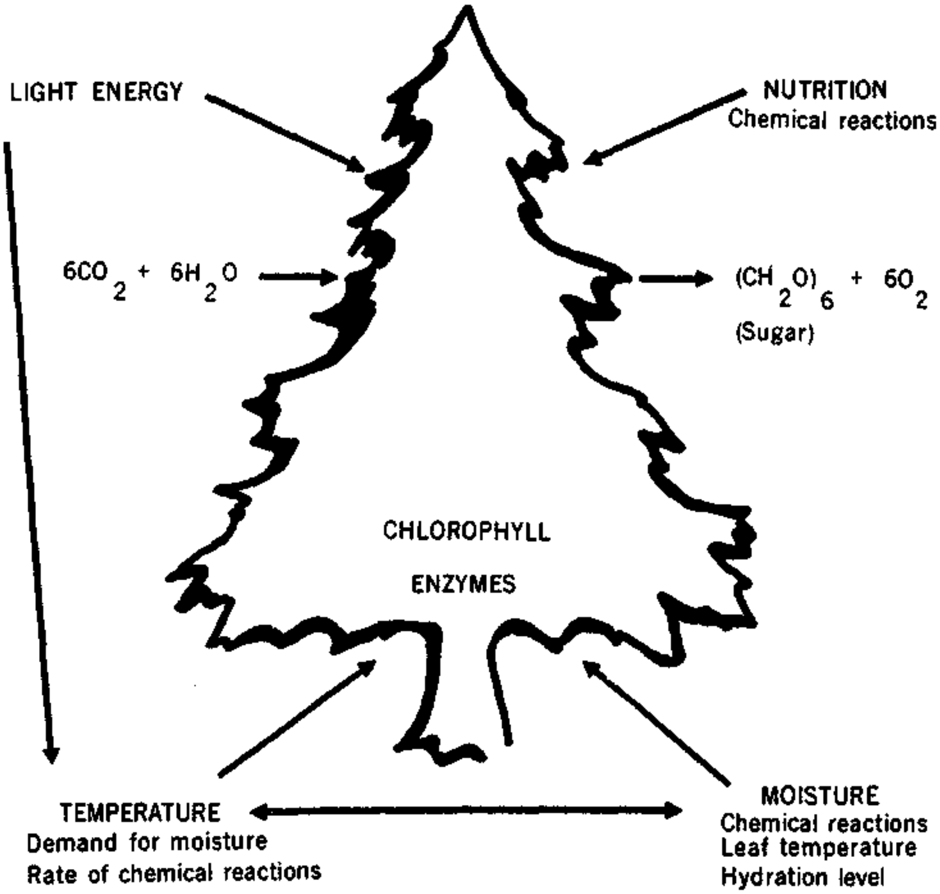


Figure 7. Interaction among four factors in the seedling environment that affect the rate of seedling photosynthesis (from Cleary et al. 1978).

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, sweatgum, 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)

	Most important method of establishment		
	Residual species	Invading species	
Section and type group	Resprouting	Buried seed	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.

