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

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

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

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

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

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

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

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

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

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

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

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

United States

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

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

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

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

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

a/ Indicates an increase in present net worth

b/ Indicates a decrease in timber production costs

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

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

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

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

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

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

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

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

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

## SUMMARY

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

# CHAPTER 2: PART 1

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

### INTRODUCTION

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

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

### THE RANGE AND PASTURE RESOURCE IN THE UNITED STATES

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

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

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

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

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

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

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

## TEXAS MESQUITE

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

## ESTABLISHED MANAGEMENT GOALS

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

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

## The Problem

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

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

## Biology/Ecology of Plant Communities Associated with Mesquite

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

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

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

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

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

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

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

## Impact on Commodity Yield

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

## MANAGEMENT STRATEGIES

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

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

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

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

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

USE OF 2,4,5-T

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

### Cut-Stump Method

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

### Basal-Spray Method

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

## Foliage Treatment of Individual Trees

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

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

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

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

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

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

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

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

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

4. Necessity for retreatment to maintain effective control.

5. Economics and the potential productivity of some rangelands.

## Estimated Levels of 2,4,5-T Use

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

## Cost for Use

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

## Effect of Use on Commodity Yield

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

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

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

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

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

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

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

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

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

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

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

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

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

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

## Herbicide Use and Wildlife Habitat

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

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

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

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

## MECHANICAL, HAND LABOR AND FIRE METHODS

### Mechanical Methods

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

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

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

#### Shredding

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

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

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

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

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

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

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

Roller Chopping

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

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

## Power Grubbing

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

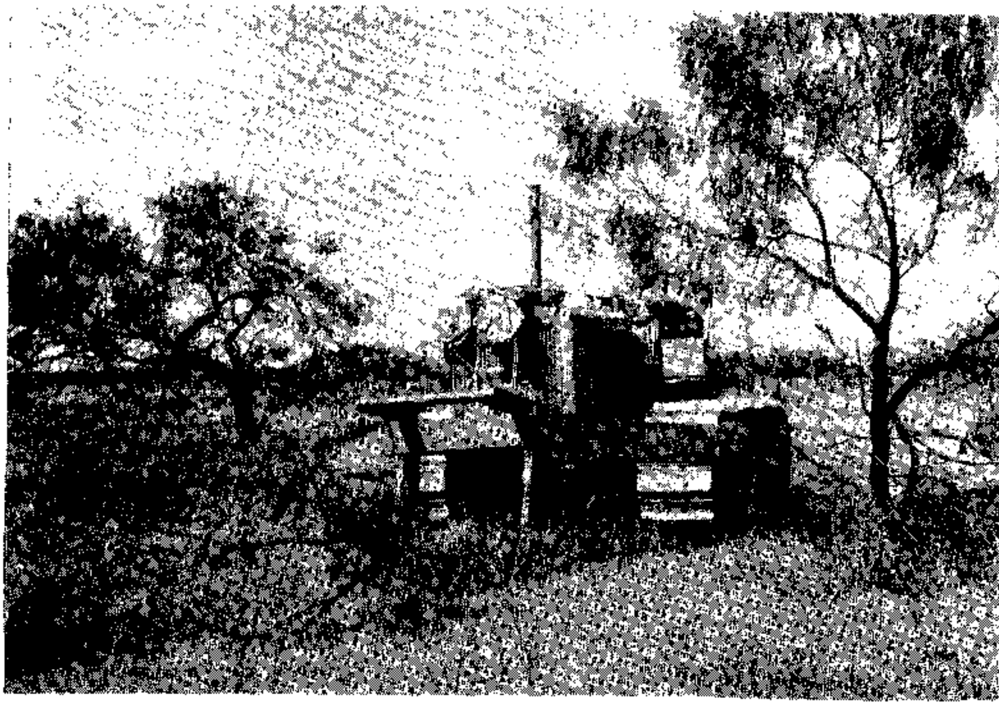

Figure 1. High energy tree grubber. Effective for remaining woody plants when density is less than 125 stems per acre.

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

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

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

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

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

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

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

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

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

Chaining

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

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

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

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

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

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

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

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

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

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

Dozing

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

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

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

### Root Plowing

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

## Hand Labor

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

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

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

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

## Prescribed Burning

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

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

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

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

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

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

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

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

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

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

POTENTIAL IMPACT OF NO CONTROL EFFORTS

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

## OAKS, OAKLAHOMA AND TEXAS

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

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

### ESTABLISHED MANAGEMENT GOALS

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

### THE PROBLEM

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

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

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

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

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

## Biology/Ecology of Plant Communties Associated with Oaks

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

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

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

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

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

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

IMPACT ON COMMODITY YIELD AND MANAGEMENT STRATEGIES WITH HERBICIDES

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

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

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

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

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

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

## MECHANICAL, FIRE AND HAND LABOR METHODS

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

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

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

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

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

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

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

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

### INTRODUCTION

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

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

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

## METHODOLOGY AND ASSUMPTIONS

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

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

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

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

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

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

## MESQUITE

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

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

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

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

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

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

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

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

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

## 1975-1977 AVERAGE COST PER ACRE FOR CONTROL METHODS

Root Plowing and Seeding

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

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

| | |
|---|---|
| Low energy | $ 7.50 |
| High energy | 12.50 - $15.00 |

| | |
|---|---|
| Hand grubbing | $88.40 |
| Burning | $0.50 - 3.00 |

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

2,4,5-T

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

Silvex

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

Dicamba

0.50 lb/a - $ 6.85

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

Broadcast methods of applying herbicides were evaluated economically since over 88 percent of brush-infested rangelands contain over 100 plants per acre. Only registered herbicides were considered. In the future, new herbicides may be registered, but the cost and effectiveness of the compound will determine the use of any new chemical.

Rotation period varied because of plant growth conditions, forage and animal production differences, and the length of time that woody plants need to grow before canopy density would reduce forage production and where herbicide treatment would be effective on regrowth.

Each area was selected to be analyzed based on production, differences in woody plant species, life span of treatment, stocking rates, and rate that regrowth required treatment. No economic analysis will be made on the 75,000 acres of mesquite and 60,000 acres of oak on the 1,000,000 acres of pasture treated with ground equipment.

Beef production per acre during the rotation period was averaged to reduce additional calculations and the number of tables. We realize that forage and beef production will increase from year one to 4-5 years until woody plant density reduces forage production to justify another treatment. Also, we realize that the production on the untreated area would not remain the same, but decrease each year during the rotation because of reduced forage production and an increase in density of woody plants.

AREA 1 - CREEPING MESQUITE

Creeping or running mesquite, a low-growing multi-stemmed plant, is a problem on about 2 million acres of heavy saline clay range sites in the Nueces and Frio River watersheds of the South Texas Plains (fig. 6, area 1). Mechanical control methods of root plowing and seeding proved unsatisfactory since re-establishment of grasses was difficult after soil disturbance. Application of 2,4,5-T to about 40,000 acres each year offered the better solution for control. However, early research data indicated that standard application of 2,4,5-T for tree-type mesquite would not produce satisfactory control on creeping mesquite. After a five-year study, it was determined that 0.67 pound of 2,4,5-T mixed in one gallon of diesel oil and water to make five gallons of solution per acre, applied aerial broadcast for three consecutive applications produced satisfactory control. Sometimes two applications produced up to 90 percent control.

In a 3500-acre pasture approximately 1200 acres of creeping mesquite was sprayed with 2,4,5-T for 3 consecutive years (fig. 7). The treated acreage received no deferment but livestock numbers were kept at the same rate as before spraying, which was one animal unit to 25 acres plus deer. At the end of the third growing season, livestock numbers were increased one animal unit to 18 acres for a 28 percent increase (Hoffman et al. 1950-77, fig. 8).

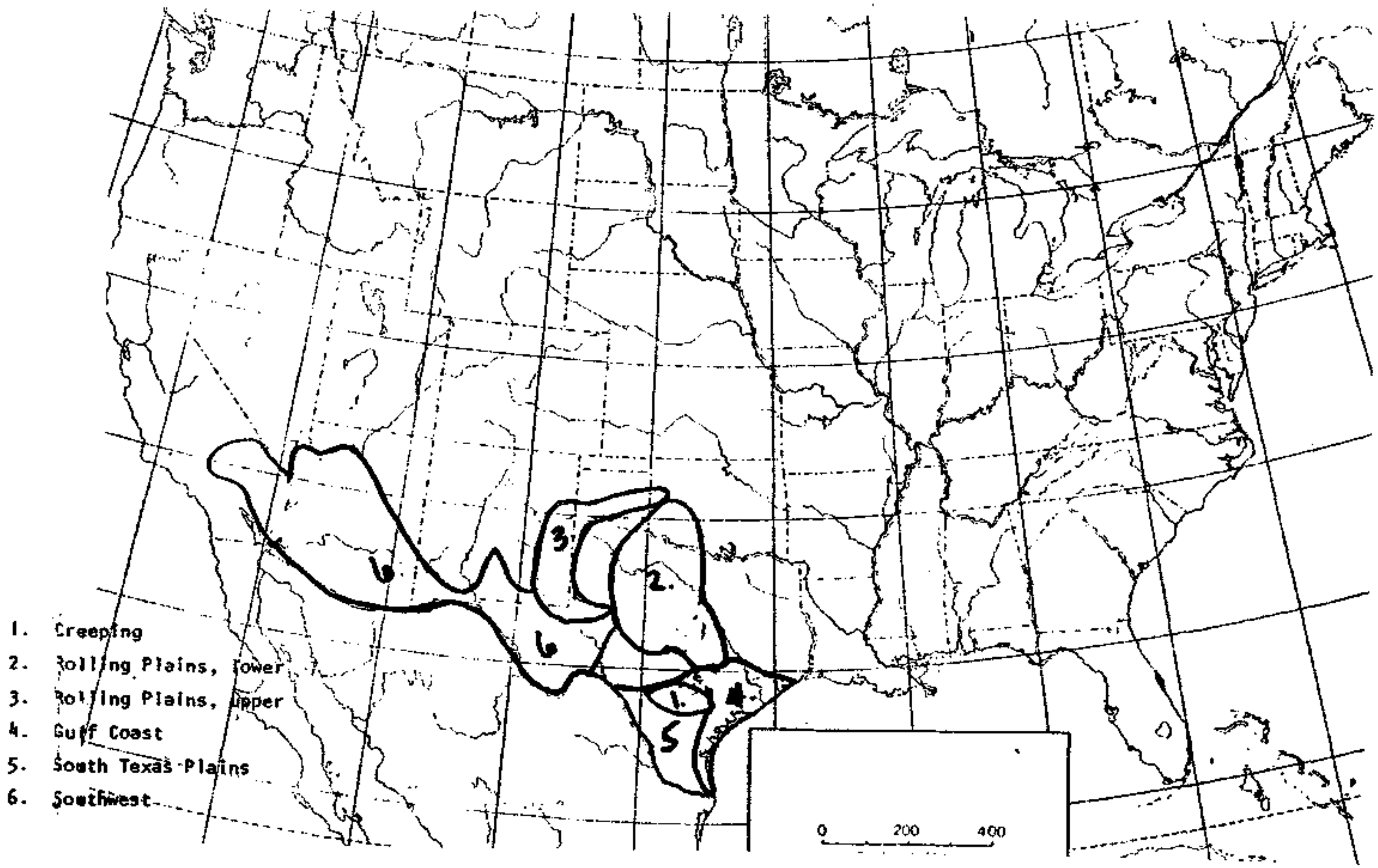


Figure 6. The 93,000,000 acres of Mesquite-dominated land in the Southwestern United States.

Figure 7. Creeping mesquite growing on a saline clay soil. Creeping mesquite becomes so dense because of root sprouting characteristics that forage grasses cannot grow. Stocking rate on this area was 1 animal unit to 40 acres.

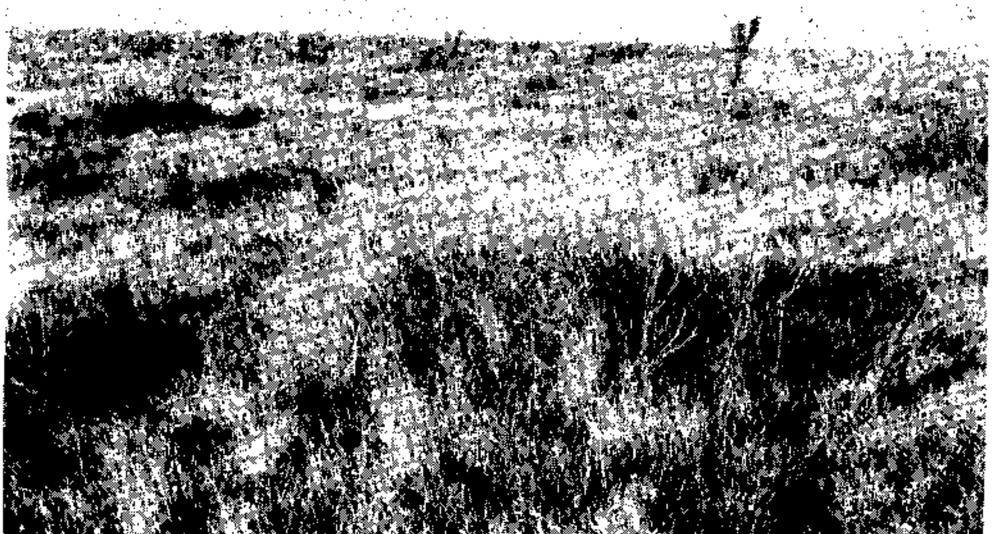

Figure 8. Three applications of 2,4,5-T a year apart. Control has lasted for 16 years. Note that woody plants suitable for wildlife were not affected. Stocking rate following control was 1 animal unit per 18 acres. This stocking rate has been maintained for 16 years and the range is in good condition.

Herbicide applications of 2,4,5-T did not control such plants as lotebush (*Condalia spp.*), agarito (*Berberis trifolidata*), granjeno (*Celtis spp.*), blackbrush (*Acacia rigidula*), and guajilio (*A. berlandieri*) that produce food and cover for wildlife animals (Hodgin 1974).

The sprayed area improved from poor to good condition during the three year spraying period. Wildlife numbers have increased along with the increase of livestock numbers. Calf weights increased 25 pounds per calf. Evaluation of the treated areas shows 3 applications of 2,4,5-T will control creeping mesquite for 16 years before another series of herbicide applications will be required. Stocking rate has remained constant throughout the control period according to statements from the landowner (Hoffman et al. 1978).

Beef production for the entire 3500 acre pasture was 21.9 pounds or $7.84 per acre where creeping mesquite was controlled, as compared to 14.4 pounds or $5.16 per acre on the uncontrolled area. Labor saved in working of livestock amounted to $.50 per acre and the increased hunting lease was $.50 per acre more on the sprayed pasture as compared to the unsprayed pasture (table 1, area 1). Total beef production loss would be 46,704,000 pounds or a net present value loss of $4,075,000 during the 16-year rotation period without the use of 2,4,5-T and silvex, (table 2).

The stocking rate on the 2,4,5-T sprayed pasture was 1 animal unit to 18 acres and remained at that number for 16 years. On the untreated area, stocking rates were 1 animal unit to 25 acres for the first 8 years and 1 animal unit to 35 acres from 9-16 years (Hoffman et al. 1978). Beef cattle production per acre is 14.4 pounds for the first 8 years and 10.3 pounds per acre for the years 9-16. It is estimated that stocking rates will remain at 1 animal unit to 35 acres for an indefinite period.

An area was root plowed and seeded to native grasses in 1960 for a total cost of $18 per acre to compare control methods. Results revealed that

Table I—Current use and benefits of 2,4,5-T, and potential alternatives, on 93 million acres of Mesquite

| Area & alternative treatment | Acres in area | Acres treated annual[a] | Rotation period | Acres treated in rotation | Per acre treatment cost[b] | Total annual cost | Total rotation cost | Amortized per acre cost[c] | Beef yield per acre[d] | Value per pound[e] | Gross value per acre |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Years | | Dollars | Dollars | Dollars | | Pounds | Dollars | Dollars |
| Area 1: | | | | | | | | | | | |
| 2,4,5-T | 2,000,000 | 40,000 | 16 | 640,000 | 14.25[f] | 190,000 | 9,120,000 | 1.51 | 21.9 | .3580 | 8.84[h] |
| Silvex | 2,000,000 | 40,000 | 16 | 640,000 | 15.00[g] | 200,00 | 9,600,000 | 1.59 | 21.9 | .3580 | 8.84[h] |
| Do nothing, 1-8 yrs | 2,000,000 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 14.4 | .3580 | 5.16 |
| Do nothing, more than 8 yrs | 2,000,000 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 10.3 | .3580 | 3.69 |
| Area 2: | | | | | | | | | | | |
| 2,4,5-T | 22,000,000 | 176,000 | 8 | 1,408,000 | 4.35 | 765,600 | 6,124,800 | 0.73 | 44.0 | .3580 | 16.75[i] |
| Silvex | 22,000,000 | 176,000 | 8 | 1,408,000 | 4.60 | 809,600 | 6,476,800 | 0.78 | 44.0 | .3580 | 16.75 |
| Dicamba | 22,000,000 | 176,000 | 8 | 1,408,000 | 6.85 | 1,205,600 | 9,644,800 | 1.15 | 44.0 | .3580 | 16.75 |
| Do nothing | 22,000,000 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 26.9 | .3580 | 9.63 |
| Area 3: | | | | | | | | | | | |
| 2,4,5-T | 22,000,000 | 176,000 | 10 | 1,760,000 | 4.35 | 765,600 | 7,656,000 | 0.62 | 21.9 | .3580 | 8.84[i] |
| Silvex | 22,000,000 | 176,000 | 10 | 1,760,000 | 4.60 | 809,600 | 8,096,000 | 0.65 | 21.9 | .3580 | 8.84[i] |
| Dicamba | 22,000,000 | 176,000 | 10 | 1,760,000 | 6.85 | 1,205,600 | 12,056,000 | 0.98 | 21.9 | .3580 | 8.84[i] |
| Do nothing | 22,000,000 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 14.4 | .3580 | 5.16 |

continued

Table 1--Current use and benefits of 2,4,5-T, and potential alternatives, on 93 million acres of Mesquite (continued)

| Area & alternative treatment | Acres in area | Acres treated annual[a] | Rotation period | Acres treated in rotation | Per acre treatment cost[b] | Total annual cost | Total rotation cost | Amortized per acre cost[c] | Beef yield per acre[d] | Value per pound[e] | Gross value per acre |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Years | | ----------- | Dollars | ----------- | | Pounds | ------Dollars | ------ |
| Area 4: | | | | | | | | | | | |
| 2,4,5-T | 9,000,000 | 56,000 | 5 | 280,000 | 6.75 | 378,000 | 1,890,000 | 1.61 | 14.0 | .3580 | 15.67[i] |
| Do nothing | 9,000,000 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 13.3 | .3580 | 4.76 |
| Area 5: | | | | | | | | | | | |
| 2,4,5-T | 15,000,000 | 41,000 | 5 | 205,000 | 6.75 | 276,750 | 1,383,750 | 1.61 | 28.0 | .3580 | 11.02[i] |
| Tordon 225[j] | 15,000,000 | 41,000 | 5 | 205,000 | 11.50 | 471,500 | 2,357,500 | 2.80 | 28.0 | .3580 | 11.02[i] |
| Do nothing | 15,000,000 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 14.4 | .3580 | 5.16 |
| Area 6: | | | | | | | | | | | |
| 2,4,5-T | 23,000,000 | 81,120 | 10 | 811,200 | 4.35 | 352,872 | 3,528,720 | 0.62 | 6.5 | .3580 | 2.33 |
| Silvex | 23,000,000 | 81,120 | 10 | 811,200 | 4.60 | 373,152 | 3,731,520 | 0.65 | 6.5 | .3580 | 2.33 |
| Dicamba | 23,000,000 | 81,120 | 10 | 811,200 | 6.85 | 555,672 | 5,556,720 | 0.98 | 6.5 | .3580 | 2.33 |
| Do nothing | 23,000,000 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 4.2 | .3580 | 1.50 |

a/ Brush & Weed Control Acreages, from State Range Specialist, 1978.

b/ Average cost from commercial applicators.

c/ Per acre cost of 2,4,5-T and alternative treatments amortized at 7% interest.

d/ CEA Result Demonstation Handbook and Range Specialists Annual Reports, TAEX.

continued

Table I--Current use and benefits of 2,4,5-T, and potential alternatives, on 93 million acres of Mesquite (continued)

e/ Average beef cattle prices, Agri. Economics Dept., TAMU-TAEX.

f/ $4.75 X 3 treatments.

g/ $5.00 X 3 treatments.

h/ Control reduced labor in working livestock of $0.50/A and return from hunting lease increased by $0.50/A.

i/ Control reduced labor in working livestock of $1.00/A.

j/ 50-50 mixture of picloram and 2,4,5-T, 2 lb. ae/gal.

SOURCE: Range Brush and Weed Control Specialists, Texas Agricultural Extension Service, Texas A&M University, College Station, Texas 77843.