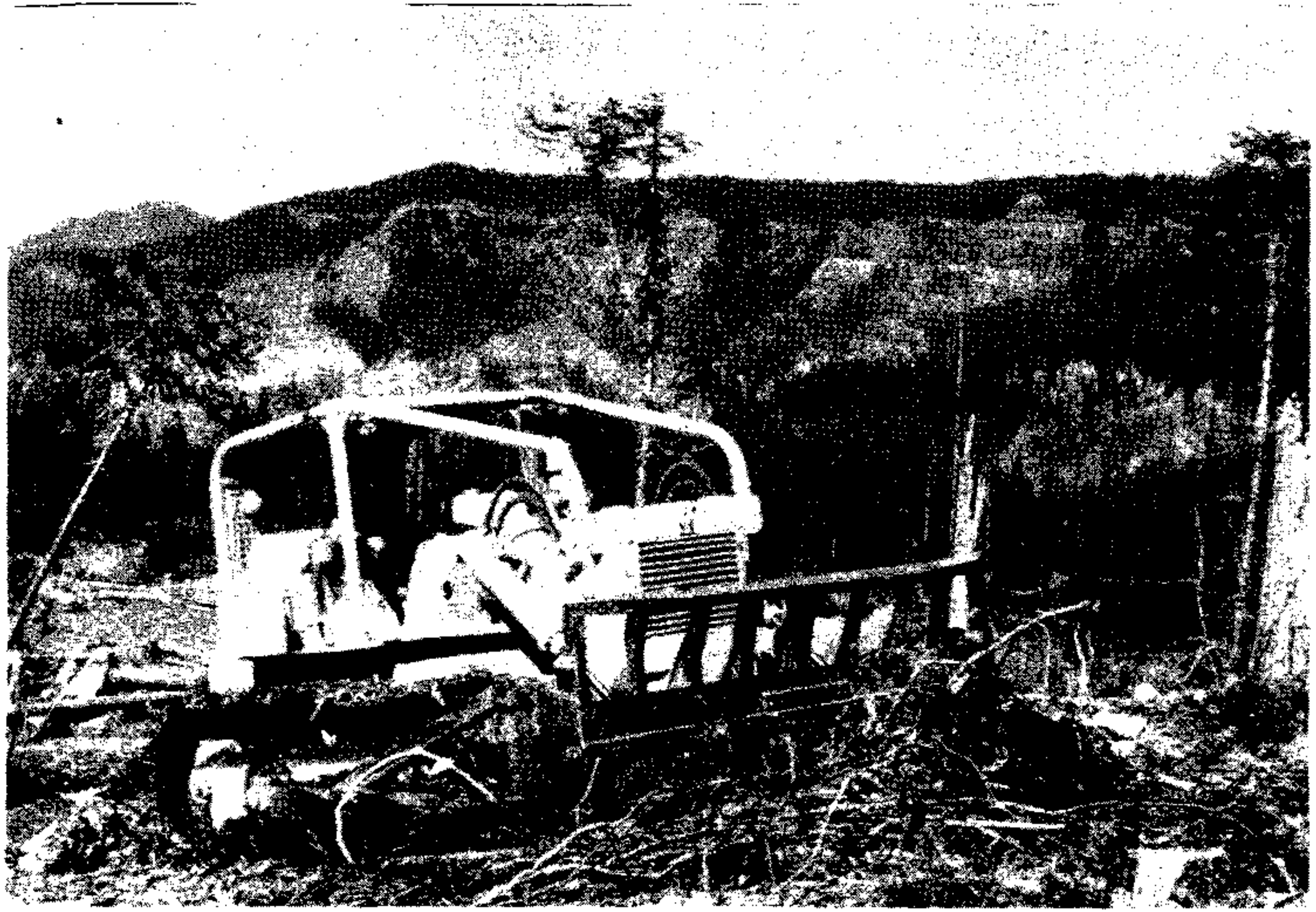


Figure 10. Tractors equipped with toothed brush rakes are best for clearing and piling logging slash and brush.

(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.

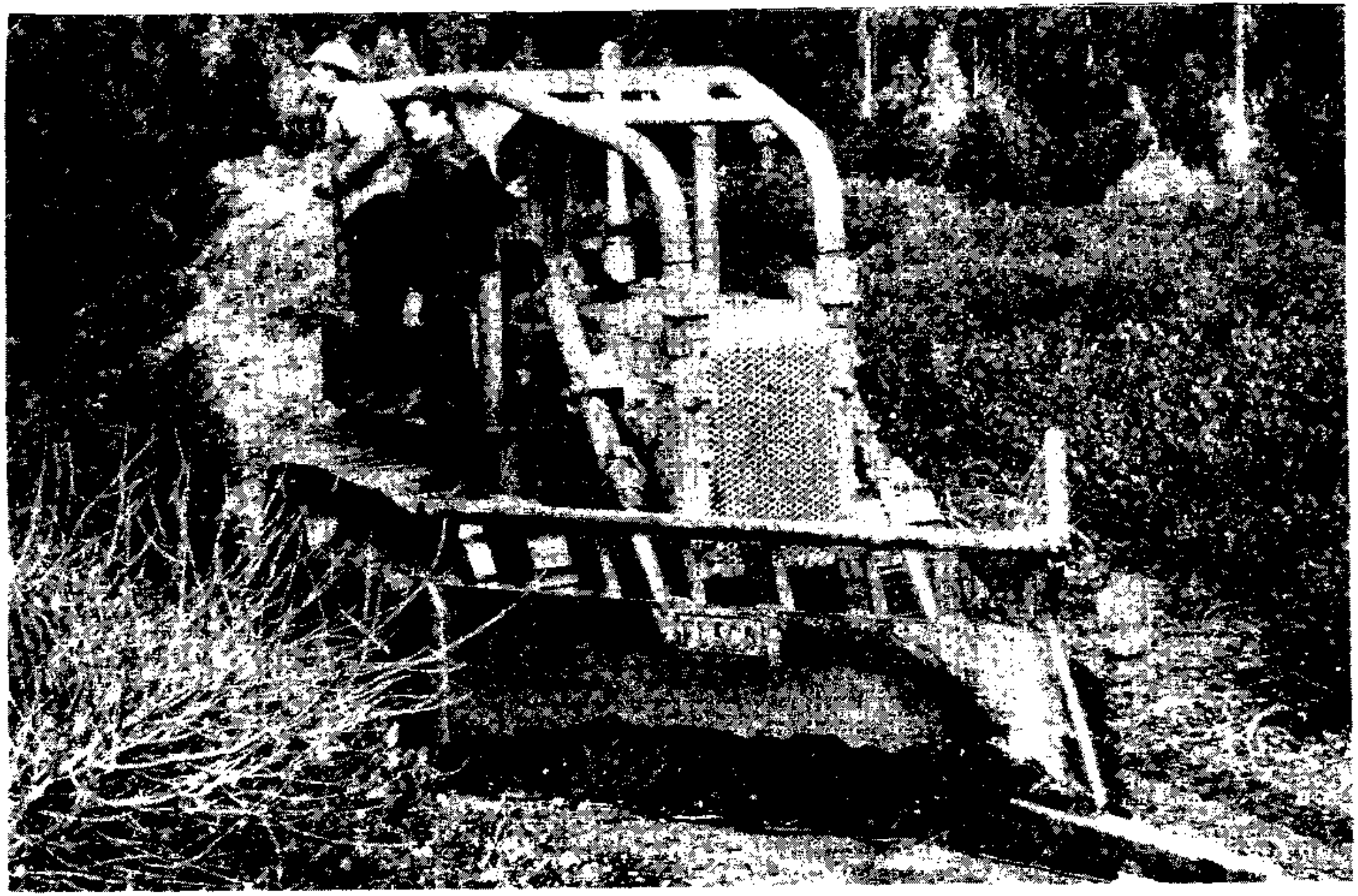


Figure 11. Shearing blades mounted on crawler can be used to clear brush and weed trees.