Table 2—Estimated decrease in value of beef production due to the nonavailability of 2,4,5-T and silvex, area one, Texas, creeping mesquite, South Texas plains

| No. years w/o 2,4,5-T | Treated area with remaining yield effects: Acres a/ | Yield a/ | Production | Previously treated area w/o remaining yield effects: Acres | Yield a/ | Production | Total beef: Production | Value b/ | Production loss w/o 2,4,5-T c/ | Value of lost production b/ | Amortized cost of lost production d/ | Net value of lost production b/ | Net present value of lost production e/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thous | Lbs | Thous lbs | Thous | Lbs | Thous lbs | Thous lbs | Dols | Thous lbs | Thousand dollars | | | |
| 0 | 640 | 21.9 | 14,016 | 0 | n/a | n/a | 14,016 | 5,018 | 0 | n/a | n/a | n/a | n/a |
| 1 | 600 | 21.9 | 13,140 | 40 | 14.4 | 576 | 13,716 | 4,910 | 300 | 107 | 60 | 47 | 47 |
| 2 | 560 | 21.9 | 12,264 | 80 | 14.4 | 1,152 | 13,416 | 4,803 | 600 | 215 | 121 | 94 | 88 |
| 3 | 520 | 21.9 | 11,388 | 120 | 14.4 | 1,728 | 13,116 | 4,696 | 900 | 322 | 181 | 141 | 123 |
| 4 | 480 | 21.9 | 10,512 | 160 | 14.4 | 2,304 | 12,816 | 4,588 | 1,200 | 430 | 242 | 188 | 153 |
| 5 | 440 | 21.9 | 9,636 | 200 | 14.4 | 2,880 | 12,516 | 4,481 | 1,500 | 537 | 302 | 235 | 179 |
| 6 | 400 | 21.9 | 8,760 | 240 | 14.4 | 3,456 | 12,216 | 4,373 | 1,800 | 644 | 362 | 282 | 201 |
| 7 | 360 | 21.9 | 7,884 | 280 | 14.4 | 4,032 | 11,916 | 4,266 | 2,100 | 752 | 423 | 329 | 219 |
| 8 | 320 | 21.9 | 7,008 | 320 | 14.4 | 4,608 | 11,616 | 4,159 | 2,400 | 859 | 483 | 376 | 234 |
| 9 | 280 | 21.9 | 6,132 | 360 | 13.9 | 5,020 | 11,152 | 3,992 | 2,864 | 1,025 | 544 | 481 | 262 |
| 10 | 240 | 21.9 | 5,256 | 400 | 13.6 | 5,432 | 10,688 | 3,826 | 3,328 | 1,191 | 604 | 587 | 298 |
| 11 | 200 | 21.9 | 4,380 | 440 | 13.3 | 5,844 | 10,224 | 3,660 | 3,792 | 1,358 | 664 | 694 | 330 |
| 12 | 160 | 21.9 | 3,504 | 480 | 13.0 | 6,256 | 9,760 | 3,494 | 4,256 | 1,524 | 725 | 799 | 355 |
| 13 | 120 | 21.9 | 2,628 | 520 | 12.8 | 6,668 | 9,296 | 3,328 | 4,720 | 1,690 | 785 | 905 | 376 |
| 14 | 80 | 21.9 | 1,752 | 560 | 12.6 | 7,080 | 8,832 | 3,162 | 5,184 | 1,856 | 846 | 1,010 | 392 |
| 15 | 40 | 21.9 | 876 | 600 | 12.5 | 7,492 | 8,368 | 2,996 | 5,648 | 2,022 | 906 | 1,116 | 404 |
| 16 | 0 | n/a | n/a | 640 | 12.4 | 7,904 | 7,904 | 2,830 | 6,112 | 2,188 | 966 | 1,222 | 414 |
| | | | | | | | | | | | | | 4,075 |

continued

Table 2—Estimated decrease in value of beef production due to the nonavailability of 2,4,5-T and silvex, area one, Texas, creeping mesquite, south Texas plains (continued)

a/ Taken from table 1.

b/ Beef value at $0.3580 per pound, 1973-77 average.

c/ Production loss calculated from column 8; i.e., 14,016 - 13,716 = 300.

d/ Treatment cost amortized at 7% interest from table 1, column 9, times acres without remaining yield effects (column 5); i.e., $1.51 X 40,000 = $60,400.

e/ Present value calculated using 7% discount factor.

SOURCE: Natural Resource Economics Division, ES&CS, USDA, Corvallis, Oregon.

range recovery could not be achieved in 12 years but woody plants had increased in such density that the area was sprayed with herbicides to control woody plants (Hoffman et al. 1950-77).

There is no alternative-control method from the 2 million acres of creeping mesquite as it grows on dense clay soils with a high saline content (fig. 1, area 1). Once the saline clay soil is disturbed, it is nearly impossible to re-establish a forage grass cover (Hoffman et al. 1950-77). The range site is very productive when the creeping mesquite is controlled with 0.67 pound per acre of 2,4,5-T applied three consecutive years or two applications of 1/2 pounds per acre of picloram: 2,4,5-T (Tordon 225$^R$) mixture (Hoffman et al. 1950-77). Dicamba: 2,4,5-T (Banvel 2+2$^R$) mixture is not an effective control for creeping mesquite, is not considered an alternative and costs $2.50 per acre more than 2,4,5-T.

Fire cannot be used unless the area is first sprayed with 2,4,5-T to reduce competition of mesquite to produce forage grasses.

AREA 2 - ROLLING PLAINS, TEXAS AND OKLAHOMA, AND EDWARDS PLATEAU

A demonstration study was started in 1972 in Haskell County in the east central part of the Rolling Plains of Texas comparing 2,4,5-T treated and untreated pastures to determine economic returns and range condition change in that area (Welch et al. 1972-77). A 559-acre pasture with a heavy infestation of mesquite was treated with 2,4,5-T in May, 1972. A 640-acre pasture with similar soil, mesquite infestation, and livestock-carrying capacity was selected as a comparison check and untreated. The treated pasture was deferred from grazing for May, June, and July following the application of 2,4,5-T for mesquite control to improve range forage conditions. Silvex and dicamba can be substituted for 2,4,5-T in this area with comparable effects and greater cost.

Results from this demonstration are typical for about 22 million acres of mesquite-infested rangeland in the Rolling Plains. During the 5-year study, the treated area produced 34.3 pounds per acre per year from the sale of beef cattle while the untreated pasture produced 26.9 pounds of beef products for a return of $9.63 per acre (table 3). Two of the years the treated pasture produced sufficient forage that could be utilized by stockers to produce 1.25 pounds per day per head for 150 days. Stocker cattle weights increased beef production an additional 9.7 pounds per acre, making a year-beef production of 44 pounds for a return of $15.75 per acre (table 1). Ease of working livestock amounts to $1 per acre saving in labor required for roundups on the treated area (Hoffman et al. 1978 and Hoffman 1975). Beef production loss would be 108,346,000 pounds or a net percent value loss of $25,137,000 during the first 8-year period if 2,4,5-T, silvex or dicamba could not be used (table 4). Production loss may be insignificant if dicamba proves to be an adequate substitute. However, treatment cost would increase $73,900 annually.

Tordan 225$^{R}$ was assumed not to be an alternative because it contains 2,4,5-T. Root plowing could not be used as an alternative as it is difficult to re-establish a forage grass cover in this area. Chaining cannot be used as trees have stems that are too small to be uprooted. Trees are too dense for tree grubbing. As herbicide prices continue to increase, the only economical alternative in this part of the Rolling Plains is not to carry out any control practice; do nothing and reduce livestock numbers as range condition deteriorates year after year (Hoffman et al. 1978).

AREA 3 - ROLLING PLAINS OF TEXAS AND NEW MEXICO

A well-planned mesquite management program has been carried out on an Oldham County, Texas, ranch since 1957 (Hoffman et al. 1950-77). Broadcast application of 2,4,5-T was used first and, if root kills were good, the area was retreated with ground power equipment using 2,4,5-T mixed in diesel oil applied with a hand gun as individual spot treatment. The mixture and rate used controlled regrowth mesquite, pricklypear (Opuntia spp.), cholla (O . spp.), yucca (Yucca spp.), catclaw (Acacia spp.), and lotebush not controlled by 2,4,5-T aerial

Table 3—Five year summary of economic returns in Rolling Plains of Texas from treated and untreated pastures

| | Per acre | | | | | 5 year | Average |
|---|---|---|---|---|---|---|---|
| | 1973 | 1974 | 1975 | 1976 | 1977 | total | yr. total |
| | Sprayed pasture | | | | | | |
| Income: | | | | | | | |
| Beef produced (lbs.) | 35.9 | 32.3 | 35.7 | 37.6 | 30.2 | 171.7 | 34.34 |
| Value of beef produced | $18.67 | $ 9.69 | $12.14 | $12.98 | $11.29 | $64.77 | $12.96 |
| Value of beef/lb. | ($0.52) | ($0.30) | ($0.34) | ($0.345) | (S.$0.3950) (H.$0.3475) | | |
| Specified expense: | | | | | | | |
| Seeding | — | — | — | — | $ 0.17 | | |
| Feed | $ 0.27 | $ 0.36 | $ 1.37 | $ 0.49 | $ 1.58 | | |
| Cost of spraying brush | $ 0.67 | $ 0.67 | $ 0.67 | $ 0.67 | $ 0.67 | $11.29 | $ 2.26 |
| Cost of spraying weeds | — | $ 0.75 | $ 0.75 | $ 0.75 | $ 1.09 | | |
| Cost of chaining | — | — | — | — | $ 0.36 | | |
| Income above feed and spraying cost | $17.73 | $ 7.91 | $ 9.35 | $11.07 | $ 7.42 | $53.48 | $10.70 |
| | Untreated pasture | | | | | | |
| Income: | | | | | | | |
| Beef produced (lbs.) | 28.8 | 25.7 | 23.3 | 28.1 | 28.44 | 134.3 | 26.86 |
| Value of beef produced | $14.97 | $ 7.70 | $ 7.92 | $ 9.68 | $10.53 | $50.80 | $10.16 |
| Value of beef/lb. | ($0.52) | ($0.30) | ($0.34) | ($0.345) | (S.$0.3950) (H.$0.3475) | | |
| Specified expense: | | | | | | | |
| Feed | $ 2.26 | $ 1.52 | $ 1.23 | $ 0.49 | $ 3.61 | $ 9.11 | $ 1.82 |
| Income above feed cost | $12.71 | $ 6.18 | $ 6.70 | $ 9.19 | $ 6.92 | $41.70 | $ 8.34 |
| Labor saving working stock treated pasture | $ 1.00 | $ 1.00 | $ 1.00 | $ 1.00 | $ 1.00 | $ 5.00 | $ 1.00 |
| Economic advantage of spraying | $ 6.02 | $ 2.73 | $ 3.65 | $ 2.88 | $ 1.50 | $16.78 | $ 3.36 |

SOURCE: Welch et al. 1972-77.

Table 4—Estimated decrease in value of beef production if 2,4,5-T and silvex become unavailable and Dicamba proves ineffective, area 2, Texas and Oklahoma, Rolling Plains

| No. years w/o 2,4,5-T | Treated area with remaining yield effects: Acres a/ | Yield a/ | Production | Previously treated area w/o remaining yield effects: Acres | Yield a/ | Production | Total beef: Production | Value b/ | Production loss w/o 2,4,5-T c/ | Value of lost production b/ | Amortized cost of lost production d/ | Net value of lost production b/ | Net present value of lost production e/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thous | Lbs | Thous lbs | Thous | Lbs | Thous lbs | Thous lbs | Dols | Thous lbs | Thousand dollars | | | |
| 0 | 1,408 | 44 | 61,952 | 0 | 26.9 | n/a | 61,952 | 22,179 | 0 | n/a | n/a | n/a | n/a |
| 1 | 1,232 | 44 | 54,208 | 176 | 26.9 | 4,734 | 58,942 | 21,101 | 3,010 | 1,078 | 128 | 950 | 950 |
| 2 | 1,056 | 44 | 46,464 | 352 | 26.9 | 9,469 | 55,933 | 20,024 | 6,019 | 2,155 | 257 | 1,890 | 1,766 |
| 3 | 880 | 44 | 38,720 | 528 | 26.9 | 14,203 | 52,923 | 18,946 | 9,029 | 3,232 | 385 | 2,847 | 2,487 |
| 4 | 704 | 44 | 30,976 | 704 | 26.9 | 18,938 | 49,914 | 17,869 | 12,038 | 4,310 | 514 | 3,796 | 3,099 |
| 5 | 528 | 44 | 23,232 | 880 | 26.9 | 23,672 | 46,904 | 16,792 | 15,048 | 5,387 | 642 | 4,745 | 3,620 |
| 6 | 352 | 44 | 15,488 | 1,056 | 26.9 | 28,406 | 43,894 | 15,714 | 18,058 | 6,465 | 771 | 5,694 | 4,060 |
| 7 | 176 | 44 | 7,744 | 1,232 | 26.9 | 33,141 | 40,885 | 14,637 | 21,067 | 7,542 | 899 | 6,643 | 4,427 |
| 8 | 0 | n/a | n/a | 1,408 | 26.9 | 37,875 | 37,875 | 13,559 | 24,077 | 8,620 | 1,028 | 7,592 | 4,728 |
| | | | | | | | | | | | | | 25,137 |

a/ Taken from table 1.

b/ Beef value at $0.3580 per pound, 1973-77 average.

c/ Production loss calculated from Column 8; i.e., 61,952 - 58,942 = 3,010.

d/ Treatment cost amortized at 7% interest from table 1, column 9, times acres without remaining yield effects (column 5); i.e., $0.73 X 176,000 = $128,480.

e/ Present value calculated using 7% discount factor.

SOURCE: Natural Resource Economics Division, ES&CS, USDA, Corvallis, Oregon.

spraying. Results from the long-term demonstration indicate the following (Hoffman et al. 1950-77).

Increased calf weights of 40 pounds per animal per year.
Increased stocking rate of 30 percent.
Increase of better forage grasses.
Labor saved in working livestock - $1 per acre per year.

Mature cows weighed 49 pounds more than on untreated area for a value of $17.54 per head (Pallmeyer 1971-76).

The 2,4,5-T treated pasture produced 23.2 pounds of beef products per acre while the untreated area produced 14.4 pounds for a value of $5.16 per acre (table 1). Beef production per acre of 21.9 pounds for a value of $7.84 per acre was selected for all of Area 3 because of growth condition variations.

Production loss would amount to 72,600,000 pounds of beef for net present value loss of $13,484,000 during the first 10-year rotation period if 2,4,5-T, silvex, or dicamba could not be used (table 5). Production loss may be insignificant when dicamba is used as a substitute; however, treatment cost would increase $63,400 annually.

Stocking rate has remained at 1 animal unit to 18 acres on the treated area. By 1970, the uncontrolled area stocking rate was reduced to 1 animal unit to 35 acres as range conditions deteriorated. Also labor cost has increased as the density of mesquite increased. Controlling mesquite appears to have increased the bobwhite quail population, and antelope have moved into the area since mesquite cover has been reduced.

## Controlling

Dicamba is very effective in controlling broadleaf weeds, and if it were substituted for 2,4,5-T, some weeds would be controlled reducing the amount of food for game birds. Silvex can be substituted for 2,4,5-T in the Rolling Plains of Texas and New Mexico. Use of fire is not effective as sufficient fuel cannot be produced to cause a hot fire.

Table 5--Estimated decrease in value of beef production if 2,4,5-T and silvex become unavailable and Dicamba proves ineffective, area 3, Texas and New Mexico Rolling Plains

| No. years w/o 2,4,5-T | Treated area with remaining yield effects: Acres a/ | Treated area with remaining yield effects: Yield a/ | Treated area with remaining yield effects: Production | Previously treated area w/o remaining yield effects: Acres | Previously treated area w/o remaining yield effects: Yield a/ | Previously treated area w/o remaining yield effects: Production | Total beef: Production | Total beef: Value b/ | Production loss w/o 2,4,5-T c/ | Value of lost production b/ | Amortized cost of lost production d/ | Net value of lost production b/ | Net present value of lost production e/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thous | Lbs | Thous lbs | Thous | Lbs | Thous lbs | Thous lbs | Dols | Thous lbs | ---Thousand dollars--- | | | |
| 0 | 1,760 | 21.9 | 38,544 | 0 | n/a | n/a | 38,544 | 13,813 | 0 | n/a | n/a | n/a | n/a |
| 1 | 1,584 | 21.9 | 34,690 | 176 | 14.4 | 2,534 | 37,224 | 13,326 | 1,320 | 473 | 109 | 364 | 364 |
| 2 | 1,408 | 21.9 | 30,835 | 352 | 14.4 | 5,069 | 35,904 | 12,854 | 2,640 | 945 | 218 | 727 | 679 |
| 3 | 1,232 | 21.9 | 26,981 | 528 | 14.4 | 7,603 | 34,584 | 12,381 | 3,960 | 1,418 | 327 | 1,091 | 953 |
| 4 | 1,056 | 21.9 | 23,126 | 704 | 14.4 | 10,138 | 33,264 | 11,909 | 5,280 | 1,890 | 436 | 1,454 | 1,162 |
| 5 | 880 | 21.9 | 19,272 | 880 | 14.4 | 12,672 | 31,944 | 11,436 | 6,600 | 2,363 | 546 | 1,817 | 1,386 |
| 6 | 704 | 21.9 | 15,418 | 1,056 | 14.4 | 15,206 | 30,624 | 10,963 | 7,920 | 2,835 | 655 | 2,180 | 1,554 |
| 7 | 528 | 21.9 | 11,563 | 1,232 | 14.4 | 17,741 | 29,304 | 10,491 | 9,240 | 3,308 | 764 | 2,544 | 1,695 |
| 8 | 352 | 21.9 | 7,709 | 1,408 | 14.4 | 20,275 | 27,984 | 10,018 | 10,560 | 3,780 | 873 | 2,907 | 1,810 |
| 9 | 176 | 21.9 | 3,854 | 1,584 | 14.4 | 22,810 | 26,664 | 9,546 | 11,880 | 4,253 | 982 | 3,271 | 1,904 |
| 10 | 0 | n/a | n/a | 1,760 | 14.4 | 25,344 | 25,344 | 9,073 | 13,200 | 4,726 | 1,091 | 3,635 | 1,977 |
| | | | | | | | | | | | | | 13,484 |

a/ Taken from table 1.

b/ Beef value at $0.3580 per pound, 1973-77 average.

c/ Production loss calculated from column 8; i.e., 38,544 - 37,224 = 1,320.

d/ Treatment cost amortized at 7% interest from table 1, column 9, times acres without remaining yield effects (column 5); i.e., $0.62 X 176,000 = $109,120.

e/ Present value calculated using 7% discount factor.

SOURCE: Natural Resource Economics Division, ES&CS, USDA, Corvallis, Oregon.

Root plowing cannot be used because of low rainfall to establish plant cover and soil erosion is increased on plowed areas. Trees are too small for effective chaining. Tordon 225[R] can be substituted for 2,4,5-T but would increase control costs.

AREA 4 - GULF COAST AND COASTAL PRAIRIE

About 9 million acres of the Gulf Coast area have become heavily infested with mesquite, as a dense overstory, and other species of granjeno, blackbrush, colima (*Zanthoxylum spp.*), Brazil (*Acacia spp.*), huisache, lotebush, retama (*Parkinsonia spp.*), and macartney rose (*Rosa bracteata*) in layers of shorter brush causing the area to be unprofitable for beef cattle production (Gould 1969). Mesquite in the Gulf Coast area is original stands or regrowth following chaining. Ranges were in poor condition with 15 percent decreaser forage plants, producing less than a third to a half of their potential.[1/]

To give ranchers an answer to this problem, a 10-year result demonstration cooperative project began in 1963 on two large ranches. The test plots included 100 acres of 5-year-old regrowth mesquite which had been chained in 1959 and 100 acres with original growth mesquite (Hoffman et al. 1969).

In May, 1964, all of the acreage on both ranches was sprayed aerially with 2,4,5-T low-volatile ester at 1/2 and 1 pound per acre mixed in 1 gallon diesel oil and sufficient water to make 5 gallons total solution per acre (fig. 9). Each year thereafter, about 15 acres were resprayed on each ranch to have plots with all combinations of retreatment years. Starting in 1965, the rate of 2,4,5-T was 0.67 pound per acre to obtain annual broomweed control. Currently, 1 pound per acre 2,4,5-T is recommended for control of regrowth mesquite and broomweed.

All plots were deferred each year from mid-March until mid-October. Before cattle were allowed to graze, forage clippings were made with the production per acre expressed on an air-dry basis. Woody plants with any green foliage were considered live.

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1/Decreaser - a range management term describing a particular group of plants.

Figure 9. Aerial application of a dense stand of regrowth mesquite which was chained 10 years previously.

Clipping results indicated the tremendous suppressing effect that mesquite, mixed brush and weeds had on grass production. The greatest increase in forage production in the Gulf area seems to have occurred during the first and second years following the first aerial spraying. To express forage production in terms of stocking rates, it was assumed that a cow's requirement for maintenance, pregnancy, and lactation was 12,000 pounds of 45 percent digestible air-dry material, plus an additional 12,000 pounds for grass plant maintenance. Based upon these assumptions, the estimated stocking rate for the 6 years in the untreated regrowth mesquite area was 26.5 acres per animal unit, compared to 9.7 acres per animal unit in the treated plot. Repeated applications maintained the stocking rate at 5.7 acres per animal unit (table 6).

Grass on the original growth mesquite had less vigor; thus the first year's response was less than on the regrowth mesquite area (table 7). Stocking rate on the untreated area was 37.6 acres per animal unit compared to 11.5 acres per animal unit on the treated area. Repeat applications maintained a stocking rate at 7.0 acres per animal unit (fig. 10 and 11).

Stocking rate in the untreated areas increased tremendously in 1967-70. The reasons were an extremely wet fall and increased plant vigor resulting from deferment for the four previous growing seasons. Forage production per acre during 1966 was less than other years since rainfall was less and especially so during the growing season.

The maximum life of one treatment was 5 years. With retreatment the third or fourth years, the life of the treatment can be 12 or more years based on evaluations made in 1977. Maximum forage increase appears to be in the year of treatment and the following year if rainfall is normal.

Figures 12 and 13 illustrate forage production per acre by years on a graph to show total effect from aerial broadcast applications of 2,4,5-T.