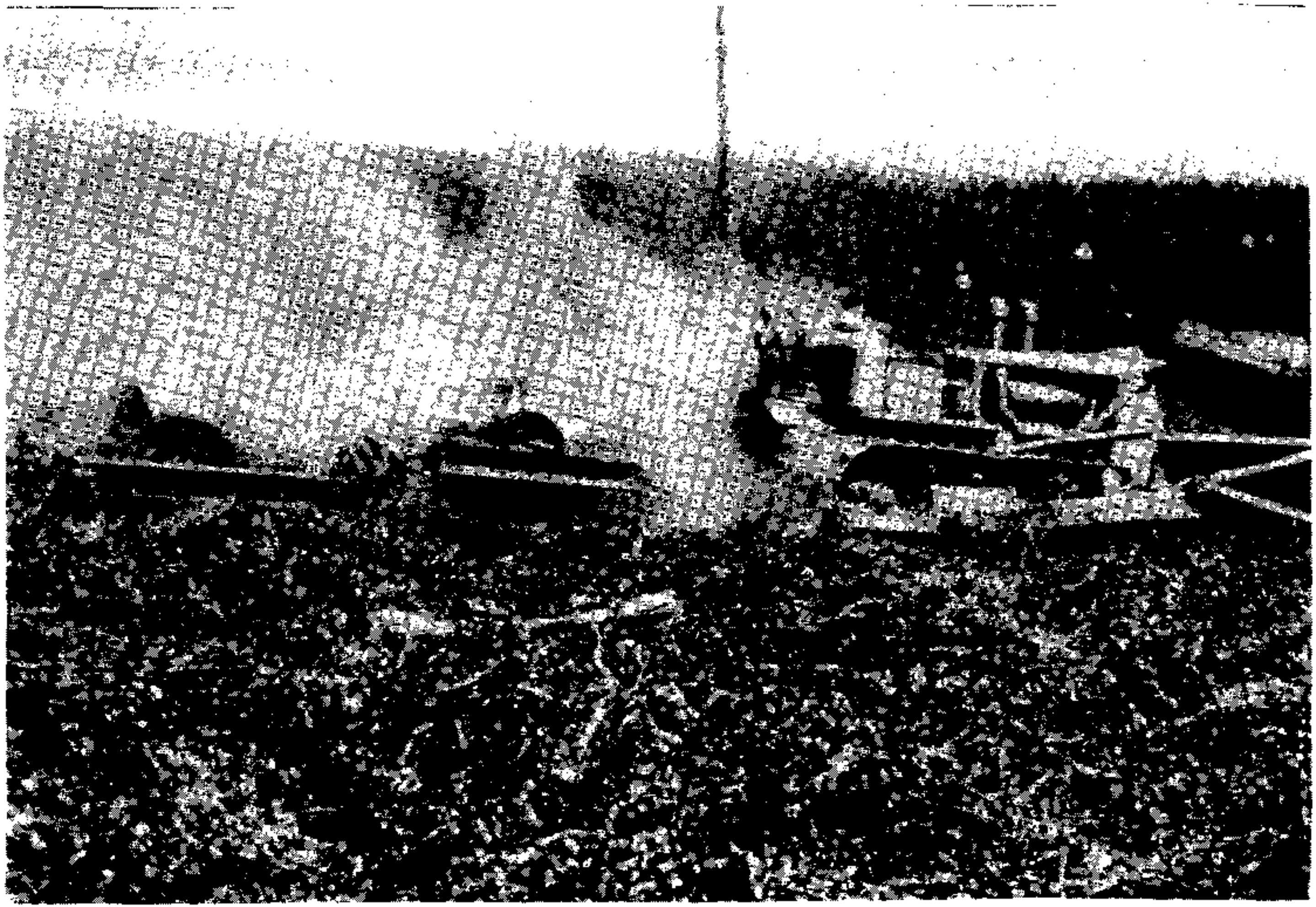


Figure 12. Rolling choppers are commonly used to prepare brushfields and new cuttings for reforestation.

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.

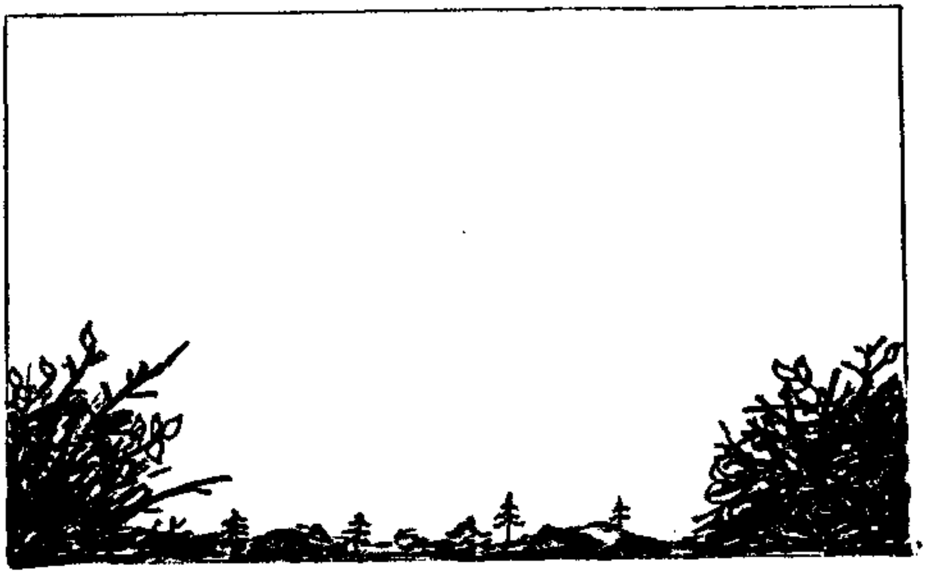
Mechanical brush control removes most of the protective cover and maximizes sunlight, soil moisture, and temperature extremes near the ground (fig. 13). Except on dry, hot sites, most of these changes are beneficial for seedling establishment (fig. 14).

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.



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:

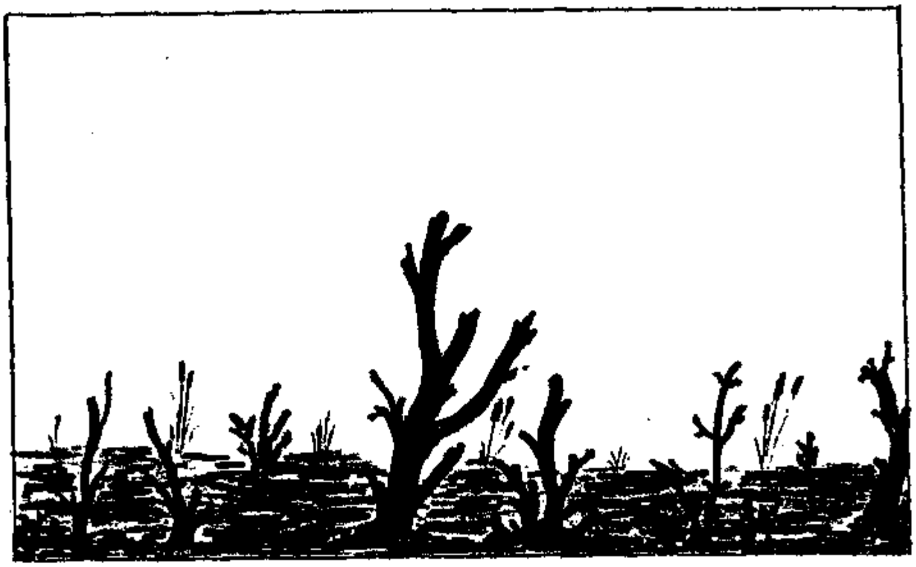
Advantages	Disadvantages
Can be used on steep terrain	Fire control can be difficult and expensive
Produces large, easily planted areas	Desired effects are difficult to achieve
Reduces fire hazard	A large complement of well-trained personnel is needed
Often costs less than mechanical treatment	Smoke pollution 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 rate[b]	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)	Triisopropanolamine salts of picloram & 2,4-D (Tordon 101R and Tordon 101)	All	None	Undiluted	Hardwoods and conifers by injection	Long	May damage untreated conifers ("flashback"); 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	Triisopropanolamine salts of picloram & 2,4-D (Tordon 101) with or without low volatile esters of 2,4,5-T or silvex	Spring to midsummer	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 preparation 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 midsummer	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[b/] rate	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