Table 6--Evaluation, Melon Creek Ranch, Refugio County, Texas, mesquite control result demonstrations, area 4, Gulf Coast and Coastal Prairie

| Date sprayed | Kill in October 64 | 65 | 66 | 67 | 68 | 70 | Forage production Oct. 64 | Oct. 65 | Oct. 66 | Oct. 67 | Oct. 68 | Oct. 70 | Actual stock. rate | Forage available for grazing 64 | 65 | 66 | 67 | 68 | 70 | Ave. stock rate 64 - 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Percent | | | | | | Lbs/acre | | | | | | Acres/AU | Acres/AU | | | | | | |
| Plot 1 | | | | | | | | | | | | | | | | | | | | |
| May 64 | | | | | | | | | | | | | | | | | | | | |
| June 65 | | | | | | | | | | | | | | | | | | | | |
| June 66 | 32 | 25 | 30 | 92 | 92+ | 96 | 3075 lbs. | 4220 lbs. | 2800 lbs. | 5310 lbs. | 7300 lbs. | 8030 lbs. | 20 | 8 | 6 | 8.6 | 5.1 | 3.3 | 3.0 | 5.7 |
| June 67 | | | | | | | | | | | | | | | | | | | | |
| June 68 | | | | | | | | | | | | | | | | | | | | |
| Plot 2 | | | | | | | | | | | | | | | | | | | | |
| May 64 | 32 | 38 | 30 | 20 | 10 | 85 | 3075 | 1655 | 1710 | 3220 | 3665 | 7430 | 20 | 8 | 15 | 14.0 | 7.5 | 6.6 | 3.2 | 9.1 |
| June 68 | | | | | | | | | | | | | | | | | | | | |
| Plot 3 | | | | | | | | | | | | | | | | | | | | |
| May 64 | | | | | | | | | | | | | | | | | | | | |
| June 68 | 32 | 38 | 30 | 20 | 10 | 85 | 3075 | 1655 | 1710 | 3220 | 3665 | 7110 | 20 | 8 | 15 | 14.0 | 7.5 | 6.6 | 3.4 | 9.1 |
| Tordon | | | | | | | | | | | | | | | | | | | | |
| Plot 4 | | | | | | | | | | | | | | | | | | | | |
| May 64 | 32 | 38 | 30 | 20 | 10 | 0 | 3075 | 1655 | 1710 | 3220 | 3665 | 3488 | 20 | 8 | 15 | 14.0 | 7.5 | 6.6 | 7.0 | 9.7 |
| Plot 5 | | | | | | | | | | | | | | | | | | | | |
| Check | 0 | 0 | 0 | 0 | 0 | 0 | 590# grass 3680# weeds | Same as 64 | 600# grass 2200# weeds | 1250# grass 800# weeds | 2050# grass 2000# weeds | 2300 | 20 | 39 | 39 | 39.0 | 19.0 | 11.7 | 11.0 | 26.5 |

Table 7--Evaluation, Scott Creek Ranch, Refugio County, Texas, mesquite control result demonstrations, area 4, Gulf Coast and Coastal Prairie

| Date sprayed | Kill in October 64 | 65 | 66 | 67 | 68 | 70 | Forage production Oct. 64 | Oct. 65 | Oct. 66 | Oct. 67 | Oct. 68 | Oct. 70 | Actual stock. rate | Forage available for grazing 64 | 65 | 66 | 67 | 68 | 70 | Ave. stock rate 64 - 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Percent | | | | | | Lbs/acre | | | | | | Acres/AU | Acres/AU | | | | | | |
| Plot 1 | | | | | | | | | | | | | | | | | | | | |
| May 64<br>June 65<br>June 66<br>June 67<br>June 68 | 10 | 24 | 50 | 88 | 90+ | 85 | 2350 | 3165 | 3170 | 3453 | 6083 | 5820 | 25 | 11 | 8 | 8.0 | 7 | 4.0 | 4.1 | 7.0 |
| Plot 2 | | | | | | | | | | | | | | | | | | | | |
| May 64<br>June 68 | 10 | 24 | 25 | 14 | 14 | 40 | 2350 | 2545 | 1590 | 1750 | 1750 | 3485 | 25 | 11 | 10 | 15.3 | 14 | 11.3 | 7.0 | 11.4 |
| Plot 3 | | | | | | | | | | | | | | | | | | | | |
| May 64<br>June 68<br>(Tordon) | 10 | 24 | 25 | 14 | 14 | 70 | 2350 | 2545 | 1590 | 1750 | 1750 | 4900 | 25 | 11 | 10 | 15.3 | 14 | 11.3 | 5.0 | 11.1 |
| Plot 4 | | | | | | | | | | | | | | | | | | | | |
| May 64 | 10 | 24 | 25 | 14 | 14 | 0 | 2350 | 2545<br>#| 1590<br>#| 1750<br>#| 2130<br>#| 3303 | 25 | 11 | 10 | 15.3 | 14 | 11.3 | 7.3 | 11.5 |
| Plot 5 | | | | | | | | | | | | | | | | | | | | |
| Check | 0 | 0 | 0 | 0 | 0 | 0 | 200# grass<br>1120# weeds | 590# grass<br>3680 weeds | 600# grass<br>2400# weeds | 1250# grass<br>800# weeds | 2050# grass<br>2000# weeds | 2300 | 25 | 106 | 39 | 39 | 19 | 11.7 | 11.0 | 37.6 |

Figure 10. Original growth mesquite on the Gulf Coast and Coastal Prairie area. Stocking rate on this area over the 8-year study was 37.6 acres per animal unit.

Figure 11. Original growth mesquite 18 months following control. Note the heavy layer of herbaceous grass cover that has re-established following control. Wildlife habitat was improved following control. Stocking rate was 7 acres per animal unit. Range conditions improved from poor to good in two growing seasons.

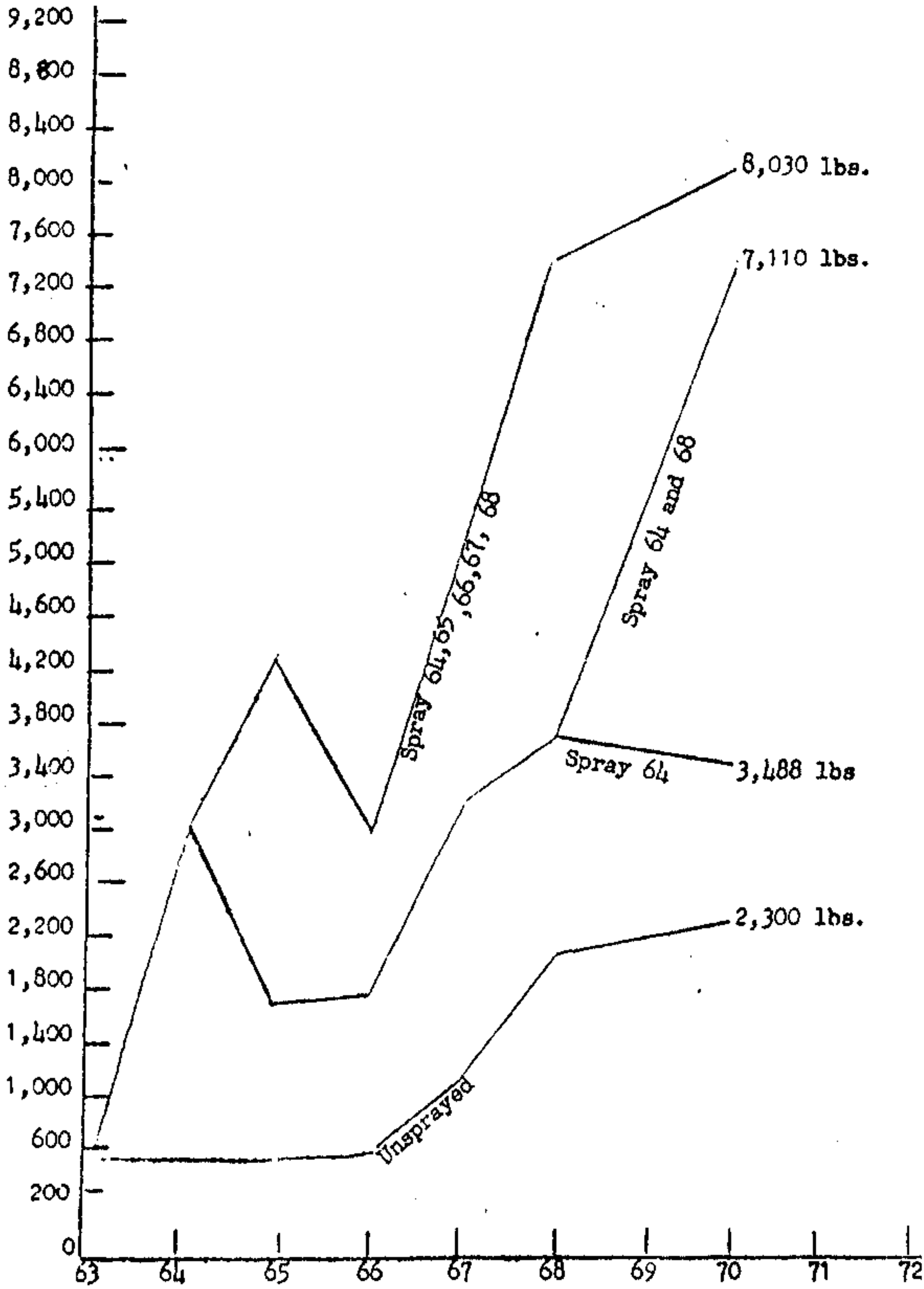



Figure 12. Forage production following 2,4,5-T treatments - regrowth mesquite.

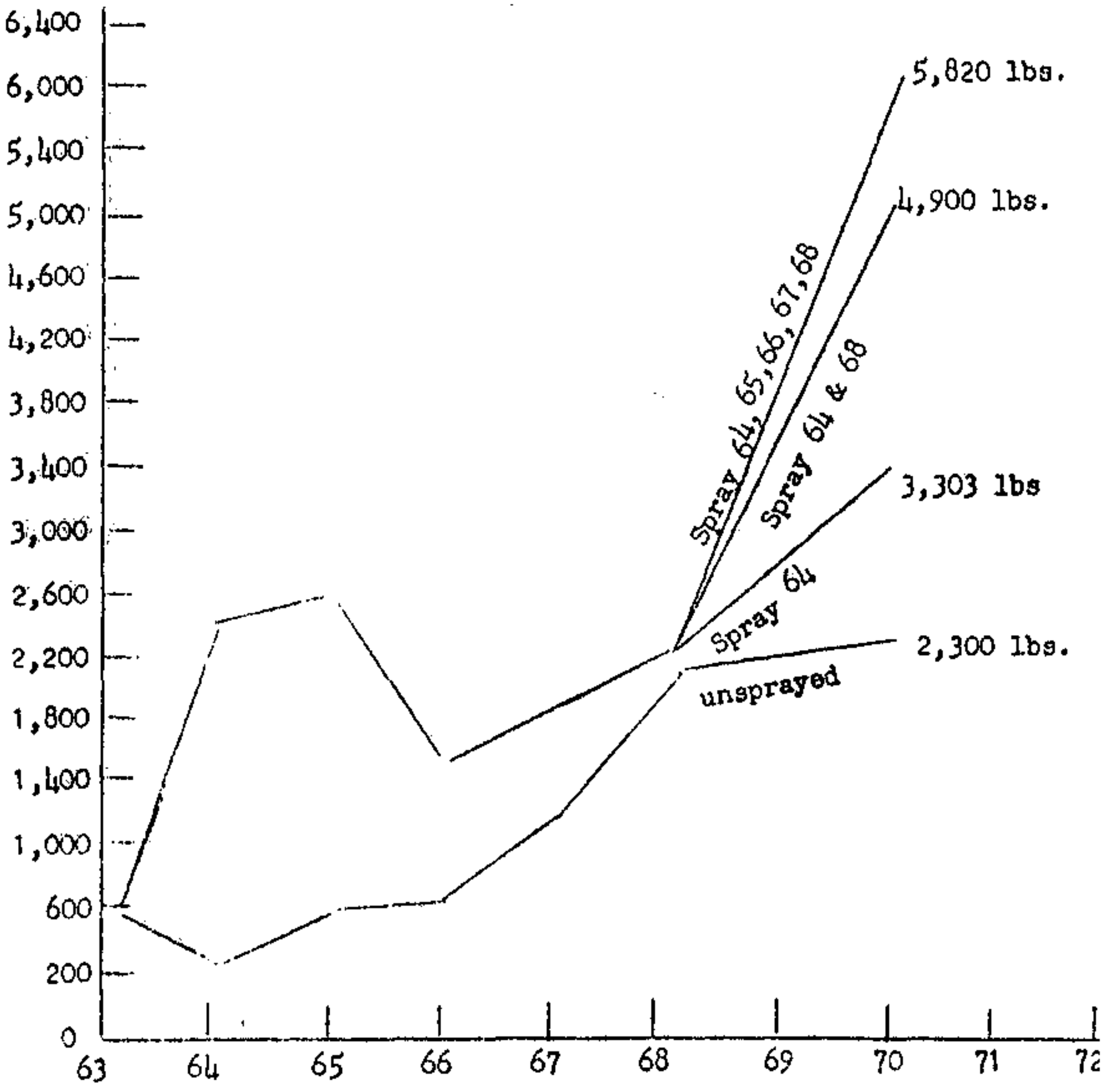



Figure 13. Forage production following 2,4,5-T treatments - original growth mesquite.

The stocking rate maintained on each ranch was 20 and 25 acres per animal unit. This rate of stocking left no forage residue for maintenance for forage plants. Stocking rate with aerial broadcast of 2,4,5-T and rapid range improvement would be 13 acres per animal unit on each area.

Landowners indicated that at least $1 per acre was saved when working livestock on the treated area when compared to the untreated area. The treated area could be worked with fewer cowboys on the ground, and the helicopter pilot could see and direct livestock better. The helicopter pilot has to be directly over the animals before he can see them in dense mesquite with a heavy canopy. Animals are more docile in treated pastures when compared to untreated pastures. Also, there is less injury to cowboys and horses when working livestock in the treated pastures.

The 2,4,5-T treated area could produce 41 pounds of saleable beef for a value of $14.67 per acre while the untreated area could produce 13.3 pounds for a value of $4.76 per acre. Beef production loss would amount to 23,268,000 pounds for a net present value loss of $5,854,000 during the first 5-year rotation without the use of 2,4,5-T (table 8).

About 4 million acres of mesquite-infested land has the potential for conversion to cultivated crop production, but the remaining five million acres are suited only for grazing lands (Hoffman et al. 1978).

On the other five million acres, root plowing cannot be considered an alternative control method because of high cost and disturbance of turf. Brush could be sprayed by aerial broadcast, and burning the area 18 months later would remove much of the dead top growth. Burning would allow livestock more access to forage plants and reduce wildlife cover. Burning can be used only with an application of herbicide to reduce woody plant competition to produce grass for a fuel (Gordon and Scifres 1978). Two-way chaining could be used on the small acreage that is remaining with original stands of mesquite. Effective control would

Table 8--Estimated decrease in value of beef production due to the nonavailability of 2,4,5-T, area 4, Texas Gulf Coast and Coastal Prairie

| No. years w/o 2,4,5-T | Treated area with remaining yield effects: Acres a/ | Yield a/ | Production | Previously treated area w/o remaining yield effects: Acres | Yield a/ | Production | Total beef: Production | Value b/ | Production loss w/o 2,4,5-T c/ | Value of lost production b/ | Amortized cost of lost production d/ | Net value of lost production b/ | Net present value of lost production e/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thous | Lbs | Thous lbs | Thous | Lbs | Thous lbs | Thous lbs | Dols | Thous lbs | Thousand dollars | | | |
| 0 | 280 | 41.0 | 11,480 | n/a | 13.3 | n/a | 11,480 | 4,110 | n/a | n/a | n/a | n/a | n/a |
| 1 | 224 | 41.0 | 9,184 | 56 | 13.3 | 745 | 9,929 | 3,555 | 1,551 | 555 | 90 | 465 | 465 |
| 2 | 168 | 41.0 | 6,888 | 112 | 13.3 | 1,490 | 8,378 | 2,999 | 3,102 | 1,111 | 179 | 932 | 871 |
| 3 | 112 | 41.0 | 4,592 | 168 | 13.3 | 2,234 | 6,826 | 2,444 | 4,654 | 1,666 | 269 | 1,397 | 1,220 |
| 4 | 56 | 41.0 | 2,296 | 224 | 13.3 | 2,979 | 5,275 | 1,888 | 6,205 | 2,221 | 358 | 1,863 | 1,521 |
| 5 | 0 | n/a | n/a | 280 | 13.3 | 3,724 | 3,724 | 1,333 | 7,756 | 2,777 | 448 | 2,329 | 1,777 |
| | | | | | | | | | | | | | 5,854 |

a/ Taken from table 1.

b/ Beef value at $0.3580 per pound, 1973-77 average.

c/ Production loss calculated from column 8; i.e., 11,480 - 9,929 = 1,551.

d/ Treatment cost amortized at 7% interest from table 1, column 9, times acres without remaining yield effects (column 5); i.e., $1.61 X 56,000 = $90,160.

e/ Present value calculated using 7% discount factor.

SOURCE: Natural Resource Economics Division, ES&CS, USDA, Corvallis, Oregon.

last for 4 years causing the chained area to be more dense with mesquite.

Dicamba is not effective for mesquite control in the humid areas of Texas. Silvex control data are not available to indicate a valid alternative. If 2,4,5-T were banned, it would appear that it is more economical to not do any mechanical control methods. Mechanical control methods would increase the density of mesquite. Tordon 225$^R$ could be substituted for 2,4,5-T but would increase control costs.

AREA 5 - SOUTH TEXAS PLAINS

The South Texas Plains contain about 15 million acres of mixed brush species which are not effectively controlled with 2,4,5-T or silvex (Gould 1969). Picloram:2,4,5-T (Tordon 225$^R$) mixture controls both mesquite and mixed brush species. The 2,4,5-T alone at the rate of 1 pound per acre removes only the overstory of mesquite while the mixed species continue to increase in density. One application lasts about 5 years, and range conditions can be maintained for an indefinite period with periodic applications of Tordon 225$^R$ mixture. Without control, stocking rates can be up to 1 animal unit per 40 acres within 15 years based on observation in the South Texas Plains area (Hoffman 1967, fig. 14 and 15).

The most productive range sites are root plowed and established to a tame pasture forage crop; therefore, root plowing and seeding are not alternative-control methods as the acreage that is root plowed is not subject to be treated with 2,4,5-T. Lands root plowed in South Texas could be potential for dryland farming (Hoffman et al. 1978).

In 1970, a state label was granted for commercial applications of the herbicide picloram:2,4,5-T, (Tordon 225$^R$), mixture. Picloram: 2,4,5-T herbicide mixture produces from 25 to 100 percent more kill on mesquite than when 2,4,5-T alone is used (Fisher et al. 1972). Herbicide mixture gives control on blackbrush, granjeno, huisache, cacti, lotebush, whitebrush, catclaw, while 2,4,5-T alone produces

Figure 14. A brush infested area in the South Texas Plains. Note the absence of desirable forage plants. Stocking rate on this area was estimated to be 40 acres per animal unit.

Figure 15. A brush area two years following herbicide application had a stocking rate of 10 acres per animal unit. Note that woody plants suitable for browsing were not affected.

control on mesquite only. No harmful effects to grasses or native legumes have resulted.

Livestock production and brush control were good on treated areas for South Texas Plains when compared to uncontrolled areas. The following table indicates benefits of treated pasture. Comparison was made with one sire herds on treated and untreated pasture in Jim Wells County in October, 1971 (Hoffman et al. 1971).

| | Treated | Untreated | Difference |
|---|---|---|---|
| Stocking Rate/A/AU | 8 | 25 | 17A |
| Avg. Calf Wt. Lbs. - 205 days | 532 | 471 | 61 |
| Supplemental feed/animal/90 days | 2 lb. CSC | 2 lb. CSC + burned pear | $15 |
| Interest on investment/AU | $3 | ---- | $3 |

Treated pasture cattle required no additonal supplemental feed while cattle in untreated pasture had to have burned pricklypear for 90 days (fig. 16). Cost of burning spines off pricklypear pads was about $5 per animal unit per month in 1970-71 which is a $15 saving per animal unit per year in favor of treated pasture. Interest on investment for control cost and purchase of additional cattle is estimated at $3 per animal unit.

Considering increased calf weight differences, supplemental feed, and interest on investment, treated pastures produce $33.84 more per animal unit per year than untreated pasture. Cost of treatment was $11.50 per acre or a $92 per animal unit cost. Treatment life lasted 5 years and treatment cost was recovered in less than three years.

Brush control plus stocking rates to obtain proper use of natural resources are profitable in the South Texas Plains. Also wildlife has increased on treated pasture. Browse and cover for wildlife were not affected by control measures.

Figure 16. Pricklypear can be utilized by cattle when the spines are burned off by using a butane pear burner. Cost is about $5 per month per animal unit. Plants regrow following the burning.

Since the above results were obtained from an area that received more than normal rainfall, the stocking rate for the South Texas Plains was set at 14 acres per animal unit on the treated area. The untreated area would have had a stocking rate of 1 animal unit per 25 acres. These stocking rates were derived from landowners and the long time experience of the Extension Range Brush and Weed Control Specialist.

The herbicide-treated area could produce $10.02 per acre as compared to $5.16 per acre for the untreated (table 1). Beef production loss would be 8,364,000 pounds for a net present value loss of $1,680,000 during the first 5-year rotation if 2,4,5-T or Tordon 225[R] cannot be used (table 9).

Dicamba is not an effective control alternative for Area 5 mesquite or other brush species. Silvex has not been tested to know if it could be an alternative. Tordon 225[R] is the only herbicide alternative for 2,4,5-T. Picloram alone is not a registered use. Fire would have to be used in combination with aerial spraying of 2,4,5-T to reduce competition and grow fuel.