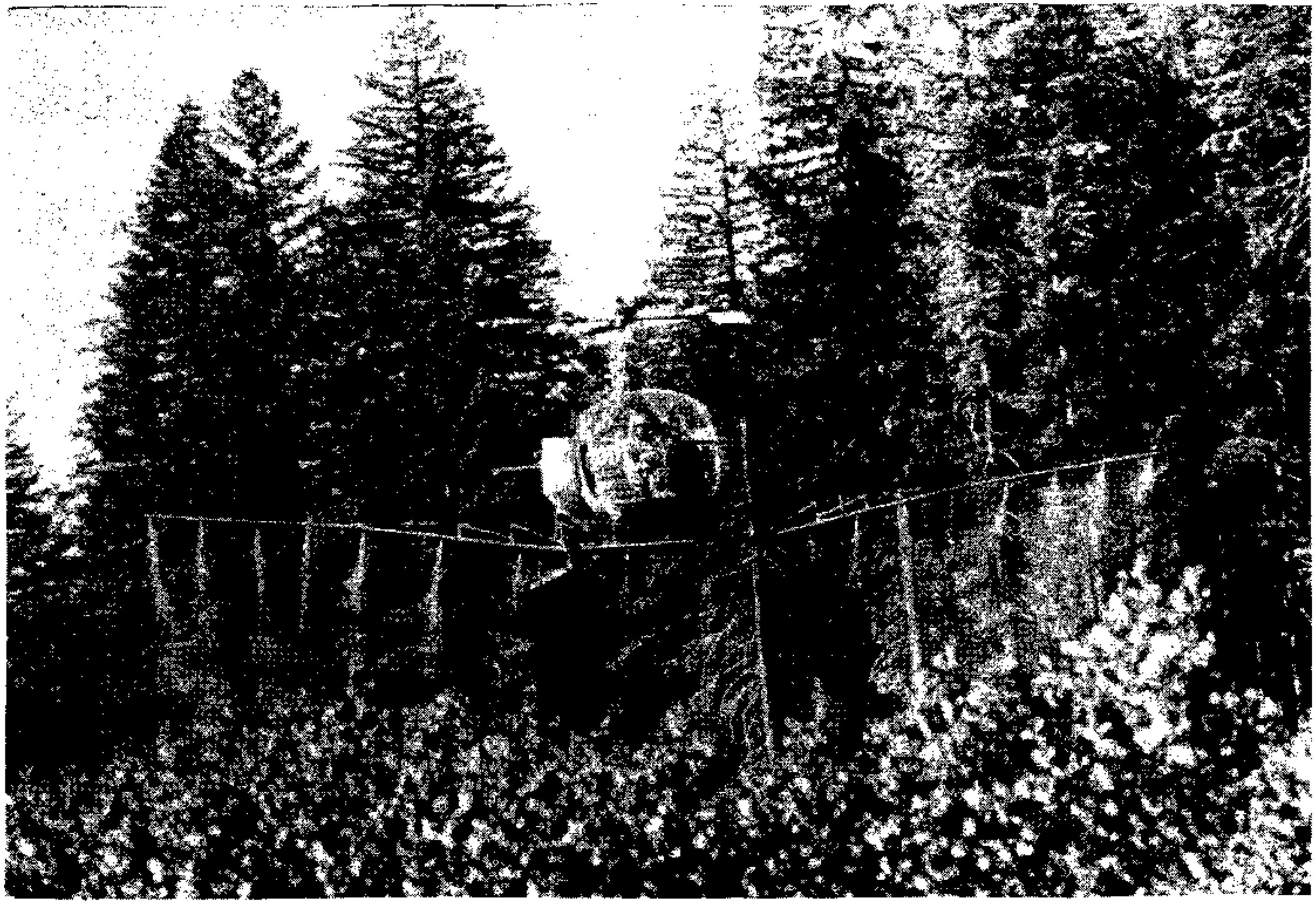


Figure 18. Helicopters are most often used to aerially apply herbicides to forest lands.

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.

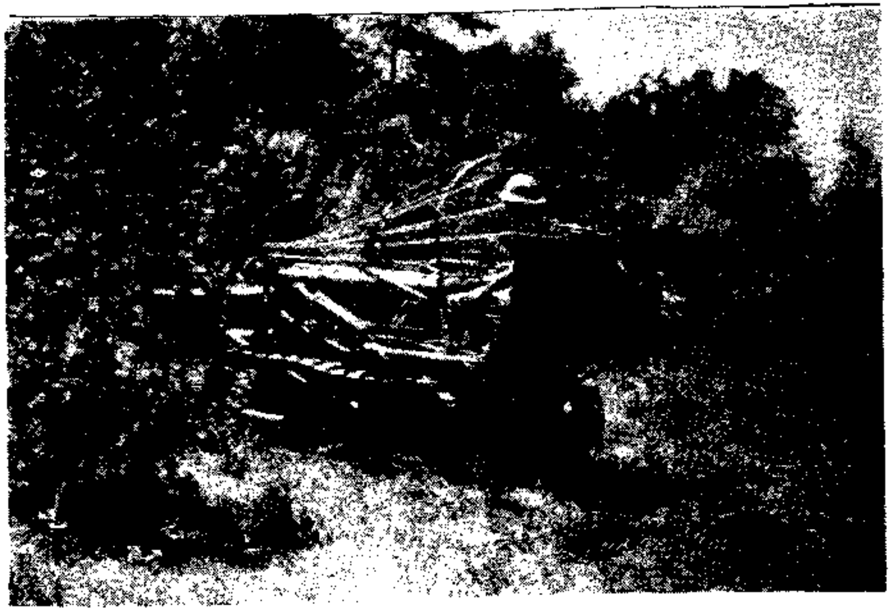


Figure 19. Tree injectors, tractor-mounted mistblowers, and pressurized sprayers are commonly used to apply herbicides in the South.

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

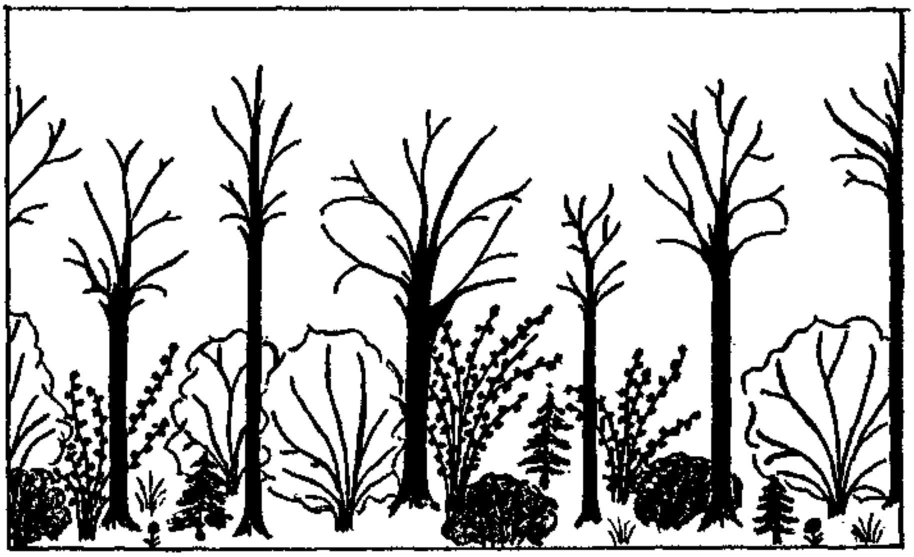
Environmental conditions are less extreme amid chemically killed brush. Removal of selected overstory trees using individual stem treatment results in slight increases in light and soil moisture near the ground (fig. 21). This is accompanied by a small increase in understory species. Removal of the canopy 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

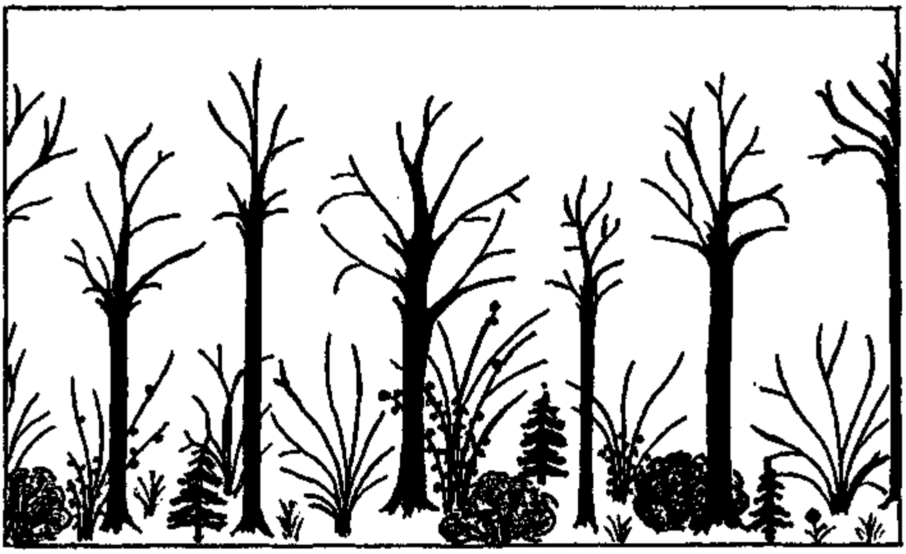


Solar radiation	
Intensity.............	+
Spectral quality......	+
Air	
Temperature...........	
Day.................	+
Night...............	-
Diurnal variation..	+
Relative humidity.....	-
Frost.................	
Precipitation	
Interception..........	-
Reaching crop.........	+

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.

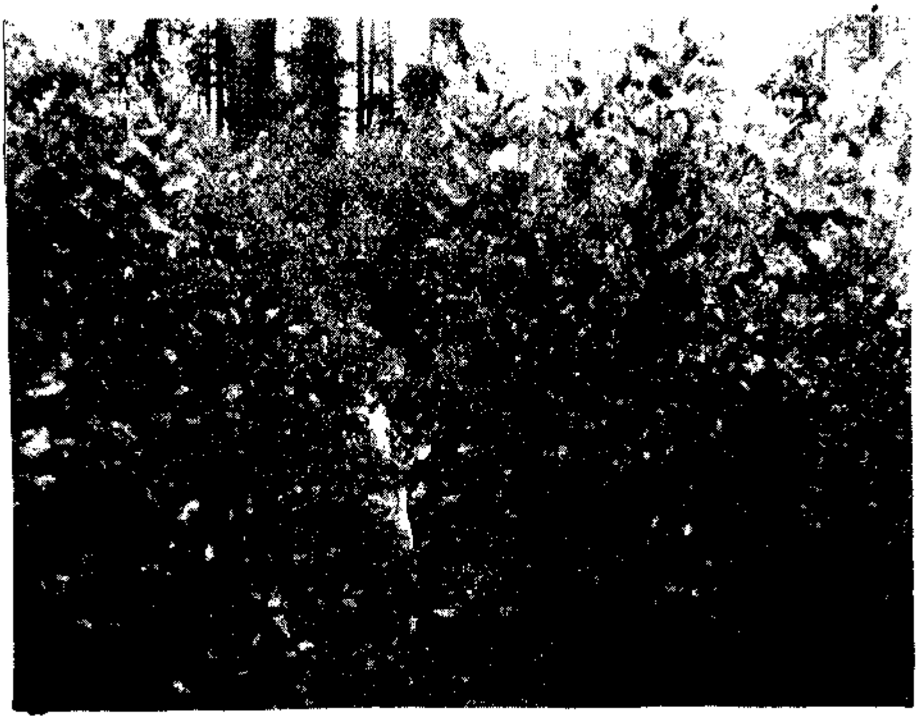


Figure 24. Varnishleaf sprouts two seasons after brush was cut 6 inches above ground.