AREA 6 - SOUTHWEST

Mesquite in the southwest occupies about 23 million acres of arid rangeland which has a low potential production (Platt 1959, fig. 1, area 6). Any disturbance of the soil destroys the existing forage plants. The 2,4,5-T or silvex application at 1/2 pound per acre is the only practical way to keep mesquite-infested rangeland in a productive state.

Stocking rates vary from 40 to 80 acres per animal unit with the average being 60 acres per animal unit for the treated area and 94 acres per animal unit for the untreated area.

Dicamba is a potential alternative control method, but increased cost per acre may eliminate it because of low production of southwestern rangelands in Area 6.

Table 9--Estimated decrease in value of beef production due to the nonavailability of 2,4,5-T and Tordon 225[R], area 5, Texas, South Texas Plains

| No. years w/o 2,4,5-T | Treated area with remaining yield effects: Acres a/ | Treated area with remaining yield effects: Yield a/ | Treated area with remaining yield effects: Production | Previously treated area w/o remaining yield effects: Acres | Previously treated area w/o remaining yield effects: Yield a/ | Previously treated area w/o remaining yield effects: Production | Total beef: Production | Total beef: Value b/ | Production loss w/o 2,4,5-T c/ | Value of lost production b/ | Amortized cost of lost production d/ | Net value of lost production b/ | Net present value of lost production e/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thous | Lbs | Thous lbs | Thous | Lbs | Thous lbs | Thous lbs | Dols | Thous lbs | Thousand dollars | Thousand dollars | Thousand dollars | Thousand dollars |
| 0 | 205 | 28.0 | 5,740 | n/a | n/a | n/a | 5,740 | 2,055 | n/a | n/a | n/a | n/a | n/a |
| 1 | 164 | 28.0 | 4,592 | 41 | 14.4 | 590 | 5,182 | 1,855 | 558 | 200 | 66 | 134 | 134 |
| 2 | 123 | 28.0 | 3.444 | 82 | 14.4 | 1,181 | 4,625 | 1,656 | 1,115 | 399 | 132 | 267 | 250 |
| 3 | 82 | 28.0 | 2,296 | 123 | 14.4 | 1,771 | 4,067 | 1,456 | 1,673 | 599 | 198 | 401 | 350 |
| 4 | 41 | 28.0 | 1,148 | 164 | 14.4 | 2,362 | 3,510 | 1,257 | 2,230 | 798 | 264 | 534 | 436 |
| 5 | 0 | n/a | n/a | 205 | 14.4 | 2,952 | 2,952 | 1,057 | 2,788 | 998 | 330 | 668 | 510 |
| | | | | | | | | | | | | | 1,680 |

a/ Taken from table 1.

b/ Beef value at $0.3580 per pound, 1973-77 average.

c/ Production loss calculated from column 8; i.e., 5,740 - 5,182 = 558.

d/ Treatment cost amortized at 7% interest from table 1, coumn 9, times acres without remaining yield effects (column 5); i.e., $1.61 X 41,000 = $66,010.

e/ Present value calculated using 7% discount factor.

SOURCE: Natural Resource Economics Division, ES&CS, USDA, Corvallis, Oregon.

Forage yields in the mesquite-dune area of New Mexico increased from 23 pounds per acre on the untreated to 192 pounds per acre on the sprayed part. The treated area could carry 1 animal unit per 107 acres with much reduction in soil loss because of wind erosion while the untreated area could support 1 animal unit per 640 acres. Once the soil is disturbed, it is subject to rapid erosion. Re-establishing a plant cover is less than 20 percent successful. Table 1 shows results from the accepted control method and the best alternative. Beef production loss would be 102,595,000 pounds for a net present value loss of $6,133,000 during the first 10-year rotation period that 2,4,5-T, silvex, and dicamba could not be used (table 10). Production loss may be insignificant if dicamba is used as a substitute; however, treatment cost would increase $29,200 annually.

## POST-BLACKJACK OAK SAVANNAH

The Post Oak Area occupies 35 million acres in Texas, Arkansas, Oklahoma, Kansas, and Missouri (Platt 1959, fig. 17). The area was once a savannah-type vegetation, but mismanagement caused oak species to increase in density which reduced carrying capacity making livestock operations unprofitable. Brush management can balance native plants and return grazing to a profitable enterprise and improve the grassland ecosystem (fig. 18 and 19).

The Post Oak Savannah Vegetation Area in Texas contains 11.3 million acres composed of overstory woody species of post oak, blackjack oak, and winged elm with an understory of yaupon and tall-growing native forage plants (Darrow and McCully 1959).

In Oklahoma, the Oak Savannah occupies some 6.0 million acres with 4.5 million acres having dominate species of post and blackjack oaks. In the remainder of the area, winged elm and hickory are a part of the overstory (Elwell et al. 1974).

Table 10--Estimated decrease in value of beef production if 2,4,5-T and silvex become unavailable and Dicamba proves ineffective, area 6, Texas, New Mexico, Arizona and California

| No. years w/o 2,4,5-T | Treated area with remaining yield effects: Acres a/ | Treated area with remaining yield effects: Yield a/ | Treated area with remaining yield effects: Production | Previously treated area w/o remaining yield effects: Acres | Previously treated area w/o remaining yield effects: Yield a/ | Previously treated area w/o remaining yield effects: Production | Total beef: Production | Total beef: Value b/ | Production loss w/o 2,4,5-T c/ | Value of lost production b/ | Amortized cost of lost production d/ | Net value of lost production b/ | Net present value of lost production e/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thous | Lbs | Thous lbs | Thous | Lbs | Thous lbs | Thous lbs | Dols | Thous lbs | Thousand dollars | Thousand dollars | Thousand dollars | Thousand dollars |
| 0 | 8,110 | 6.5 | 52,715 | n/a | n/a | n/a | 52,715 | 18,872 | n/a | n/a | n/a | n/a | n/a |
| 1 | 7,299 | 6.5 | 47,443 | 811 | 4.2 | 3,406 | 50,849 | 18,204 | 1,866 | 668 | 503 | 165 | 165 |
| 2 | 6,488 | 6.5 | 42,172 | 1,622 | 4.2 | 6,812 | 48,984 | 17,536 | 3,731 | 1,336 | 1,006 | 330 | 308 |
| 3 | 5,677 | 6.5 | 36,900 | 2,433 | 4.2 | 10,218 | 47,118 | 16,868 | 5,597 | 2,004 | 1,508 | 496 | 433 |
| 4 | 4,866 | 6.5 | 31,629 | 3,244 | 4.2 | 13,625 | 45,254 | 16,201 | 7,461 | 2,671 | 2,011 | 660 | 539 |
| 5 | 4,055 | 6.5 | 26,357 | 4,055 | 4.2 | 17,031 | 43,388 | 15,533 | 9,327 | 3,339 | 2,514 | 825 | 629 |
| 6 | 3,244 | 6.5 | 21,086 | 4,866 | 4.2 | 20,437 | 41,523 | 14,865 | 11,192 | 4,007 | 3,017 | 990 | 706 |
| 7 | 2,433 | 6.5 | 15,814 | 5,677 | 4.2 | 23,843 | 39,657 | 14,197 | 13,058 | 4,675 | 3,520 | 1,155 | 770 |
| 8 | 1,622 | 6.5 | 10,543 | 6,488 | 4.2 | 27,250 | 37,793 | 13,530 | 14,922 | 5,342 | 4,023 | 1,319 | 821 |
| 9 | 811 | 6.5 | 5,271 | 7,299 | 4.2 | 30,656 | 35,927 | 12,862 | 16,788 | 6,010 | 4,525 | 1,485 | 864 |
| 10 | 0 | n/a | n/a | 8,110 | 4.2 | 34,062 | 34,062 | 12,194 | 18,653 | 6,678 | 5,028 | 1,650 | 898 |
| | | | | | | | | | | | | | 6,133 |

a/ Taken from table 1.

b/ Beef value at $0.3580 per pound, 1973-77 average.

c/ Production loss calculated from column 8, i.e., 52,715-50,849 = 51,866

d/ Treatment cost amortized at 7% interest from table 1, column 9, times acres without remaining yield effects (column 5); i.e., $0.62 X 811,000 = $502,820.

e/ Present value calculated using 7% discount factor.

SOURCE: Natural Resource Economics Division, ES&CS, USDA, Corvallis, Oregon.

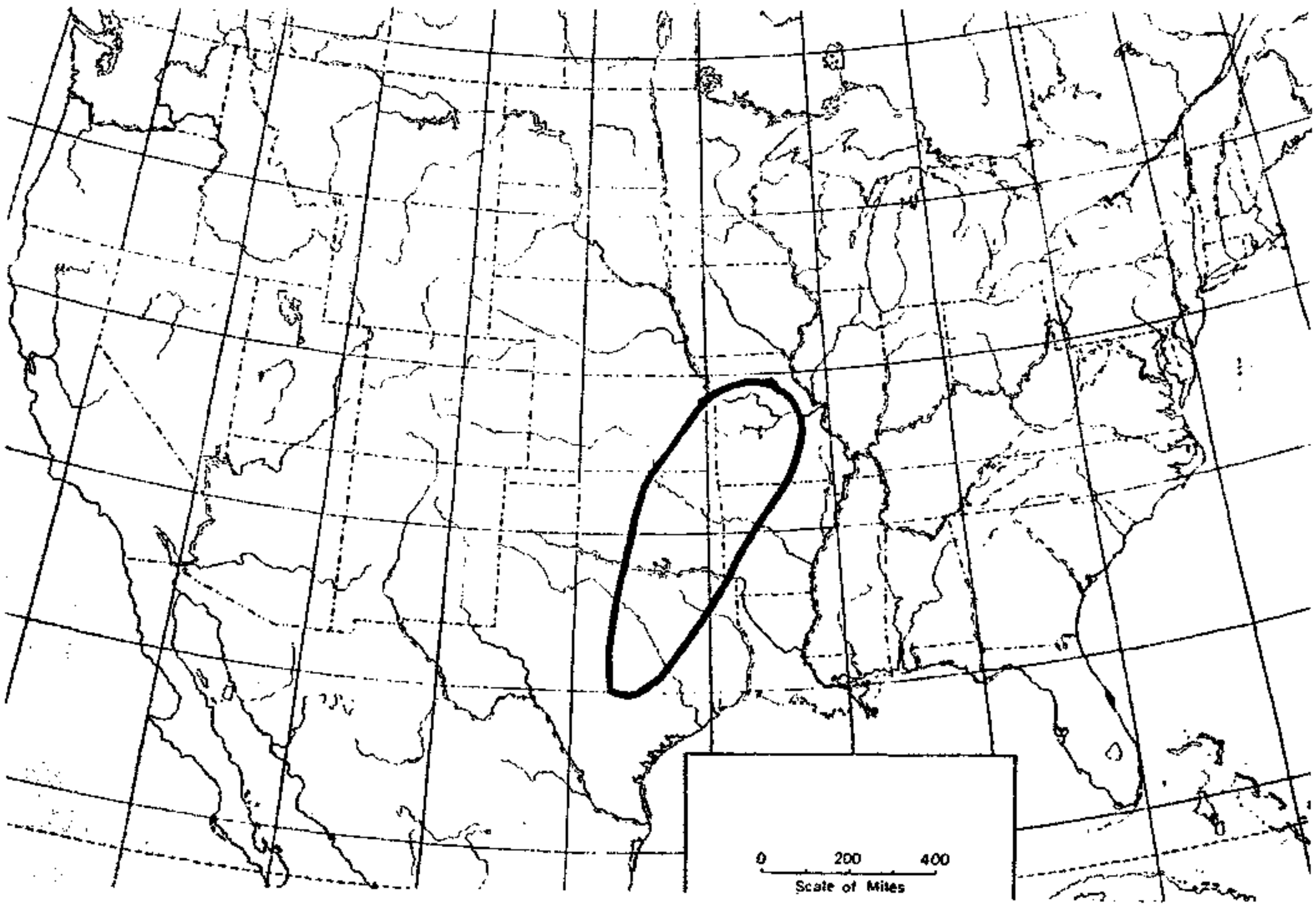



Figure 17. Post-Blackjack Oak area, 35,000,000 acres.

Figure 18. Post Oak Savannah range which has degraded because of the increase of overstory oaks and an understory of shorter growing woody plants. Stocking rate on this area was 40 acres per animal unit. Oak leaf buds are toxic to livestock.

Figure 19. Post Oak Savannah range which had one application of 2,4,5-T. Tall native grasses re-established the first growing season following application of 2,4,5-T. Stocking rate on this area was 8 acres per animal unit.

Oaks occupy 2.8 million acres in Arkansas, 0.3 million acres in Kansas, and Missouri contains about 16.1 million acres with hickory being an associated species in this area.

Throughout much of the Post-Blackjack Oak Savannah Area, forage grass release occurs in the first year following an application of 2,4,5-T or silvex. In areas with heavy brush densities, re-establishment is slower with greatest production occurring 3-5 years following the application of a herbicide. A single application of 2 pounds a.e. of 2,4,5-T per acre is satisfactory for forage release. However, woody plant root kill and resulting longevity of treatment is more dependable with two applications of 2,4,5-T or silvex applied in consecutive years.

In Texas, the Agricultural Extension Service personnel conducted 2,189 oak demonstrations involving 210,853 acres by chemical control and 240,586 acres with mechanical control from 1950-1977 (Hoffman 1978b). Range improvement was slow when mechanical control methods were used. In the 1950's 2,4,5-T was used as a comparative control method of broadcast and spot treatment which proved very successful for fast range improvement and a better method to balance the native plant community.

Individual plant treatments using phenoxy herbicides provided satisfactory control but density of plants made these methods impractical except for maintenance control. Aerial broadcast sprays of 2,4,5-T began in 1952 with 2,4,5-T and silvex producing the greatest control of the herbicides tested. It required 2 pounds per acre as first application, followed the next year with 1 1/2 to 2 pounds per acre. This produced up to 80 percent woody plant reduction and life span of the treatment was at least 10 years.

Demonstrators stated that stocking rates increased from 30 acres per animal unit to 11 acres per animal unit and ranges improved from poor to good condition in two years following control with 2,4,5-T (Hoffman et al. 1950-77). Stocking rates were doubled in Texas and Oklahoma on most treated areas (Stritzke 1965-72). Calves marketed from 2,4,5-T treated areas average 100 pounds per head more than calves grazing on untreated pastures. Landowners liked the advantage of oak brush management with 2,4,5-T over mechanical methods because (1) it did not disturb the soil, (2) better range forage plants re-established faster as partial protection was offered by standing dead trees, (3) there was less sprouting from stumps, and (4) it was not a complete shock to soil and plants ecosystem (Hoffman et al. 1950-77).

RESULTS OF BRUSH CONTROL DEMONSTRATIONS

In Erath County of Texas a treated and untreated pasture were compared to determine benefits from chemical control of oak. Post oak has value for firewood and possibly a source of emergency fuel, but economical harvesting methods have not been developed. Many result demonstrations have been conducted using 2,4,5-T and/or mechanical methods followed by grazing with goats to control sprout growth. However, recent increases of predators, such as coyotes, bobcats, fox, lynx, and wild dogs, prevented landowners from stocking goats. A solution of 2,4,5-T and straight diesel oil to make one gallon per acre was demonstrated in 1972-73 and results compared with standard volume per acre. Low volume application saved $0.75 per acre over the standard volume and appeared to deposit 2,4,5-T spray on the target area equally as well as the standard volume.

Stocker cattle gained 2.5 pounds per day for 270 days from October 15 to July 15. The uncontrolled area could carry only 43 animals per 640 acres (15A/AU) while the controlled areas carried 80 animals per 640 acres (8 A/AU). The 2,4,5-T sprayed area produced an increase of 24,975 pounds of cattle weight in favor of controlled area (table 11). Ease of working livestock on controlled areas amounted to about $1 per acre in labor saved during roundups. Also, wildlife habitats appear not to be affected.

About two-thirds of the post-oak area is managed as cow-calf operations and one-third as stocker operations. Some land owners carry over calves to make maximum utilization of the increased native forage on controlled

Table 11--Current use and benefits of 2,4,5-T, and potential alternatives, on 35 million acres of oaks, Texas, Oklahoma, Arkansas, Missouri, and Kansas

| Use & alternative treatment | Acres in area a/ | Acres treated annual | Rotation period | Acres treated in rotation | Per acre treatment cost 1975-77 b/ | Total annual cost | Total rotation cost | Amortized per acre cost c/ | Beef yield per acre d/ | Value per pound 1975-77 e/ | Gross value per acre |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Years | | Dollars | | | | Pounds | Dollars | |
| Cow-calf operations: | | | | | | | | | | | |
| 2,4,5-T | 35,000,000 | 360,700 | 5 | 1,803,500 | 11.00 | 3,967,700 | 19,838,500 | 2.68 | 28.5 | .3580 | 11.20[f] |
| Silvex | 35,000,000 | 360,700 | 5 | 1,803,500 | 12.00 | 4,328,400 | 21,642,000 | 2.93 | 28.5 | .3580 | 11.20[f] |
| Do nothing | 35,000,000 | NA | NA | NA | NA | NA | NA | NA | 11.2 | .3580 | 4.01 |
| Stocker operations: | | | | | | | | | | | |
| 2,4,5-T | 35,000,000 | 180,300 | 5 | 901,500 | 11.00 | 1,983,300 | 9,916,500 | 2.68 | 84.4[g] | .3580 | 31.22[f] |
| Silvex | 35,000,000 | 180,300 | 5 | 901,500 | 12.00 | 2,163,600 | 10,818,000 | 2.93 | 84.4[g] | .3580 | 31.22[f] |
| Do nothing | 35,000,000 | NA | NA | NA | NA | NA | NA | NA | 45.4[g] | .3580 | 16.25 |

a/ Range Specialist each state.

b/ Average cost from commercial applicators.

c/ Per acre cost of 2,4,5-T and alternative treatment amortized over-year rotation period at 7% interest; i.e.

d/ Percent calf crop 85%, stocking rate treated 15 A/AU and 500 lb calves, stocking rate untreated 30 A/AU and 400 lb calves.

e/ Agri. Eco. Dept., Marketing, TAEX-TAMU, College Station, Texas.

f/ Labor savings of $1 per acre on treated area.

g/ Treated, stocking rate 8 A/AU, 675 lb gain/hd; untreated, stocking 15 A/AU, 675 lb gain/hd.

SOURCE: Range Brush and Weed Control Specialists, Texas Agricultural Extension Service, Texas A&M University, College Station, Texas 77843.

areas. These cow-calf operators that carry over their calves increase their profits by finishing their calves to higher grades and heavier weights. Analyses of cow-calf and stocker operations are presented in table 11.

Goats have been used for brush control with only limited success in Oklahoma. It took 100 head of goats per 150 acres to keep brush suppressed, and resprouts would come into the area as soon as the goats were moved. There was little or no profit in the operation because of increased losses from coyotes (Stritzke 1965-72).

Mechanical removal has also been used. It took an average of 53 man-hours to hand clear brush from an acre (Elwell et al. 1974). Part of this labor expense can be recovered by selling firewood. This is only temporary because without 2,4,5-T treatment of the stumps, resprouts are a major problem. Mowing of these sprouts was not effective and after 3 annual mowings, there was a significant increase in stems (Elwell et al. 1974). Dozing and converting to an improved pasture is an alternative on some of the better sites but is not recommended for sites with steep slopes and shallow soils (McMurphy et al. 1975). Most of the good sites have already been converted so only a small percent of existing area could be root plowed or bulldozed. Chaining was not effective for oak control in Oklahoma as three years after chaining, resprouts were 6-8 feet tall (Stritzke 1965-72). Use of fire will control the tops of oak sprouts but it will not control trees with stem diameters over 2 inches without prior herbicide treatment.

There is no satisfactory or economical alternative control method that can be substituted for the current broadcast application of 2,4,5-T or silvex (Hoffman et al. 1978). Herbicides such as 2,4-D or 2,4-DP are not as effective as 2,4,5-T or silvex for oak control. Both 2,4-D and dicamba are registered for oak brush control but neither are extensively used. Early work comparing 2,4-D and 2,45-T showed that results with

2,4,5-T were more effective and more consistent than with 2,4-D (Elwell et al. 1974).

Little extensive research work has been conducted with 2,4-D for oak brush control. However, numerous investigators have observed and worked with 2,4-D over the years and they usually rate the oaks as intermediate to resistant to foliar sprays of 2,4-D (Bovey 1977). These same workers rated the oaks as susceptible or resistant to dicamba, depending on the individual oak species. Some of the early work with dicamba on seedling oaks indicated that as foliage spray it was only at high rates of 4 pounds per acre that dicamba approached the effectiveness of 2,4,5-T. Dicamba was evaluated in aerial studies as an additive to 2,4,5-T for oak control and increased kill was noted only in one of seven studies (Hoffman et al. 1978).

An additional example of economical benefits concerned a ranchman in Young County in 1954 who had this to say about aerial control of oak with 2,4,5-T, "Stocking capacity of grass was at least 450 percent greater than before spraying. The cost of two applications was $10.00 per acre. If good hay were selling for $20.00 per ton, you had better spend your money for chemicals for brush control because you will get more than a half ton of dry forage per acre and the benefits will be continuous. The stocking rate on 800 acres increased from 27 head before brush control to 74 head afterwards." He estimated a kill of 62 percent was obtained from two sprayings and 34 percent kill from one spraying (Hoffman et al. 1950-1977).