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.

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

ENVIRONMENTAL EFFECTS OF VEGETATION MANAGEMENT

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

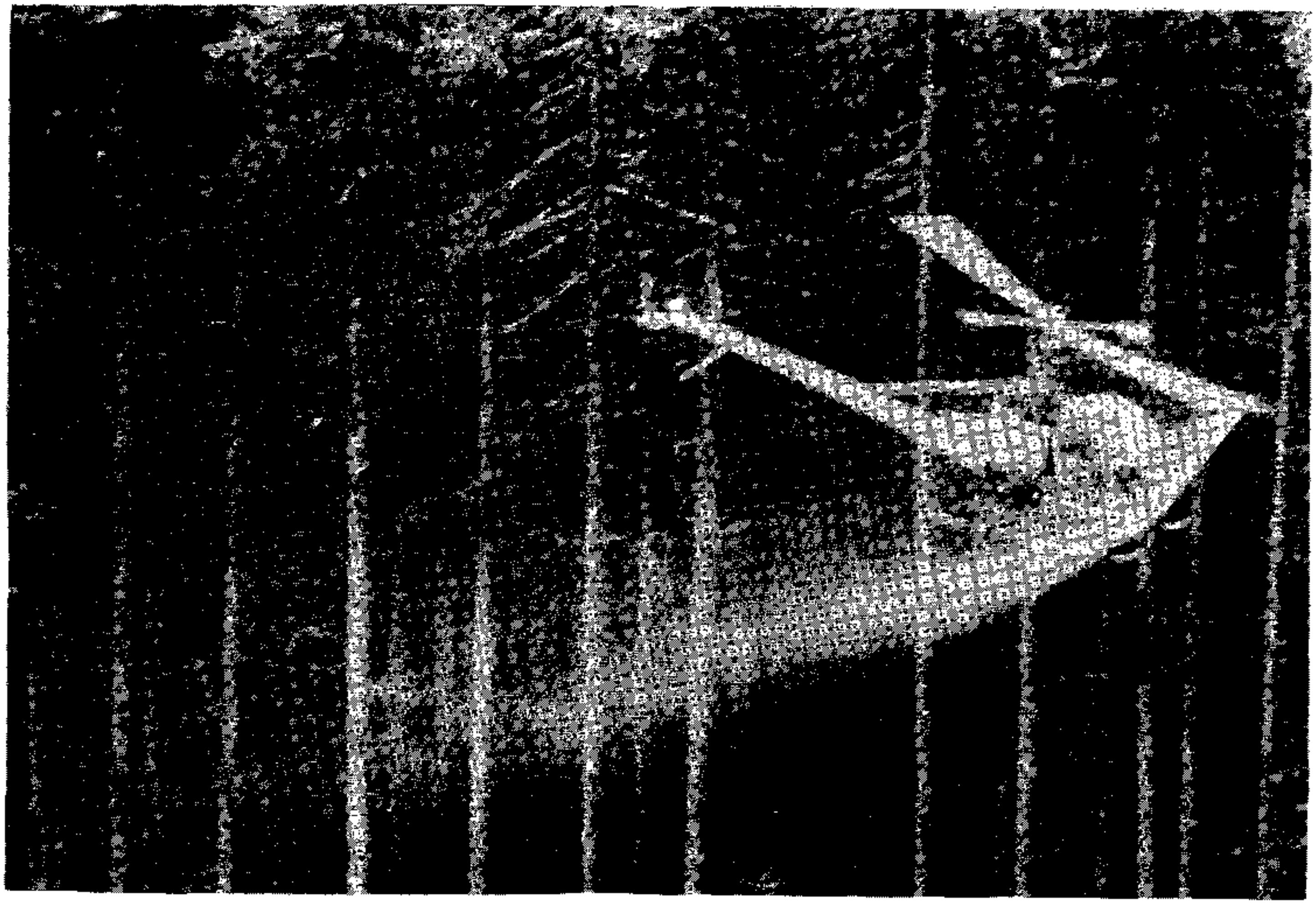

Figure 25. Aerial sprays are best for herbicide application in the mountainous terrain of the western United States.

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 $10-75 Ground spray $32-153 Hand injection $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 $10-75 Ground spray $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.