The Jack County agent reported in 1954 about range recovery following aerial spraying of oak. "In spite of four years of drouth, spraying of oak trees on two ranches increased climax grass growth 100 percent." On a demonstration of 100 acres, oak growth was so dense at the start that nothing but wild animals could get through. Now, in spite of drouth, he is running a cow to every 10 acres and they are in excellent shape. No supplemental feeding has been given to these animals. Oak-controlled areas had a stocking rate of 14-16 acres per animal unit while untreated areas had a stocking rate of 30-40 acres per animal unit (Hoffman et al. 1950-77).

The Young County agent reported in 1957 that brush and weeds cause more production loss than soil erosion or all insects combined. Results from 2,4,5-T aerial spraying showed that oak kill ranges from 90 to 95 percent. The grass production on controlled areas was doubled when compared to uncontrolled areas. This means more livestock products produced per acre, with the cost of the improved practice being paid for in four years. Brush control usually lasts seven to eight years in this county (Hoffman et al. 1950-77).

A Robertson County agent reported in 1958 that good perennial grasses completely covered an area after the oak trees and brush were individually treated and controlled with chemicals (Hoffman et al. 1950-77).

The Camp County agent in 1958 stated one of his demonstrators reported that control of weeds and brush resulted in an increased stocking rate of 25 percent (Hoffman et al. 1950-77).

A Leon County agent stated that grass production increased several fold on areas where brush was controlled with chemicals and proper management followed (Hoffman et al. 1950-77).

Based on the results obtained and presented, it appears that 2,4,5-T and/or silvex are needed to balance the native plant community and return it to the original savannah-type vegetation. If the oaks are not controlled, the oaks on many areas will be so dense as to make livestock production unprofitable. This could cause a shortage of red meat since many of the oak areas are now supporting cow-calf operations.

Table 11 shows results for the accepted control method and the best alternative. Beef production loss would be 93,602,000 pounds for cow-calf and 105,478,000 pounds for stocker operation for a net present value loss of $15,929,000 for cow-calf and $25,568,000 for stocker operation during the first 5-year rotation period that 2, 4, 5-T or silvex could not be used (table 12).

## SAND-SHINNERY OAK

Sand-shinnery oak, Quercus havardii, occupies 14,331,000 acres of sandy soils in New Mexico, Oklahoma, and Texas (Platt 1959). Sand-shinnery oak is a low-growing shrubby oak usually less than six feet tall. It grows very dense because it sprouts along the lateral roots. Sand-shinnery oak density reduces forage grass species but if the seed source is available, forage production is great following control with 2,4,5-T or silvex. Sand-shinnery oak causes livestock poisoning losses when cattle consume the leaf buds in spring.

The normal practice for controlling sand-shinnery oak is to apply 2 successive sprayings of 1/2 pounds per acre a.e. of 2,4,5-T or silvex in the spring after the leaves are fully developed for maximum stem kill for a life span of 10 years (Hoffman et al. 1978). Some landowners spray with only one application for forage production and small percentage stem kill followed with a repeat treatment at 4 to 5-year intervals.

In Oklahoma, stocking rates have increased from 10.5 to 5.5 acres per animal unit following control of sand-shinnery oak with 2 applications of 2,4,5-T or silvex (Stritzke 1965-72). In Texas and New Mexico, stocking rates have increased from 20-25 acres to 12-14 acres per animal unit following control. Livestock weight and death losses are reduced following control, but this will not be considered in the economic analysis of the control practice even though economic gain is great. Also, beef calf weight was about 65 pounds more per head on controlled areas than on uncontrolled areas.

Table 12A--Estimated decrease in value of beef production due to the nonavailability of 2,4,5-T and silvex, post-blackjack oak rangeland, cow-calf operation

| No. years w/o 2,4,5-T | Treated area with remaining yield effects: Acres a/ | Treated area with remaining yield effects: Yield a/ | Treated area with remaining yield effects: Production | Previously treated area w/o remaining yield effects: Acres | Previously treated area w/o remaining yield effects: Yield a/ | Previously treated area w/o remaining yield effects: Production | Total beef: Production | Total beef: Value b/ | Production loss w/o 2,4,5-T c/ | Value of lost production b/ | Amortized cost of lost production d/ | Net value of lost production b/ | Net present value of lost production e/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Lbs | Thous lbs | | Lbs | Thous lbs | Thous lbs | Dols | Thous lbs | Thousand dollars | | | |
| 0 | 1,803,500 | 28.5 | 51,400 | 0 | n/a | n/a | 51,400 | 18,401 | 0 | n/a | n/a | n/a | n/a |
| 1 | 1,442,800 | 28.5 | 41,120 | 360,700 | 11.2 | 4,040 | 45,160 | 16,167 | 6,240 | 2,234 | 967 | 1,267 | 1,267 |
| 2 | 1,082,100 | 28.5 | 30,840 | 721,400 | 11.2 | 8,080 | 38,920 | 13,933 | 12,480 | 4,468 | 1,933 | 2,535 | 2,369 |
| 3 | 721,400 | 28.5 | 20,560 | 1,082,100 | 11.2 | 12,120 | 32,680 | 11,699 | 18,720 | 6,702 | 2,900 | 3,802 | 3,321 |
| 4 | 360,700 | 28.5 | 10,280 | 1,442,800 | 11.2 | 16,159 | 26,439 | 9,465 | 24,961 | 8,936 | 3,867 | 5,069 | 4,138 |
| 5 | 0 | n/a | n/a | 1,803,500 | 11.2 | 20,199 | 20,199 | 7,231 | 31,201 | 11,170 | 4,833 | 6,337 | 4,834 |
| | | | | | | | | | | | | | 15,929 |

a/ Taken from table 11.

b/ Beef value at $0.3580 per pound, 1973-77 average.

c/ Production loss calculated from column 8; i.e., 51,400 - 45,160 = 6,240.

d/ Treatment cost amortized at 7% interest from table 11, column 9, times acres without remaining yield effects (column 5); i.e., $2.68 X 360,700 = $966,676.

e/ Present value calculated using 7% discount factor.

SOURCE: Natural Resource Economics Division, ES&CS, USDA, Corvallis, Oregon.

Table 12B--Estimated decrease in value of beef production due to the nonavailability of 2,4,5-T and silvex, post-blackjack oak rangeland stocker operation

| No. years w/o 2,4,5-T | Treated area with remaining yield effects: Acres a/ | Treated area with remaining yield effects: Yield a/ | Treated area with remaining yield effects: Production | Previously treated area w/o remaining yield effects: Acres | Previously treated area w/o remaining yield effects: Yield a/ | Previously treated area w/o remaining yield effects: Production | Total beef: Production | Total beef: Value b/ | Production loss w/o 2,4,5-T c/ | Value of lost production b/ | Amortized cost of lost production d/ | Net value of lost production b/ | Net present value of lost production e/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Lbs | Thous lbs | | Lbs | Thous lbs | Thous lbs | Dols | Thous lbs | Thousand dollars | | | |
| 0 | 901,500 | 84.4 | 76,087 | 0 | n/a | n/a | 76,087 | 27,239 | 0 | n/a | n/a | n/a | n/a |
| 1 | 721,200 | 84.4 | 60,869 | 180,300 | 45.4 | 8,186 | 69,055 | 24,722 | 7,032 | 2,517 | 483 | 2,034 | 2,034 |
| 2 | 540,900 | 84.4 | 45,652 | 360,600 | 45.4 | 16,371 | 62,023 | 22,204 | 14,064 | 5,035 | 966 | 4,069 | 3,803 |
| 3 | 360,600 | 84.4 | 30,435 | 540,900 | 45.4 | 24,557 | 54,992 | 19,687 | 21,095 | 7,552 | 1,450 | 6,102 | 5,330 |
| 4 | 180,300 | 84.4 | 15,217 | 721,200 | 45.4 | 32,742 | 47,959 | 17,169 | 28,128 | 10,070 | 1,933 | 8,137 | 6,642 |
| 5 | 0 | n/a | n/a | 901,500 | 45.4 | 40,928 | 40,928 | 14,652 | 35,159 | 12,587 | 2,416 | 10,171 | 7,759 |
| | | | | | | | | | | | | | 25,568 |

a/ Taken from table 11.

b/ Beef value at $0.3580 per pound, 1973-77 average.

c/ Production loss calculated from column 8; i.e., 76,087-69,055 = 7,032

d/ Treatment cost amortized at 7% interest from table 11, column 9, times acres without remaining yield effects (column 5); i.e., $2.68 X 180,300 = $483,204.

e/ Present value calculated using 7% discount factor.

SOURCE: Natural Resource Economics Division, ES&CS, USDA, Corvallis, Oregon.

Burning has not been effective for control of shinnery oak (Stritzke 1965-72). However, burning every 3rd year did release some grass with a resulting increase in cattle gains. Over an 8-year span, grass production was increased an average of 20 percent. Since shinnery oak occurs on sandy lands that are easily eroded by wind, precautions will need to be taken with any burning program (Stritzke 1965-72).

Mowing, even in combination with spraying was not effective for shinnery oak control (Stritzke 1965-72). Deep plowing to reclaim shinnery oak land is an alternative that is practiced to a limited extent (Stritzke 1965-72). It involves several years of farming and then converting to lovegrass. It is expensive and needs to be limited to those areas having clay soil in the top two feet of the profile. These soils are limited to a small percentage in the sand-shinnery oak area.

Dicamba and 2,4-D are not alternatives as these two herbicides may not produce defoliation of sand-shinnery oak even when applied at two pounds a.e. per acre. Silvex, 2,4,5-T and 2,4,5-T:picloram (Tordon 225$^{R}$) are the only herbicides that produce satisfactory control in the order named. Economically 2,4,5-T is favored over silvex or 2,4,5-T:picloram mixture. Picloram alone is not registered.

Controlled areas can produce 26.9 pounds of saleable beef products or $9.63 per acre as compared to the untreated area producing 14.0 pounds or $5.01 per acre (table 13). Beef production loss without the use of 2,4,5-T or silvex would amount to 319,275,000 pounds for a net present value loss of $56,508,000 the first 10-year rotation period that 2,4,5-T or silvex is not used (table 14).

## CACTUS

Cactus species, *Opuntia spp.*, infests 78.6 million acres of rangelands in the U.S. (Platt 1959), with the greatest concentration in the Southern Great Plains with Texas having nearly 31 million acres (Smith and Rechentin 1964). Cactus species are natural components of native grasslands

Table 13--Current use and benefits of 2,4,5-T, and potential alternatives, on 14.3 million acres of sand-shinnery oak, New Mexico, Texas, and Oklahoma

| Area & alternative treatment | Acres in area a/ | Acres treated annual a/ | Rotation period | Acres treated in rotation | Per acre treatment cost 1975-77 b/ | Total annual cost | Total rotation cost | Amortized per acre cost c/ | Beef yield per acre | Value per pound d/ | Gross value per acre |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Years | | Dollars | | | | Pounds | Dollars | |
| Sand-shinnery oak: | | | | | | | | | | | |
| 2,4,5-T | 14,331,000 | 450,000 | 10 | 4,500,000 | 8.70 | 1,957,500 | 39,150,000 | 1.24 | 26.9 | .3580 | 9.63 |
| Silvex | 14,331,000 | 450,000 | 10 | 4,500,000 | 9.20 | 2,070,000 | 41,400,000 | 1.31 | 26.9 | .3580 | 9.63 |
| Do nothing | 14,331,000 | NA | NA | NA | NA | NA | NA | NA | 14.0 | .3580 | 5.01 |

a/ Range Specialist each state.

b/ Average cost from commerical applicators.

c/ Per acre cost of 2,4,5-T and alternative treatment amortized over-year rotation period at 7% interest; i.e.

d/ Agri. Eco. Dept., Marketing, TAEX-TAMU, College Station, Texas.

SOURCE: Range Brush and Weed Control Specialists, Texas Agricultural Extension Service, Texas A&M University, College Station, Texas 77843.

Table 14--Estimated decrease in value of beef production due to the nonavailability of 2,4,5-T and silvex, on 14.3 million acres of sand-shinnery oak - Texas, Oklahoma and New Mexico

| No. years w/o 2,4,5-T | Treated area with remaining yield effects: Acres a/ | Treated area with remaining yield effects: Yield a/ | Treated area with remaining yield effects: Production | Previously treated area w/o remaining yield effects: Acres | Previously treated area w/o remaining yield effects: Yield a/ | Previously treated area w/o remaining yield effects: Production | Total beef: Production | Total beef: Value b/ | Production loss w/o 2,4,5-T c/ | Value of lost production b/ | Amortized cost of lost production d/ | Net value of lost production b/ | Net present value of lost production e/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thous | Lbs | Thous lbs | Thous | Lbs | Thous lbs | Thous lbs | Dols | Thous lbs | Thousand dollars | | | |
| 0 | 4,500 | 26.9 | 121,050 | 0 | n/a | n/a | 121,050 | 43,336 | 0 | n/a | n/a | n/a | n/a |
| 1 | 4.050 | 26.9 | 108,950 | 450 | 14.0 | 6,300 | 115,245 | 41,258 | 5,805 | 2,078 | 558 | 1,520 | 1,520 |
| 2 | 3,600 | 26.9 | 96,840 | 900 | 14.0 | 12,600 | 109,440 | 39,180 | 11,610 | 4,156 | 1,116 | 3,040 | 2,841 |
| 3 | 3,150 | 26.9 | 84,735 | 1,350 | 14.0 | 18,900 | 103,635 | 37,101 | 17,415 | 6,235 | 1,674 | 4,561 | 3,984 |
| 4 | 2,700 | 26.9 | 72,630 | 1,800 | 14.0 | 25,200 | 97,830 | 35,023 | 23,220 | 8,313 | 2,232 | 6,081 | 4,964 |
| 5 | 2,250 | 26.9 | 60,525 | 2,250 | 14.0 | 31,500 | 92,025 | 32,945 | 29,025 | 10,391 | 2,790 | 7,601 | 5,799 |
| 6 | 1,800 | 26.9 | 48,420 | 2,700 | 14.0 | 37,800 | 86,220 | 30,867 | 34,830 | 12,469 | 3,348 | 9,121 | 6,503 |
| 7 | 1,350 | 26.9 | 36,315 | 3,150 | 14.0 | 44,100 | 80,415 | 28,789 | 40,635 | 14,547 | 3,906 | 10,641 | 7,091 |
| 8 | 900 | 26.9 | 24,210 | 3,600 | 14.0 | 50,400 | 74,610 | 26,710 | 46,440 | 16,626 | 4,464 | 12,162 | 7,574 |
| 9 | 450 | 26.9 | 12,105 | 4,050 | 14.0 | 56,700 | 68,805 | 24,632 | 52,245 | 18,704 | 5,022 | 13,682 | 7,963 |
| 10 | 0 | n/a | n/a | 4,500 | 14.0 | 63,000 | 63,000 | 22,554 | 58,050 | 20,782 | 5,580 | 15,202 | 8,269 |
| | | | | | | | | | | | | | 56,508 |

a/ Taken from table 1.

b/ Beef value at $0.3580 per pound, 1973-77 average.

c/ Production loss calculated from column 8; i.e., 121,050 - 115,245 = 5,805.

d/ Treatment cost amortized at 7% interest from table 13, column 9, times acres without remaining yield effects (column 5); i.e., $1.24 X 450,000 = $ 558,000.

e/ Present value calculated using 7% discount factor.

SOURCE: Natural Resource Economics Division, ES&CS, USDA, Corvallis, Oregon.

and become major invaders when improper range-management practices are used. The three major problem species of cacti are pricklypear, tasajillo, and cholla.

In September, 1963, Starr County Program Building Committee selected 100 acres for a demonstration-research test. Additional test areas were selected at Zapata, McMullen, and Jim Hogg Counties to include all range sites in the South Texas Plains to compare results before recommending specific methods of control. During the past 26 years Extension personnel conducted 1,281 demonstrations to show various methods for control of cacti in different areas of Texas (Hoffman 1978c).

The demonstration area was root plowed and seeded to buffelgrass (*Cenchrus ciliaris*) in spring of 1959. Root plowing produced excellent control of mesquite but not for mixed brush or pricklypear. The root plowed area contained over 3,000 pricklypear plants per acre which reduced grazing greatly (fig. 20). Stocking rates were (Hoffman 1967):

| | |
|---|---|
| Prior to 1959 - 1 AU/40 a | |
| 1959-62 - 1 AU/16 a | |
| 1962-64 - 1 AU/40 a | Root plowed and seeded to buffelgrass |
| 1964-66 - 1 AU/16 a | |
| 1967-71 - 1 AU/6 a | Cactus and mixed brush controlled with herbicides or a combination |

The demonstration was carried on for sufficient time to include wet and dry years and area stocked to use forage growth properly.

METHODS OF CONTROL

Based on results obtained at four locations, dense stands of pricklypear can be controlled effectively and economically by broadcast methods. Following are 1977 projected cost per acre for methods which have produced satisfactory control:

Figure 20. Dense stand of pricklypear cactus which established within three years following mechanical control methods. The area contained over 3,000 plants per acre and stocking rate was 40 acres per animal unit.

| | | |
|---|---|---|
| (1) | Double dragging + 2.0 lb/A of 2,4,5-T or silvex | $18.50 |
| (2) | Double dragging only - 3 times over 18 months period | 24.00 |
| (3) | Chemical only - 1.0 lb/A picloram: 2,4,5-T mixture | 12.50 |
| (4) | Double dragging + 1/2 lb/A picloram: 2,4,5-T mixture | 16.50 |
| (5) | Double dragging + 2 lb/A hexaflorate (not registered) | 13.00 |
| (6) | Shredding + 1/2 lb/A picloram: 2,4,5-T mixture | 16.00 |
| (7) | Shredding + 2 lb/A dicamba: 2,4,5-T mixture | 21.50 |
| (8) | Individual plant spray - 8 lb., 2,4,5-T/100 gal. oil | 30.00 |
| (9) | Mechanical front-end stacking | 12.00 |
| 10) | Mechanical front-end stacking + 1/2 lb/A picloram: 2,4,5-T | 20.50 |
| 11) | Stacking + root plowing + seeding | 52.00 |
| 12) | Mechanical front-end stacking + ind. plant treatment | 20.00 |

Methods 1, 2, 8, 9, and 11 required followup maintenance in 1971 for a cost of about $2 per acre. Methods 3, 4, 5, 6, 7, 10, and 12 did not require additional treatments at last evaluation in 1977. Method 3 requires two years following application of Tordon 225$^{R}$ before all cactus species are controlled. Treated area improved from poor to good range condition in three years (fig. 21).

Pricklypear should not become a problem for 20 years on areas where complete control was done and proper grazing management carried out. A dense stand of tall grass produces sufficient competition that pricklypear seedings would have difficulty in establishing. Sufficient areas of pricklypear must be left to provide food for wildlife such as the javelina population.

One of the 12 methods can be used to control the 31 million acres of rangeland infested with different species of cacti. In many areas of the 78.6 million acres, returns per acre will not be as great as in the South Texas Plains. On many ranches, controlling cacti will not increase stocking rate, but will allow more area to produce forage for grazing thus reducing cost of supplemental feed which is of great economic benefit.

Figure 21. Pricklypear controlled with dragging followed with application of 2,4,5-T or silvex. Area improved in range condition within three growing seasons. Controlled area now supports 1 animal unit per 6 acres.

Broadcast spray of 2, 4, 5-T: Picloram, (Tordon 225[R]) mixture at 1 pound per acre is the only method that can be used throughout the Great Plains for cacti control. There is strong indication that 1/2 pounds per acre of Tordon 225[R] will produce satisfactory control of cacti about the 32° latitude.

Individual plant treatment using 2,4,5-T mixed in diesel oil or picloram pellets (Tordon 10K[R]) costs from $250 to $350 per acre on areas with over 125 plants per acre and is considered non-economical (Hoffman et al. 1978).

Mechanical methods of dragging, shredding, stacking, and root plowing plus seeding can be used only on areas with woody plants less than 3 inches in diameter, and these methods alone are suitable on about 10 million acres of the Great Plains (Hoffman et al. 1978).

Hand grubbing is a very limited alternative because of the $85 to $340 cost per acre and the unavailable source of labor (Norris et al. 1979 and Hoffman et al. 1978). Fire is not an alternative as sufficient fuel cannot be produced to cause a fire hot enough to control cacti species.

BENEFITS

Areas where pricklypear was controlled in South Texas Plains produced 69.8 pounds per acre of beef while untreated dense stand of cacti area produced only 9.6 pounds per acre of beef products. On the treated acres, variable cost, gross returns, and net returns per acre from beef production were $15.23, $23.86, and $8.63, respectively. On the untreated acres variable cost, gross returns, and net returns per acre were $2.38, $3.28, and $0.90, respectively. In the area re-established to native grasses, the stocking rate would be 1 animal unit per 16 acres while the uncontrolled area would be stocked at 1 animal unit per 40 acres. Beef production on native grass rangelands would be 26.2 pounds per acre while the uncontrolled area would be 9.6 pounds per acre.

One or more cactus species can become a major problem on rangeland or pastureland adjacent to the Atlantic and Gulf Coasts and on rangeland west of the 95° longitude. The herbicides 2,4,5-T, silvex, and 2,4,5-T: picloram mixture will be needed for control of cacti. Picloram liquid alone is not registered. No economic analysis will be made for the cacti species as it was difficult to determine the number of acres treated each year.

## HARDWOODS WITHIN THE POST-BLACKJACK OAK AND PINE AREA

Many acres of bottomland are occupied by various species of hardwoods, oaks, gums, hickory, and other species throughout the oak-hickory-pine areas. The canopy is so dense the area produces small amounts of forage for yearlong grazing. If hardwood species are not suitable for lumber and drainage is adequate, a small percentage of the area can be converted to tame pasture forage plants for a cost of about $120 per acre. The area could be managed for hardwood timber production when the species are desirable. The hardwood areas can be reestablished to native forage species with two treatments of 2 pounds of 2,4,5-T per acre applied a year apart. The life span is 10 years. Silvex is not as effective for control of many hardwoods as 2,4,5-T, and the life span of using silvex would be about 7 years (Hoffman et al. 1978).

The following chart shows results of beef production following control of bottomland hardwoods on 600 acres in Texas (Hoffman et al. 1950-77). These results would be similar to all bottomland areas east of the 95° longitude in the U.S.

| Year | Rate A's/AU | Beef Produced/A | Return/A ($0.3580/lb) | Cost 2 Sprays/A | Return A/Yr Above Spray Cost |
|---|---|---|---|---|---|
| Before Control | 20.0 | 20.9 | $ 7.48 | N/A | $ 7.48 |
| 2 Yrs. After | 10.5 | 39.5 | $14.14 | $3.13 | $11.01 |
| 4 Yrs. After | 9.2 | 37.9 | $13.57 | $3.13 | $10.44 |

Refer to the post-blackjack oak section for alternative-control methods. Bottomland hardwood areas will remain in an unproductive condition if herbicides cannot be used as a control measure.

## YUCCA

Yucca, (Yucca spp.,) is a natural species occurring on millions of acres of native rangelands. Generally it is a problem species on limited range sites following severe droughts or over use of rangeland. Some yuccas have root-sprouting characteristics when the main portion of the plant is disturbed. During droughts yucca flower stems are cut so livestock can consume the nutritious heads. Removing the flower stalk has no effect upon the established plant.

### METHODS OF TREATMENT

Yucca can be controlled by broadcast and individual spot treatment. Broadcast application in Texas should be made before the plant has fully bloomed, usually May 15 to June 30 using 0.67 pounds per acre a.e. of 2,4,5-T or silvex. The herbicide carrier should be a 1:4 oil-water emulsion and applied at 4 gallons total volume per acre by aircraft or 25 gallons per acre by ground broadcast. One application reduces the yucca population 35 to 80 percent with a life span of 10 to 15 years, depending upon the range site (Hoffman 1976).

Individual spot treatment is done by treating central bud with 2,4,5-T or silvex mixed at 8 pounds a.e. per 98 gallons of diesel oil. The application can be made throughout the year in the western U.S (Hoffman 1976).

Desirable forage species reestablish within the dead plant residue during the two growing seasons following control. Range condition improved from poor to good within two years following control.

Since yucca is not a major problem on all range sites, there have been little data collected to show economic benefits following control. In a study by Robison (1965), Yucca glauca occurred on 10 percent of the rangeland in a 54-county area of the Texas Plains in sufficient density to warrant control.

BENEFITS

Forage production on controlled areas increased by an average of 565 pounds per acre more than uncontrolled areas. Proper use of the increased forage production per acre would supply grazing for an extra 11 days per animal unit. In one study, controlled area produced 1,707 pounds per acre and uncontrolled produced 1,194 pounds per acre. The controlled area could have a stocking rate of 1 animal unit to 13 acres while uncontrolled would be 1 animal unit to 18 acres. The controlled area could produce 30 pounds per acre of beef while the uncontrolled could produce only 19 pounds per acre. The controlled area could have a return of $3.94 per acre more over a 10-year period than the uncontrolled area.

ALTERNATIVES FOR 2,4,5-T

At present there is no herbicide or mechanical method or biological method that will control yucca species other than silvex and/or 2,4,5-T either broadcast or individual spot treatment which is the only economical and satisfactory means of control.

No economic analysis will be made for this species since it was difficult to obtain acres treated each year. It is necessary that landowners have the herbicides 2,4,5-T and/or silvex available to control yucca when it becomes a problem on rangeland.

## POISONOUS PLANTS

A poisonous plant is one which causes chemical or physiological disturbances when consumed by livestock. The effects may vary from mild sickness to death. The economic impact on the livestock industry caused by poisonous plants in the United States is enormous. Poisonous plants are estimated to kill from 3 to 5 percent of the livestock on western ranges. Loss from poisonous plants is one of the major economic problems in livestock production. A compilation of numerous reports indicates that the annual loss from poisonous plants in Texas is between 50 and 100 million dollars (Sperry et al. 1976). Approximately 80 species and varieties of poisonous plants growing in pastures and on range areas of Texas cause toxicity problems (Sperry et al. 1976).

Poisoning of livestock is more commonly the result of management, range conditions, or kinds of animals rather than the presence of the plants concerned. Poor range condition from overgrazing or other conditions resulting in a lack of palatable forage are the common causes of poisoning. The real danger is whether or not the toxic species is grazed. Many species are seldom eaten, but some are relished by certain animals and may be taken in preference to other forage. In some instances animals will select flowers or fruits or new growth; in other situations grazing is less discriminate. Many poisonous plants are green at a time of the year when other plants are dormant. Small amounts of plant material can be lethal shortly after consumption in some cases. In others, the toxic substances are cumulative and the species must be grazed over a period of time before signs of poisoning appear.

Frequent cases of poisoning occur when hungry animals are turned into new pastures or are given access to poisonous plants near pens, watering places, or along trails. Most poisonous plants are eaten because the animal is hungry and the poisonous plant is readily available (Sperry et al. 1976).

Many poisonous plants can be controlled with the application of a particular herbicide at specific plant growth stages. Phenoxy herbicides offer the most effective and economic control measures with 2,4,5-T or silvex being required to control certain species. Listed below are some poisonous plants that are best controlled with 2,4,5-T. Many of the plants would increase in density rapidly if allowed to go uncontrolled. Millions of acres of rangelands would go ungrazed at certain times during the year.

Poisonous Plants Controlled with 2,4,5-T or Silvex Only

| Common Name | Scientific Name | States With Problem Area |
|---|---|---|
| Guajillo | Acacia berlandieri | Southwest |
| Buckeye | Aesculus glabra and A. pavia | Southeast and Southwest |
| Garbancillo | Astragalus wootonii | West and Plains |
| White snakeroot | Eupatorium rugosum | Southeast and Southwest |
| Larkspurs | Delphinium spp. | West |
| Coyotillo | Karwinskia humboldtiana | Southwest |
| Lantana | Lantana camara | Eastern and Southwest |
| Wild plum | Prunus spp. | All of United States |
| Shin oak | Quercus spp. and Quercus havardii | Southwest and Plains |
| Mescalbean | Sophora secundiflora | Southwest |
| Smartweed | Polygonum spp. | All of United States |
| Chinaberry | Melia azedarach | All of United States |
| Lechuguilla | Agave lecheguilla | Southwest |
| Black locust | Robinia pseudo-acacia | Eastern and Southwest |
| Poison hemlock | Conium maculatum | West and Southeast |
| Waterhemlock | Cicuta douglasii and C.maculata | West |
| Mountain laurel | Kalmia latiflolia | Northeast and Southeast |
| Buttonbush | Cephalanthus occidentalis | Southeast, Southwest, West |
| Sacahuista | Nolina microcarpa and N. texana | Southwest |
| Timber milkvetch | Astragulus miser. | West |
| Lupines | Lupinus spp. | West, Plains, Southeast |

## DESERT SHRUB AND SOUTHWESTERN SHRUB ECOSYSTEMS

Desert Shrub, Chaparral-Mountain Shrub, and Southwestern Shrub ecosystems contain 124.6 million acres of important western arid rangeland. Much of the area has low potential production for livestock but is very important for wildlife habitat and watershed yields.

Woody plant species that grow on the area to varying densities include blackbrush, Flourensia cernua; creosotebush, Larrea divaricata; saltbush, Atriplux spp.; greasewood, Larcobatus spp.; Palo Verde, Cercidium spp.; cactus, scrub oak, and mesquite. About 33 percent of the total acreage could be treated with 2,4,5-T to prevent the woody plants from increasing in density. Woody plants, if not controlled, will continue to increase in density to the point that the area may not be suitable as wildlife habitat or for supporting watershed yields.

There is no registered herbicide that can be substituted for 2,4,5-T to control all species to the same degree and as economically as does 2,4,5-T. Mesquite and scrub oak are the only species that are susceptible to broadcast foliage application of 2,4,5-T. The other woody species must be treated with 2,4,5-T mixed in diesel oil as individual spot application. Figure 22 shows the states covered by these ecosystems.

The herbicide 2,4,5-T is needed to treat large acreages economically to provide as much increase in water yields, due primarily to reduced transpiration, and improve wildlife habitat as possible. If the western range shrub ecosystems are not maintained, this would be a serious threat to future generations.

## CULTIVATED PASTURES

Cultivated pastures are a most important part of the livestock industry for supplying hay and furnishing many months of grazing to allow deferment of native rangeland. Within the 48 states there are 101.1 million acres of cultivated pastures (Anonymous 1977a).

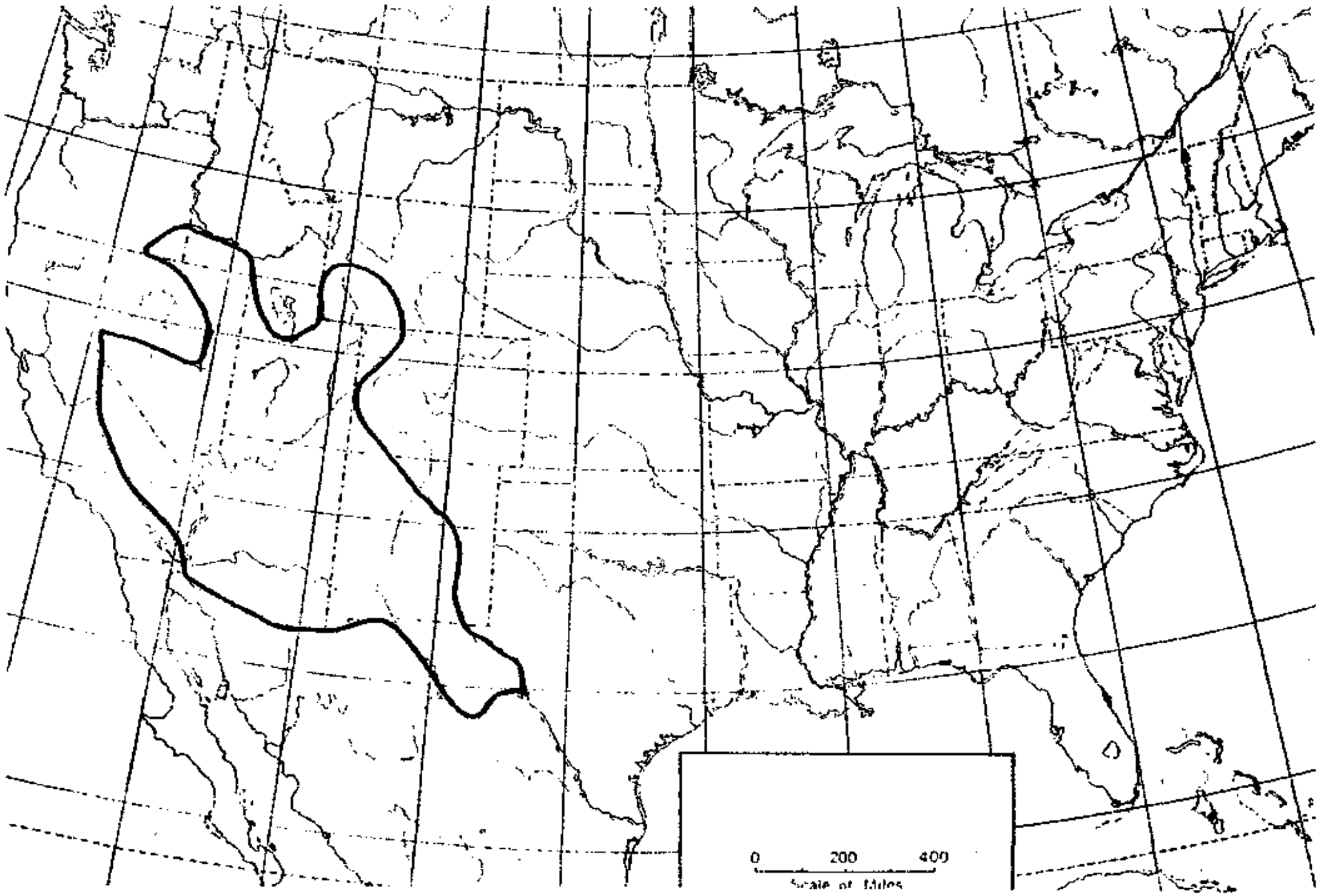


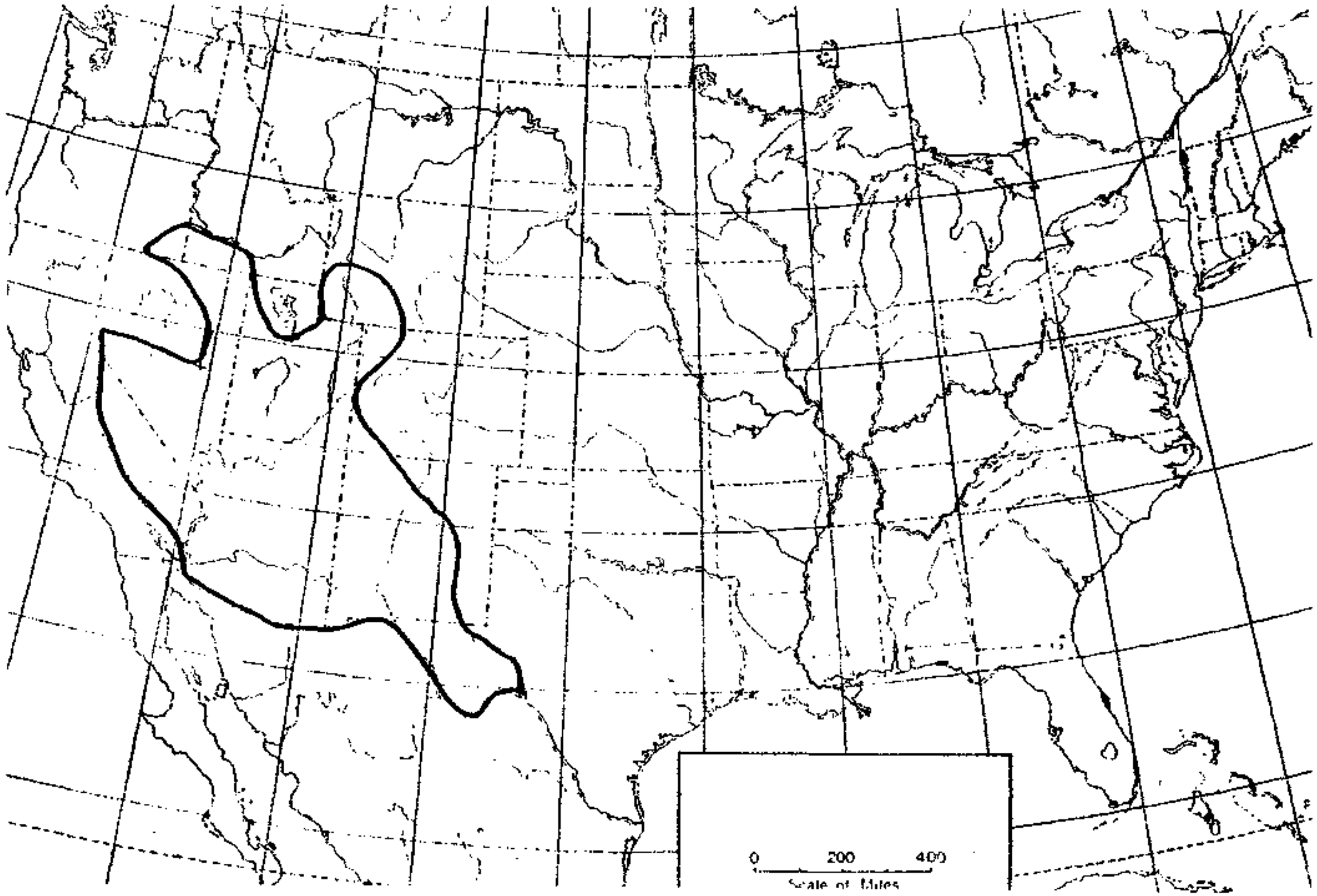

Figure 22. Desert shrub and southwestern shrub.

There are over 68 million acres of pastures in the eastern half of the U.S., with the Northeast having 39.9 million and Southeast with 28.3 million, where normal rainfall is adequate for forage production with minimum amounts of irrigation. The Plains States contain over 24 million acres and the majority of the pastures are located east of the 25 inch rainfall line. A minimum amount of acreage is under irrigation except for alfalfa. The Western states contain less than 9 million acres which are mostly irrigated to produce maximum amounts of high tonnage and quality hay which demands premium prices.

METHODS FOR CONTROL

Pastures in the Eastern three-fourths of the United States which are managed extensively are subject to being invaded by various species of woody plants (Hoffman et al. 1978). Many of these invaders cannot be controlled with the existing registered herbicides except for 2,4,5-T. The most widely used control method is individual spot treatment using 2,4,5-T mixed in diesel oil as a basal or cut surface treatment or as a foliage spray using 2,4,5-T mixed in water. In some cases a minimum acreage would be treated with broadcast using ground equipment. Generally, landowners treat woody plants in cultivated pastures as they appear. This allows the pasture to be maintained free of woody plants with a minimum amount of 2,4,5-T being used. Aerial application has limited use as many woody plant species are not controlled with small amounts of herbicide as with mesquite and the oaks.

Woody and herbaceous plants that occur widely on cultivated pastures as weed problems included blackberry, chokecherry, hawthorn, honeysuckle, horsenettle, ironweed, oaks, poison ivy, multiflora rose, sumac, willows, pricklypear, and juniper. Weed species occurring as a serious problem but in fewer states, include alder, American crabapple, American elm, aspen, birch, black cherry, black locust, cottonwood, elderberry, hazel, hickory, osage-orange, poison oak, poplar, sweetgum, sycamore, Virginia creeper, sassafras, dewberry, hackberry, persimmon, greenbrier, gallberry, honey locust, palmetto, redcedar, smooth sumac,

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Fire, when properly used, is an effective and economical control measure, but currently is discouraged because of atmospheric pollution. Mechanical control is widely used for pastureland improvement on extensively managed pastures but is expensive. Mechanical control leaves soil surface rough which is not suitable for intensively managed hay pastures. Biological control includes use of concentrating cattle to reduce undesirable vegetation. Planned grazing stimulates grass and forb production and improves the food supply for deer and birds. However, as indicated earlier, livestock can be used only in special situations and with care since they may graze the more desirable species.

In general, higher moisture conditions in eastern pastures may allow greater carrying capacity than western pastures, except under irrigated conditions. Woody plants and weeds may have a tendency to grow and recover faster under humid versus more arid conditions; consequently, more frequent treatment may be required for satisfactory pasture improvement.

Under the more humid climate, herbicides such as 2,4,5-T would also have a tendency to disappear more rapidly from the environment than drier climates. The same principles apply to the fate and toxicity of 2,4,5-T on eastern versus western range and pasturelands. The use of 2,4,5-T for woody plant control on eastern pastures is an important tool in grazing land management. It is estimated that at least one million acres of pastures are treated annually with 2,4,5-T.

ALTERNATIVES

Picloram (Tordon 10K$^{R}$) pellet is approved for use on grasslands in the southeast but for particular species such as kudz sumac, cacti, multiflora rose, white brush and huisache. If Tordon 10K$^R$ pellet label were expanded to include all woody species, the Tordon 10K$^R$ could be used as a substitute for 2,4,5-T except for control of mesquite. Dicamba liquid and granular have limited use in the humid areas. Additional testing would be necessary to determine how extensively dicamba could be used. Dicamba granular controls common persimmon effectively. Cut surface of frill and stump treatment using undiluted 2,4-D would control most woody plants except mesquite, huisache, cacti, and yucca to list a few (Elwell et al. 1974 and Hoffman 1978).

Mechanical shredding is not effective as the sprouting crowns are not removed from the soil. Mechanical grubbing leaves the soil surface rough and unsuitable for using expensive haying equipment. Burning at two year intervals would maintain woody plants at a low density.

The herbicide 2,4,5-T is needed to aid landowners in all of the United States in maintaining pastures free of woody plants. There appears to be only a small quantity of 2,4,5-T used for woody plant control each year.

Cultivated pastures were not included in the economic analysis as sufficient data were not available from all areas. It would be difficult to make a total economic assessment for the benefits of keeping pastures free of invading woody plants with periodic spot treatments with 2,4,5-T. Life span of treatment should be 10 years.

## FENCE ROWS

Fence rows are an integral part of farming and ranching. Fence rows become infested with woody and herbaceous plants as weeds lodge during windstorms, and birds deposit seeds in their droppings while resting on the wires. Invading plants cause fences to deteriorate and increase labor cost for repairs. In some cases it would be necessary to rebuild a new fence at 10-year intervals in some areas of the U.S. Life span of a maintained fence is 20 to 45 years.

METHODS FOR CONTROL

Herbicide 2,4,5-T can be used to treat woody plants growing on fence rows thoughout the U.S. Application equipment for 2,4,5-T includes ground handsprayers. Diesel oil is used as a carrier for 2,4,5-T when a knapsack handsprayer is used while a 1:4 oil-water emulsion can be used with a power sprayer. Oil-water emulsion reduces cost, but more volume is needed to obtain satisfactory plant kill. Oil-water emulsion does not burn the existing forage grasses as much as does straight diesel oil.

Standard rate of application is 16 pounds of 2,4,5-T per 100 gallons of diesel oil when the knapsack handsprayer is used for a cost of $105. Each gallon of mixture should treat 20-4 inch diameter trees. The lower 12 inches of the stems are treated. Standard rate of application for a 1:4 oil-water emulsion is 8 pounds of 2,4,5-T per 100 gallons for a cost of $38.10. Each gallon should treat about 10-4 inch diameter trees. The lower 18-36 inches of the stems are treated. The degree of control on woody species would be comparable with each herbicide mixture. Life span of herbicide treatment would be 5 to 10 years depending on the rate of regrowth and re-infestation. Labor cost is in addition to the 2,4,5-T mixture.