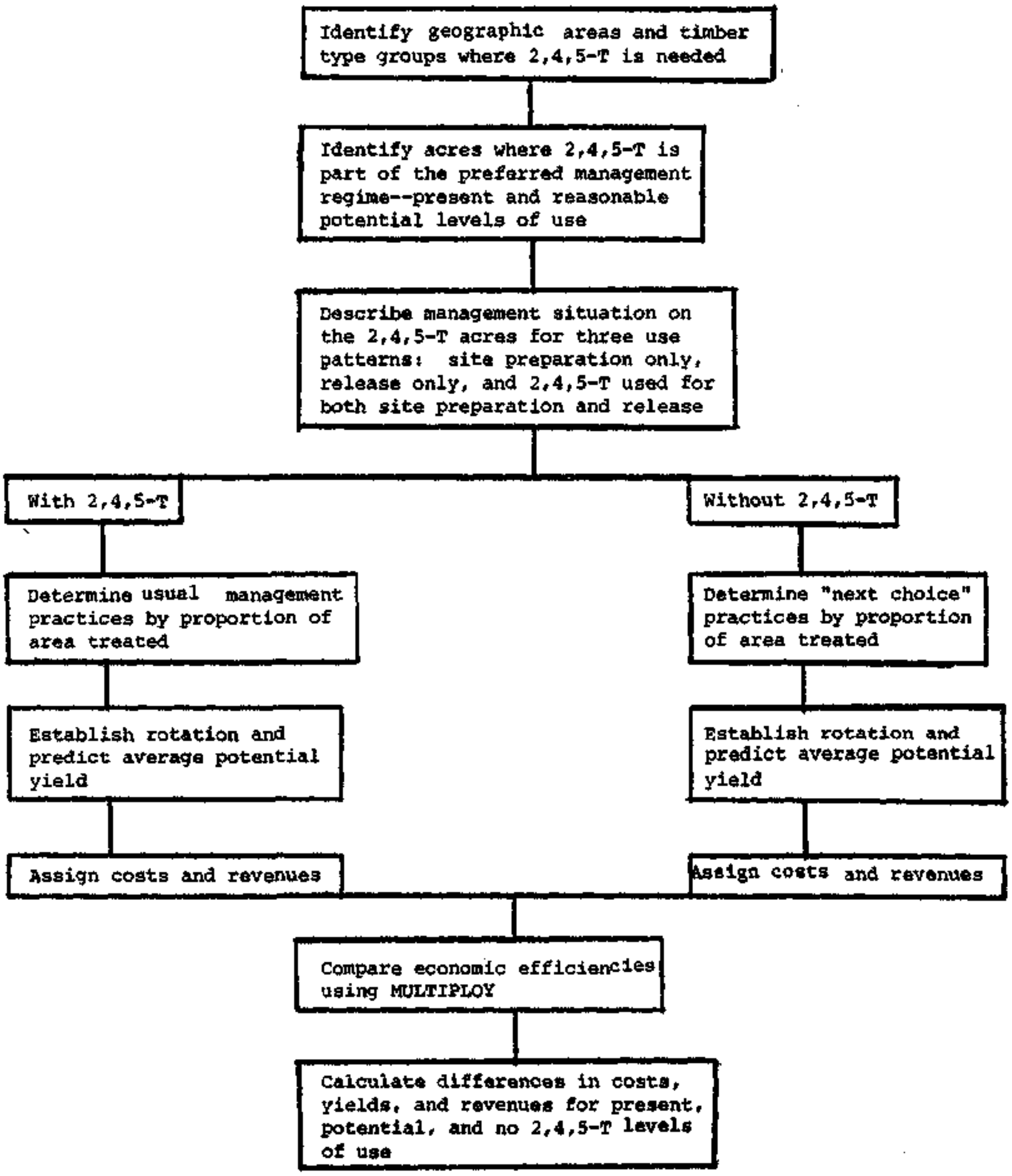

Figure 26. Diagram of procedures for developing management regimes, cost, and yield data for analysis of economic efficiency.

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

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[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:

$$\text{Initial change in present net worth (dollars/year)} = (\text{present net worth with 2,4,5-T} - \text{present net worth without 2,4,5-T}) \times (\text{acres treated per year})$$

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		Release only		Site preparation and release	
			Present	Potential	Present	Potential	Present	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

			Total silvicultural cost		Productivity		Present net worth	
Timber type group	Use pattern	Use level	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
			---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

		Site preparation only[a]			Release only[a]		
Timber type group	Use level	Production cost	Productivity	Present net worth	Production cost	Productivity	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	Cumulative Reduced timber harvest	Cumulative 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.

South Section

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

	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	
Timber type group			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	 Productivity	 Present net worth	Release only[a/] Production cost	 Productivity	 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	Reduced timber harvest	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, Present	Site preparation only, Potential	Release only, Present	Release only, Potential	Site preparation and release, Present	Site preparation and release, 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: Present	Potential	Release only: Present	Potential	Site preparation and release: 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

				Total silvicultural cost		Productivity		Present net worth	
		Annual 2,4,5-T use		with	without	with	without	with	without
Timber type group[a]	Use pattern	Present	Potential	2,4,5-T	2,4,5-T	2,4,5-T	2,4,5-T	2,4,5-T	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

		Annual 2,4,5-T use		Total silvicultural cost		Productivity		Present net worth	
Timber type group[b]	Use pattern	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.