Controlling woody plants with 2,4,5-T along fence rows aids in reducing sprouting woody plants from invading cultivated pastures. Basal sprouting of woody plants is reduced greatly when 2,4,5-T is used as compared to hand labor clearing. Also, treatment with 2,4,5-T allows forage grasses to reestablish and offers cover, food, and nesting areas for ground birds. Manual labor with axes is the only method for control if herbicides are not available. Manual labor causes greater repairs, as many times fence wires are cut during the clearing operation. Fences can remain intact during the full life span with minimum cost for maintenance when woody plants are controlled with 2,4,5-T.

## ALTERNATIVES

There are no alternative-control methods that can be adapted nationwide other than hand-labor clearing.

Many herbicides are registered for control of plants on fence rows, but few are registered when the forage on the fence row is subject to being grazed by livestock. Soil-applied herbicides could cause injury to nearby shade trees or to valuable plants along rights-of-ways. Also soil-applied herbicides can move down slope before the chemical is set within the soil.

Picloram (Tordon 10K$^{R}$) pellet is approved for use in the southeast. If the label registration were expanded to include all of the U.S., then Tordon 10K could be used to control many species except mesquite. Silvex is not an alternative as it is ineffective on many species of woody plants (Bovey 1977).

## ESTIMATED USE OF 2,4,5-T

Approximately 1.6 million acres of mesquite-infested rangelands, post-blackjack oak rangelands, and sand-shinnery oak rangelands are treated annually with 2,4,5-T (table 15). Treatment rates vary from .5 to 2 pounds per acre for a total use of about 1.9 million pounds of 2,4,5-T. Only minor quantities of silvex and dicamba are currently used.

If 2,4,5-T becomes unavailable and silvex remains available, silvex would be expected to be applied on 1.5 million of the 1.6 million acres currently treated with 2,4,5-T (table 16). Similar application rates would be used, and total silvex use would be about 1.8 million pounds.

If 2,4,5-T and silvex become unavailable, dicamba would be expected to be applied on approximately 433,000 acres of the 1.6 million acres currently treated with 2,4,5-T (table 16). Application rates similar to 2,4,5-T would be used and a total of about 217,000 pounds of dicamba would be used.

Table 15--Estimated acres of rangeland treated annually with 2,4,5-T and pounds of 2,4,5-T used

| Area | Treated annually | 2,4,5-T per acre | Total use of 2,4,5-T |
| --- | --- | --- | --- |
| | Acres | ------Pounds | ---------- |
| Mesquite area: | | | |
| One | 40,000 | .67 | 26,800 |
| Two | 176,000 | .50 | 88,000 |
| Three | 176,000 | .50 | 88,000 |
| Four | 56,000 | 1.0 | 56,000 |
| Five | 41,000 | 1.00 | 41,000 |
| Six | 81,120 | .50 | 40,600 |
| Post-blackjack oak rangeland: | | | |
| Cow-calf operation | 360,700 | 2.00 | 721,400 |
| Stocker operation | 180,300 | 2.00 | 360,600 |
| Sand-shinnery oak | | | |
| Rangeland | 450,000 | 1.00 | 450,000 |
| Total | 1,561,120 | xx | 1,872,400 |

SOURCE: Natural Resource Economics Division, Economics, Statistics, and Cooperatives Service, U.S. Department of Agriculture, Corvallis, Oregon.

Table 16--Estimated acres of rangeland that may be treated annually with the alternatives Silvex and Dicamba if 2,4,5-T becomes unavailable, and amount of Silvex and Dicamba that may be applied

| Area | Silvex[a/] | | | Dicamba[b/] | | |
|---|---|---|---|---|---|---|
| | Treated annually | Silvex per acre | Total use of Silvex | Treated annually | Dicamba per acre | Total use of Dicamba |
| | Acres | Pounds | Pounds | Acres | Pounds | Pounds |
| Mesquite area: | | | | | | |
| One.................... | 40,000 | .67 | 26,800 | -- | -- | -- |
| Two.................... | 176,000 | .50 | 88,000 | 176,000 | .50 | 88,000 |
| Three.................. | 176,000 | .50 | 88,000 | 176,000 | .50 | 88,000 |
| Four................... | -- | -- | -- | -- | -- | -- |
| Five................... | -- | -- | -- | -- | -- | -- |
| Six.................... | 81,120 | .50 | 40,600 | 81,120 | .50 | 40,600 |
| Post-blackjack oak rangeland: | | | | | | |
| Cow-calf operation..... | 360,700 | 2.00 | 721,400 | -- | -- | -- |
| Stocker operation...... | 180,300 | 2.00 | 360,600 | -- | -- | -- |
| Sand-shinnery oak rangeland............. | 450,000 | 1.00 | 450,000 | -- | -- | -- |
| Total.................. | 1,464,120 | xx | 1,775,400 | 433,120 | xx | 216,600 |

a/ Estimates based on the assumption that silvex is the best alternative to 2,4,5-T.

b/ Estimates based on the assumption that 2,4,5-T and silvex would not be available.

SOURCE: Natural Resource Economics Division, Economics, Statistics, and Cooperatives Service, U.S. Department of Agriculture, Corvallis, Oregon.

## USER IMPACTS SUMMARY

Expected revenue losses are estimated for three scenarios: (1) 2,4,5-T only becomes unavailable, (2) 2,4,5-T and silvex become unavailable, and (3) 2,4,5-T and silvex become unavailable and dicamba is not used. Partial analyses were accomplished on 93 million acres of mesquite-infested rangelands, 35 million acres of post-blackjack oak rangelands and 14.3 million acres of sand-shinnery oak rangelands. Sufficient data were not available to do more than narratively describe the uses of 2,4,5-T on the following species and problems in pastures, rangelands and farm, and other farm and ranchlands:

| Species or problem | Area | Acres infested | Economic Importance of 2,4,5-T |
|---|---|---|---|
| | | --thousands--- | |
| Cactus | U.S. | 78,600 | Significant |
| Hardwoods | U.S. | Unknown 1/ | " |
| Yucca | U.S. | 50,000 2/ | " |
| Poisonous plants | U.S. | Unknown 3/ | " |
| Desert shrub | West | 124,600 | " |
| Fence rows | U.S. | Unknown | " |
| Pastures | U.S. | 101,061 | " |
| Misc. woody plants 4/ | U.S. | 1,000,000 | " |

1/10,000,000 or less.

2/Estimated - no known recorded acreage data exist.

3/Localized problem on many range and pasture lands. Annual losses are estimated to be between 50 and 100 million dollars in Texas and 14 million dollars for cattle alone in Idaho.

4/Agarito, alder, ash, catclaw, chinaberry, elm, gum, hackberry, hawthorne, herisache, ironwood, locust, lotebush, prickly ash, sumac, Texas persimmon, wax myrtle, yaupon, other oaks, osage-orange (this is not an all-inclusive. list).

Economic losses associated with these uses if 2,4,5-T becomes unavailable, are unknown. However, these uses are considered very important to affected land users.

To summarize the expected income losses on the mesquite-infested rangelands, post-blackjack oak rangelands, and sand-shinnery oak rangelands if 2,4,5-T and silvex become unavailable and dicamba proves ineffective in the future, it is necessary to express each year's loss in terms of value as of a base year. This is accomplished by discounting the estimated future revenue losses and reduced spray costs without 2,4,5-T back to a present value for 1978, using a rate of 7 percent. This is a reasonable procedure because a $1 loss in 1979 or any future year is worth less to a beef producer than a $1 loss in 1978.

Reductions in income to producers from beef production (given current prices) from lower production due to weed and brush competition on rangeland are expected to be $785,500 the first year without 2,4,5-T, if silvex and dicamba are available (table 17) ceteris paribus.[2/] Losses due to the unavailability of 2,4,5-T are projected to increase to a net present value of $1,153,900 in the sixteenth year. If silvex, which is similar to 2,4,5-T, becomes unavailable with 2,4,5-T, reductions in income to producers would be expected to increase to $5,633,500 the first year and are projected to have a net present value of $13,082,800 in the sixteenth year (table 18) ceteris paribus. Further, if 2,4,5-T and silvex become unavailable and dicamba is not used, reductions in income to producers would be expected to increase to $6,946,000 the first year and are projected to have a net present value of $17,690,000 in the sixteenth year (table 19) ceteris paribus.

Expected changes in beef production from the mesquite-infested rangelands, post-blackjack oak rangelands and sand-shinnery oak rangelands due to the lack of 2,4,5-T and possible alternative are shown in tables 20, 21, and 22. If 2,4,5-T becomes unavailable and silvex remains available, beef production would be expected to decrease 2.1 million pounds the first year without 2,4,5-T (table 20). Beef production losses would be maximized the fifth year without 2,4,5-T at 10.5 million pounds. Cumulative losses over the 16-year evaluation period are estimated to be 147.6 million pounds of beef without 2,4,5-T.

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[2/] Means "all other things being equal or unchanged."

Table 17--Estimated increase in herbicide treatment cost and/or decrease in value of beef production if 2,4,5-T becomes unavailable for use on weed and brush infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest and Great Plains regions

| No. years w/o 2,4,5-T | Rangeland areas infested with mesquite: One[a] | Two[a] | Three[a] | Four[b] | Five[c] | Six[a] | Post-blackjack oak rangeland: Cow-calf[b] | Stocker[d] | Sand-shinnery oak rangeland[e] | Total | Total impact discounted to 1978[f] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thousands of Dollars | | | | | | | | | | |
| 1 | 3.2 | 8.8 | 5.3 | 465 | 134 | 2.4 | 90.2 | 45.1 | 31.5 | 785.5 | 785.5 |
| 2 | 3.2 | 8.8 | 5.3 | 932 | 267 | 2.4 | 90.2 | 45.1 | 31.5 | 1,385.5 | 1,294.9 |
| 3 | 3.2 | 8.8 | 5.3 | 1,397 | 401 | 2.4 | 90.2 | 45.1 | 31.5 | 1,984.5 | 1,733.3 |
| 4 | 3.2 | 8.8 | 5.3 | 1,863 | 534 | 2.4 | 90.2 | 45.1 | 31.5 | 2,583.5 | 2,108.9 |
| 5 | 3.2 | 8.8 | 5.3 | 2,329* | 668* | 2.4 | 90.2* | 45.1* | 31.5 | 3,183.5 | 2,428.7 |
| Sub-total 1 to 5 yrs. | 16.0 | 44.0 | 26.5 | 6,986 | 2,004 | 12.0 | 451.0 | 225.5 | 157.5 | 9,922.5 | 8,351.3 |
| 6 | 3.2 | 8.8 | 5.3 | 2,329 | 668 | 2.4 | 90.2 | 45.1 | 31.5 | 3,183.5 | 2,269.8 |
| 7 | 3.2 | 8.8 | 5.3 | 2,329 | 668 | 2.4 | 90.2 | 45.1 | 31.5 | 3,183.5 | 2,121.3 |
| 8 | 3.2 | 8.8* | 5.3 | 2,329 | 668 | 2.4 | 90.2 | 45.1 | 31.5 | 3,183.5 | 1,982.6 |
| 9 | 3.2 | 8.8 | 5.3 | 2,329 | 668 | 2.4 | 90.2 | 45.1 | 31.5 | 3,183.5 | 1,852.9 |
| 10 | 3.2 | 8.8 | 5.3* | 2,329 | 668 | 2.4* | 90.2 | 45.1 | 31.5* | 3,183.5 | 1,731.6 |
| Sub-total 6 to 10 yrs. | 16.0 | 44.0 | 26.5 | 11,645 | 3,340 | 12.0 | 451.0 | 225.5 | 157.5 | 15,917.5 | 9,958.2 |

continued

Table 17--Estimated increase in herbicide treatment cost and/or decrease in value of beef production if 2,4,5-T becomes unavailable for use on weed and brush infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest and Great Plains regions (continued)

| No. years w/o 2,4,5-T | Rangeland areas infested with mesquite: One[a/] | Two[a/] | Three[a/] | Four[b/] | Five[c/] | Six[a/] | Post-blackjack oak rangeland: Cow-calf[b/] | Stocker[d/] | Sand-shinnery oak rangeland[e/] | Total | Total impact discounted to 1978[f/] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thousands of Dollars | | | | | | | | | | |
| 11 | 3.2 | 8.8 | 5.3 | 2,329 | 668 | 2.4 | 90.2 | 45.1 | 31.5 | 3,183.5 | 1,618.4 |
| 12 | 3.2 | 8.8 | 5.3 | 2,329 | 668 | 2.4 | 90.2 | 45.1 | 31.5 | 3,183.5 | 1,512.5 |
| 13 | 3.2 | 8.8 | 5.3 | 2,329 | 668 | 2.4 | 90.2 | 45.1 | 31.5 | 3,183.5 | 1,413.5 |
| 14 | 3.2 | 8.8 | 5.3 | 2,329 | 668 | 2.4 | 90.2 | 45.1 | 31.5 | 3,183.5 | 1,321.1 |
| 15 | 3.2 | 8.8 | 5.3 | 2,329 | 668 | 2.4 | 90.2 | 45.1 | 31.5 | 3,183.5 | 1,234.6 |
| 16 | 3.2* | 8.8 | 5.3 | 2,329 | 668 | 2.4 | 90.2 | 45.1 | 31.5 | 3,183.5 | 1,153.9 |
| Sub-total 11 to 16 yrs. | 19.2 | 52.8 | 31.8 | 13,974 | 4,008 | 14.4 | 541.2 | 270.6 | 189.0 | 19,101.0 | 8,254.0 |
| Total | 51.2 | 140.8 | 84.8 | 32,605 | 9,352 | 38.4 | 1,443.2 | 721.6 | 504.0 | 44,941.0 | 26,563.5 |

* Indicates first year with no remaining effects from previous use of 2,4,5-T.

a/ Increased cost of using the alternative Silvex (table 1).

b/ Value of lost beef produciton minus decrease in cost of herbicide treatment (tables 1 and 8).

c/ Value of lost beef produciton minus decrease in cost of herbicide treatment (tables 1 and 9).

d/ Increased cost of using the alternative Silvex (table 11).

e/ Increased cost of using the alternative Silvex (table 13).

f/ Total impact discounted to 1979 using a 7% discount factor.

SOURCE: Natural Resource Economics Division, Economics, Statistics and Cooperatives Service, U.S. Department of Agriculture, Corvallis, Oregon.

Table 18--Estimated increase in herbicide treatment cost and/or decrease in value of beef production if 2,4,5-T and Silvex become unavailable for use on weed and brush infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest and Great Plains regions

| No. years w/o 2,4,5-T | Rangeland areas infested with mesquite | | | | | | Post-blackjack oak rangeland | | Sand-shinnery oak rangeland[g] | Total | Total impact discounted to 1978[h] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | One[a] | Two[b] | Three[b] | Four[c] | Five[d] | Six[b] | Cow-calf[e] | Stocker[f] | | | |
| | Thousands of Dollars | | | | | | | | | | |
| 1 | 47.0 | 73.9 | 63.4 | 465 | 134 | 29.2 | 1,267 | 2,034 | 1,520 | 5,633.5 | 5,633.5 |
| 2 | 94.0 | 73.9 | 63.4 | 932 | 267 | 29.2 | 2,535 | 4,069 | 3,040 | 11,103.5 | 10,377.1 |
| 3 | 141.0 | 73.9 | 63.4 | 1,397 | 401 | 29.2 | 3,802 | 6,102 | 4,561 | 16,570.5 | 14,473.3 |
| 4 | 118.0 | 73.9 | 63.4 | 1,863 | 534 | 29.2 | 5,069 | 8,137 | 6,081 | 22,038.5 | 17,990.0 |
| 5 | 235.0 | 73.9 | 63.4 | 2,329* | 668* | 29.2 | 6,337* | 10,171* | 7,601 | 27,507.5 | 20,985.5 |
| Sub-total 1 to 5 yrs. | 705.0 | 369.5 | 317.0 | 6,986 | 2,004 | 146.0 | 19,010 | 30,513 | 22,803 | 82,853.5 | 69,459.4 |
| 6 | 282.0 | 73.9 | 63.4 | 2,329 | 668 | 29.2 | 6,337 | 10,171 | 9,121 | 29,074.5 | 20,729.8 |
| 7 | 329.0 | 73.9 | 63.4 | 2,329 | 668 | 29.2 | 6,337 | 10,171 | 10,641 | 30,641.5 | 20,418.0 |
| 8 | 376.0 | 73.9* | 63.4 | 2,329 | 668 | 29.2 | 6,337 | 10,171 | 12,162 | 32,209.5 | 20,058.8 |
| 9 | 481.0 | 73.9 | 63.4 | 2,329 | 668 | 29.2 | 6,337 | 10,171 | 13,682 | 33,834.5 | 19,692.4 |
| 10 | 587.0 | 73.9 | 63.4* | 2,329 | 668 | 29.2* | 6,337 | 10,171 | 15,202* | 35,460.5 | 19,288.4 |
| Sub-total 6 to 10 yrs. | 2,055.0 | 369.5 | 317.0 | 11,645 | 3,340 | 146.0 | 31,685 | 50,855 | 60,808 | 161,220.5 | 100,187.4 |
| 11 | 694.0 | 73.9 | 63.4 | 2,329 | 668 | 29.2 | 6,337 | 10,171 | 15,202 | 35,567.5 | 18,081.1 |

continued

Table 18--Estimated increase in herbicide treatment cost and/or decrease in value of beef production if 2,4,5-T and Silvex become unavailable for use on weed and brush infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest and Great Plains regions (continued)

| No. years w/o 2,4,5-T | Rangeland areas infested with mesquite | | | | | | Post-blackjack oak rangeland | | Sand-shinnery oak rangeland[g/] | Total | Total impact discounted to 1978[h/] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | One[a/] | Two[b/] | Three[b/] | Four[c/] | Five[d/] | Six[b/] | Cow-calf[e/] | Stocker[f/] | | | |
| | Thousands of Dollars | | | | | | | | | | |
| 12 | 799.0 | 73.9 | 63.4 | 2,329 | 668 | 29.2 | 6,337 | 10,171 | 15,202 | 35,672.5 | 16,948.0 |
| 13 | 905.0 | 73.9 | 63.4 | 2,329 | 668 | 29.2 | 6,337 | 10,171 | 15,202 | 35,778.5 | 15,886.4 |
| 14 | 1,010.0 | 73.9 | 63.4 | 2,329 | 668 | 29.2 | 6,337 | 10,171 | 15,202 | 35,883.5 | 14,890.6 |
| 15 | 1,116.0 | 73.9 | 63.4 | 2,329 | 668 | 29.2 | 6,337 | 10,171 | 15,202 | 35,989.5 | 13,957.4 |
| 16 | 1,222.0* | 73.9 | 63.4 | 2,329 | 668 | 29.2 | 6,337 | 10,171 | 15,202 | 36,095.5 | 13,082.8 |
| Sub-total 11 to 16 years | 5,746.0 | 443.4 | 380.4 | 13,974 | 4,008 | 175.2 | 38,022 | 61,026 | 91,212 | 214,987.0 | 92,846.3 |
| Total | 8,506.0 | 1,182.4 | 1,014.4 | 32,605 | 9,352 | 467.2 | 88,717 | 142,394 | 174,823 | 459,061.0 | 262,493.1 |

* Indicates first year with no remaining effects from previous use of 2,4,5-T.

a/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 1 and 2).

b/ Increased cost of using the alternative Dicamba (table 1).

c/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 1 and 8).

d/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 1 and 9).

e/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 11 and 12A).

f/ Value of lost beef produciton minus decrease in cost of herbicide treatment (tables 11 and 12B).

g/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 13 and 14).

h/ Total impact discounted to 1979 using a 7% discount factor.

SOURCE: Natural Resource Economics Division, Economics, Statistics and Cooperative Service, U.S. Department of Agriculture, Corvallis, Oregon.

Table 19--Estimated increase in herbicide treatment cost and/or decrease in value of beef production if 2,4,5-T, and Silvex become unavailable and dicamba is not used for weed and brush control on infested rangeland in the Southern Rocky Mountains, Pacific Southwest and Great Plains regions

| No. years w/o 2,4,5-T | Rangeland areas infested with mesquite: One[a/] | Two[b/] | Three[c/] | Four[d/] | Five[e/] | Six[f/] | Post-blackjack oak rangeland: Cow-calf[g/] | Stocker[h/] | Sand-shinnery oak rangeland[i/] | Total | Total impact discounted to 1978[j/] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thousands of Dollars | | | | | | | | | | |
| 1 | 47 | 950 | 364 | 465 | 134 | 165 | 1,267 | 2,034 | 1,520 | 6,946 | 6,946 |
| 2 | 94 | 1,890 | 727 | 932 | 267 | 330 | 2,535 | 4,069 | 3,040 | 13,884 | 12,976 |
| 3 | 141 | 2,847 | 1,091 | 1,397 | 401 | 496 | 3,802 | 6,102 | 4,561 | 20,838 | 18,200 |
| 4 | 188 | 3,796 | 1,454 | 1,863 | 534 | 660 | 5,069 | 8,137 | 6,081 | 27,782 | 22,678 |
| 5 | 235 | 4,745 | 1,817 | 2,329* | 668* | 825 | 6,337* | 10,171* | 7,601 | 34,728 | 26,494 |
| Sub-total 1 to 5 yrs. | 705 | 14,228 | 5,453 | 6,986 | 2,004 | 2,476 | 19,010 | 30,513 | 22,803 | 104,178 | 87,294 |
| 6 | 282 | 5,694 | 2,180 | 2,329 | 668 | 990 | 6,337 | 10,171 | 9,121 | 37,772 | 26,931 |
| 7 | 329 | 6,643 | 2,544 | 2,329 | 668 | 1,155 | 6,337 | 10,171 | 10,641 | 40,817 | 27,198 |
| 8 | 376 | 7,592* | 2,907 | 2,329 | 668 | 1,319 | 6,337 | 10,171 | 12,162 | 43,861 | 27,315 |
| 9 | 481 | 7,592 | 3,271 | 2,329 | 668 | 1,485 | 6,337 | 10,171 | 13,682 | 46,016 | 26,782 |
| 10 | 587 | 7,592 | 3,635* | 2,329 | 668 | 1,650* | 6,337 | 10,171 | 15,202* | 48,171 | 26,202 |
| Sub-total 6 to 10 yrs. | 2,055 | 35,113 | 14,537 | 11,645 | 3,340 | 6,599 | 31,685 | 50,855 | 60,808 | 216,637 | 134,428 |
| 11 | 694 | 7,592 | 3,635 | 2,329 | 668 | 1,650 | 6,337 | 10,171 | 15,202 | 48,278 | 24,543 |

continued

Table 19--Estimated increase in herbicide treatment cost and/or decrease in value of beef production if 2,4,5-T, and Silvex become unavailable and dicamba is not used for weed and brush control on infested rangeland in the Southern Rocky Mountains, Pacific Southwest and Great Plains regions (continued)

| No. years w/o 2,4,5-T | Rangeland areas infested with mesquite: One[a/] | Two[b/] | Three[c/] | Four[d/] | Five[e/] | Six[f/] | Post-blackjack oak rangeland: Cow-calf[g/] | Stocker[h/] | Sand-shinnery oak rangeland[i/] | Total | Total impact discounted to 1978[j/] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thousands of Dollars | | | | | | | | | | |
| 12 | 799 | 7,592 | 3,635 | 2,329 | 668 | 1,650 | 6,337 | 10,171 | 15,202 | 48,383 | 22,987 |
| 13 | 905 | 7,592 | 3,635 | 2,329 | 668 | 1,650 | 6,337 | 10,171 | 15,202 | 48,489 | 21,530 |
| 14 | 1,010 | 7,592 | 3,635 | 2,329 | 668 | 1,650 | 6,337 | 10,171 | 15,202 | 48,594 | 20,165 |
| 15 | 1,116 | 7,592 | 3,635 | 2,329 | 668 | 1,650 | 6,337 | 10,171 | 15,202 | 48,700 | 18,887 |
| 16 | 1,222* | 7,592 | 3,635 | 2,329 | 668 | 1,650 | 6,337 | 10,171 | 15,202 | 48,806 | 17,690 |
| Sub-total 11 to 16 years | 5,746 | 45,552 | 21,810 | 13,974 | 4,008 | 9,900 | 38,022 | 61,026 | 91,212 | 291,250 | 125,802 |
| Total | 8,506 | 94,893 | 41,800 | 32,605 | 9,352 | 18,975 | 88,717 | 142,394 | 174,823 | 612,065 | 347,524 |

* Indicates first year with no remaining effects from previous use of 2,4,5-T.

a/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 1 and 2).

b/ Value of lost beef produciton minus decrease in cost of herbicide treatment (tables 1 and 4).

c/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 1 and 5).

d/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 1 and 8).

e/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 1 and 9).

f/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 1 and 10).

g/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 11 and 12A).

continued

Table 19—Estimated increase in herbicide treatment cost and/or decrease in value of beef production if 2,4,5-T, and Silvex become unavailable and dicamba is not used for weed and brush control on infested rangeland in the Southern Rocky Mountains, Pacific Southwest and Great Plains regions (continued)

h/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 11 and 12B).

i/ Value of lost beef production minus decrease in cost of herbicide treatment (tables 13 and 14).

j/ Total impact discounted to 1979 using a 7% discount factor.

SOURCE: Natural Resource Economics Division, Economics, Statistics and Cooperative Service, U.S. Department of Agriculture, Corvallis, Oregon.

Table 20—Estimated loss of beef production if 2,4,5-T becomes unavailable for use on weed and brush infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest and Great Plains regions

| No. years | Rangeland areas infested with mesquite | | | | | | Post-blackjack oak rangeland | | Sand-shinnery oak | |
|---|---|---|---|---|---|---|---|---|---|---|
| w/o 2,4,5-T | One | Two | Three | Four[a/] | Five[b/] | Six | Cow-calf | Stocker | rangeland | Total |
| | Thousands of Pounds | | | | | | | | | |
| 1 | — | — | — | 1,551 | 558 | — | — | — | — | 2,109 |
| 2 | — | — | — | 3,102 | 1,115 | — | — | — | — | 4,217 |
| 3 | — | — | — | 4,654 | 1,673 | — | — | — | — | 6,327 |
| 4 | — | — | — | 6,205 | 2,230 | — | — | — | — | 8,435 |
| 5 | — | — | — | 7,756* | 2,788* | — | — | — | — | 10,544 |
| Sub-total 1 to 5 yrs. | — | — | — | 23,268 | 8,364 | — | — | — | — | 31,632 |
| 6 | — | — | — | 7,756 | 2,788 | — | — | — | — | 10,544 |
| 7 | — | — | — | 7,756 | 2,788 | — | — | — | — | 10,544 |
| 8 | — | — | — | 7,756 | 2,788 | — | — | — | — | 10,544 |
| 9 | — | — | — | 7,756 | 2,788 | — | — | — | — | 10,544 |
| 10 | — | — | — | 7,756 | 2,788 | — | — | — | — | 10,544 |
| Sub-total 6 to 10 yrs. | — | — | — | 38,780 | 13,940 | — | — | — | — | 52,720 |

continued

Table 20—Estimated loss of beef production if 2,4,5-T becomes unavailable for use on weed and brush infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest and Great Plains regions (continued)

| No. years w/o 2,4,5-T | Rangeland areas infested with mesquite: One | Two | Three | Four[a/] | Five[b/] | Six | Post-blackjack oak rangeland: Cow-calf | Stocker | Sand-shinnery oak rangeland | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | Thousands of Pounds | | | | | | | | | |
| 11 | — | — | — | 7,756 | 2,788 | — | — | — | — | 10,544 |
| 12 | — | — | — | 7,756 | 2,788 | — | — | — | — | 10,544 |
| 13 | — | — | — | 7,756 | 2,788 | — | — | — | — | 10,544 |
| 14 | — | — | — | 7,756 | 2,788 | — | — | — | — | 10,544 |
| 15 | — | — | — | 7,756 | 2,788 | — | — | — | — | 10,544 |
| 16 | — | — | — | 7,756 | 2,788 | — | — | — | — | 10,544 |
| Sub-total 11 to 16 years | — | — | — | 46,536 | 16,728 | — | — | — | — | 63,264 |
| Total | — | — | — | 108,584 | 39,032 | — | — | — | — | 147,616 |

* Indicates first year with no remaining effects from previous use of 2,4,5-T.

a/ Taken from table 8, column 10.

b/ Taken from table 9, column 10.

SOURCE: Natural Resource Economics Division, Economics, Statisitics and Cooperatives Service, U.S. Department of Agriculture, Corvallis, Oregon.

Table 21—Estimated loss of beef production if 2,4,5-T and Silvex become unavailable for use on weed and brush infested rangeland in the Southern Rocky Mountain, Pacific Southwest, Southwest and Great Plains regions

| No. years w/o 2,4,5-T | Rangeland areas infested with mesquite | | | | | | Post-blackjack oak rangeland | | Sand-shinnery oak rangeland[f] | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | One[a] | Two | Three | Four[b] | Five[c] | Six | Cow-calf[d] | Stocker[e] | | |
| | Thousands of Pounds | | | | | | | | | |
| 1 | 300 | — | — | 1,551 | 558 | — | 6,240 | 7,032 | 5,805 | 21,486 |
| 2 | 600 | — | — | 3,102 | 1,115 | — | 12,480 | 14,064 | 11,610 | 42,971 |
| 3 | 900 | — | — | 4,654 | 1,673 | — | 18,720 | 21,095 | 17,415 | 64,457 |
| 4 | 1,200 | — | — | 6,205 | 2,230 | — | 24,961 | 28,128 | 23,220 | 85,944 |
| 5 | 1,500 | — | — | 7,756* | 2,788* | — | 31,201* | 35,159 | 29,025 | 107,429 |
| Sub-total 1 to 5 yrs. | 4,500 | — | — | 23,268 | 8,364 | — | 93,602 | 105,478 | 87,075 | 322,287 |
| 6 | 1,800 | — | — | 7,756 | 2,788 | — | 31,201 | 35,159 | 34,830 | 113,534 |
| 7 | 2,100 | — | — | 7,756 | 2,788 | — | 31,201 | 35,159 | 40,635 | 119,639 |
| 8 | 2,400 | — | — | 7,756 | 2,788 | — | 31,201 | 35,159 | 46,440 | 125,744 |
| 9 | 2,864 | — | — | 7,756 | 2,788 | — | 31,201 | 35,159 | 52,245 | 132,013 |
| 10 | 3,328 | — | — | 7,756 | 2,788 | — | 31,201 | 35,159 | 58,050* | 138,282 |
| Sub-total 6 to 10 yrs | 12,492 | — | — | 38,780 | 13,940 | — | 156,005 | 175,795 | 232,200 | 629,212 |
| 11 | 3,792 | — | — | 7,756 | 2,788 | — | 31,201 | 35,159 | 58,050 | 138,746 |

continued

Table 21--Estimated loss of beef production if 2,4,5-T and Silvex become unavailable for use on weed and brush infested rangeland in the Southern Rocky Mountain, Pacific Southwest, Southwest and Great Plains regions (continued)

| No. years w/o 2,4,5-T | Rangeland areas infested with mesquite: One[a/] | Two | Three | Four[b/] | Five[c/] | Six | Post-blackjack oak rangeland: Cow-calf[d/] | Stocker[e/] | Sand-shinnery oak rangeland[f/] | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | ---Thousands of Pounds--- | | | | | | | | | |
| 12 | 4,256 | — | — | 7,756 | 2,788 | — | 31,201 | 35,159 | 58,050 | 139,210 |
| 13 | 4,720 | — | — | 7,756 | 2,788 | — | 31,201 | 35,159 | 58,050 | 139,674 |
| 14 | 5,184 | — | — | 7,756 | 2,788 | — | 31,201 | 35,159 | 58,050 | 140,138 |
| 15 | 5,648 | — | — | 7,756 | 2,788 | — | 31,201 | 35,159 | 58,050 | 140,602 |
| 16 | 6,112* | — | — | 7,756 | 2,788 | — | 31,201 | 35,159 | 58,050 | 141,066 |
| Sub-total 11 to 16 years | 29,712 | — | — | 46,536 | 16,728 | — | 187,206 | 210,954 | 348,300 | 839,436 |
| Total | 46,704 | — | — | 108,584 | 39,032 | — | 436,813 | 492,227 | 667,575 | 1,790,935 |

* Indicates first year with no remaining effects from previous use of 2,4,5-T.

a/ Taken from table 2, column 10.

b/ Taken from table 8, column 10.

c/ Taken from table 9, column 10.

d/ Taken from table 12A, column 10.

e/ Taken from table 12B, column 10.

f/ Taken from table 14, column 10.

SOURCE: Natural Resource Economics Division, Economics, Statistics and Cooperatives Service, U.S. Department of Agriculture, Corvallis, Oregon.

Table 22—Estimated loss of beef production if 2,4,5-T and silvex become unavailable and dicamba is not used for weed and brush infested rangeland in the Southern Rocky Mountains, Pacific Southwest and Great Plains regions (continued)

| No. years w/o 2,4,5-T | Rangeland areas infested with mesquite: One[a/] | Two[b/] | Three[c/] | Four[d/] | Five[e/] | Six[f/] | Post-blackjack oak rangeland: Cow-calf[g/] | Stocker[h/] | Sand-shinnery oak rangeland[i/] | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | Thousands of Pounds | | | | | | | | | |
| 13 | 4,720 | 24,077 | 13,200 | 7,756 | 2,788 | 18,653 | 31,201 | 35,159 | 58,050 | 195,604 |
| 14 | 5,184 | 24,077 | 13,200 | 7,756 | 2,788 | 18,653 | 31,201 | 35,159 | 58,050 | 196,068 |
| 15 | 5,648 | 24,077 | 13,200 | 7,756 | 2,788 | 18,653 | 31,201 | 35,159 | 58,050 | 196,532 |
| 16 | 6,112* | 24,077 | 13,200 | 7,756 | 2,788 | 18,653 | 31,201 | 35,159 | 58,050 | 196,996 |
| Sub-total 11 to 16 years | 29,712 | 144,462 | 79,200 | 46,536 | 16,728 | 111,918 | 187,206 | 210,954 | 348,300 | 1,175,016 |
| Total | 46,704 | 300,962 | 151,800 | 108,584 | 39,032 | 214,513 | 436,813 | 492,227 | 667,575 | 2,458,210 |

* Indicates first year with no remaining effects from previous use of 2,4,5-T.

a/ Taken from table 2, column 10.

b/ Taken from table 4, column 10.

c/ Taken from table 5, column 10.

d/ Taken from table 8, column 10.

e/ Taken from table 9, column 10.

f/ Taken from table 10, column 10.

g/ Taken from table 12A, column 10.

h/ Taken from table 12B, column 10.

i/ Taken from table 14, column 10.

SOURCE: Natural Resource Economics Division, Economics, Statistics and Cooperatives Service, U.S. Depatment of Agriculture, Corvallis, Oregon.

Table 22--Estimated loss of beef production if 2,4,5-T and silvex become unavailable and dicamba is not used for weed and brush infested rangeland in the Southern Rocky Mountains, Pacific Southwest and Great Plains regions (continued)

| No. years w/o 2,4,5-T | Rangeland areas infested with mesquite: One[a] | Two[b] | Three[c] | Four[d] | Five[e] | Six[f] | Post-blackjack oak rangeland: Cow-calf[g] | Stocker[h] | Sand-shinnery oak rangeland[i] | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | Thousands of Pounds | | | | | | | | | |
| 13 | 4,720 | 24,077 | 13,200 | 7,756 | 2,788 | 18,653 | 31,201 | 35,159 | 58,050 | 195,604 |
| 14 | 5,184 | 24,077 | 13,200 | 7,756 | 2,788 | 18,653 | 31,201 | 35,159 | 58,050 | 196,068 |
| 15 | 5,648 | 24,077 | 13,200 | 7,756 | 2,788 | 18,653 | 31,201 | 35,159 | 58,050 | 196,532 |
| 16 | 6,112* | 24,077 | 13,200 | 7,756 | 2,788 | 18,653 | 31,201 | 35,159 | 58,050 | 196,996 |
| Sub-total 11 to 16 years | 29,712 | 144,462 | 79,200 | 46,536 | 16,728 | 111,918 | 187,206 | 210,954 | 348,300 | 1,175,016 |
| Total | 46,704 | 300,962 | 151,800 | 108,584 | 39,032 | 214,513 | 436,813 | 492,227 | 667,575 | 2,458,210 |

* Indicates first year with no remaining effects from previous use of 2,4,5-T.

a/ Taken from table 2, column 10.

b/ Taken from table 4, column 10.

c/ Taken from table 5, column 10.

d/ Taken from table 8, column 10.

e/ Taken from table 9, column 10.

f/ Taken from table 10, column 10.

g/ Taken from table 12A, column 10.

h/ Taken from table 12B, column 10.

i/ Taken from table 14, column 10.

SOURCE: Natural Resource Economics Division, Economics, Statistics and Cooperatives Service, U.S. Depatment of Agriculture, Corvallis, Oregon.

If 2,4,5-T and silvex become unavailable, beef production would be expected to decrease 21.5 million pounds the first year without 2,4,5-T and silvex (table 21). Beef production losses would increase to 141.1 million pounds in the sixteenth year. Cummulative losses over the 16-year evaluation period are estimated to be 1.8 billion pounds of beef.

If 2,4,5-T and silvex become unavailable and dicamba is not used, beef production would be expected to decrease 27.7 million pounds the first year (table 22). In the sixteenth year, beef production losses would increase to 197.0 million pounds. Cummulative losses over the 16-year evaluation period are estimated to be 2.5 billion pounds.

Expected changes in beef production from the rangeland areas due to a lack of 2,4,5-T and/or effective alternatives for weed and brush control are small compared to U.S. beef production and range from .015 to .470 percent of U.S. beef production (table 23). The expected quantity change is certainly more significant to the affected producers.

AVERAGE PER ACRE RETURNS

Average per acre gross returns from beef production on rangeland treated with 2,4,5-T varied from $2.33 to $31.22 (table 24). These estimates are based on 1973-77 average prices received by producers. Average per acre production costs on the treated rangelands varied from $1.48 to $28.99. Thus, the average returns to land, overhead, risk, and management from beef production varies from $0.85 to $11.59 per acre with 2,4,5-T. With these low returns per acre, the decrease in returns, indicated in table 24 if 2,4,5-T and/or silvex become unavailable, will significantly reduce the income of affected producers. Beef production returns with no mesquite or brush control on the rangelands are also shown.

Returns and analysis were based on the production of beef and labor saved in working livestock. There are other items that producers

Table 23--Summary of estimated beef production loss if 2,4,5-T and silvex become unavailable and dicamba proves to be ineffective for controlling weeds and brush-infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest, and Great Plains regions

| Alternatives and number of years without 2,4,5-T | Production loss each year | Percent of U.S. beef production[a] |
|---|---|---|
| | Thousand pounds | Percent |
| Silvex and Dicamba:[b] | | |
| 1-5 | 6,326 | .015 |
| 6-10 | 10,544 | .025 |
| 11-16 | 10,544 | .025 |
| Dicamba:[c] | | |
| 1-5 | 64,457 | .155 |
| 6-10 | 125,842 | .302 |
| 11-16 | 139,906 | .335 |
| Do nothing:[d] | | |
| 1-5 | 83,043 | .199 |
| 6-10 | 173,596 | .416 |
| 11-16 | 195,836 | .470 |

a/ Calculations based on an average 1973-76 U.S. liveweight beef production of 41,706,229,000 pounds.

b/ Calculated from table 20.

c/ Calculated from table 21.

d/ Calculated from table 22.

SOURCE: Natural Resource Economics Division, Economics, Statistics, and Cooperatives Service, U.S. Department of Agriculture, Corvallis, Oregon.

Table 24--Average per-acre returns to land, overhead, risk, and management with and without 2,4,5-T, Silvex, and Dicamba on weed and brush-infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest, and Great Plains regions a/

| Area & alternative | Gross returns[b] | Production costs: Herbicide treatment[b] | Production costs: Beef[c] | Production costs: Livestock-handling labor[b] | Production costs: Total | Returns to land, overhead, risk, & management |
|---|---|---|---|---|---|---|
| | Dollars | | | | | |
| Mesquite area: | | | | | | |
| One: | | | | | | |
| 2,4,5-T........................ | 7.84 | 1.51 | 4.75 | -0.50 | 5.76 | 2.08[d] |
| Silvex......................... | 7.84 | 1.59 | 4.75 | -0.50 | 5.84 | 2.00[d] |
| Do nothing, 1-8 years.......... | 5.16 | -- | 2.74 | -- | 2.74 | 2.42 |
| Do nothing, more than 8 years.. | 3.69 | -- | 1.96 | -- | 1.96 | 1.73 |
| Two: | | | | | | |
| 2,4,5-T........................ | 15.75 | 0.73 | 4.43 | -1.00 | 4.16 | 11.59[d] |
| Silvex......................... | 15.75 | 0.78 | 4.43 | -1.00 | 4.21 | 11.54[d] |
| Dicamba........................ | 15.75 | 1.15 | 4.43 | -1.00 | 4.58 | 11.17[d] |
| Do nothing..................... | 9.63 | -- | 2.76 | -- | 2.76 | 6.87 |
| Three: | | | | | | |
| 2,4,5-T........................ | 7.84 | 0.62 | 5.69 | -1.00 | 5.31 | 2.53[d] |
| Silvex......................... | 7.84 | 0.65 | 5.69 | -1.00 | 5.34 | 2.50[d] |
| Dicamba........................ | 7.84 | 0.98 | 5.69 | -1.00 | 5.67 | 2.17[d] |
| Do nothing..................... | 5.16 | -- | 3.84 | -- | 3.84 | 1.32 |

continued

Table 24--Average per-acre returns to land, overhead, risk, and management with and without 2,4,5-T, Silvex, and Dicamba on weed and brush-infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest, and Great Plains regions a/ (continued)

| Area & alternative | Gross returns[b/] | Production costs: Herbicide treatment[b/] | Production costs: Beef[c/] | Production costs: Livestock-handling labor[b/] | Production costs: Total | Returns to land, overhead, risk, & management |
|---|---|---|---|---|---|---|
| | Dollars | | | | | |
| **Four:** | | | | | | |
| 2,4,5-T........................ | 14.67 | 1.61 | 6.06 | -1.00 | 6.67 | 8.00[d/] |
| Do nothing..................... | 4.76 | — | 3.29 | — | 3.29 | 1.47 |
| **Five:** | | | | | | |
| 2,4,5-T........................ | 10.02 | 1.61 | 4.57 | -1.00 | 5.18 | 4.84[d/] |
| Tordon 225..................... | 10.02 | 2.80 | 4.57 | -1.00 | 6.37 | 3.65[d/] |
| Do nothing..................... | 5.16 | — | 2.57 | — | 2.57 | 2.59 |
| **Six:** | | | | | | |
| 2,4,5-T........................ | 2.33 | 0.62 | 0.86 | — | 1.48 | 0.85[d/] |
| Silvex......................... | 2.33 | 0.65 | 0.86 | — | 1.56 | 0.77[d/] |
| Dicamba........................ | 2.33 | 0.98 | 0.86 | — | 1.84 | 0.49[d/] |
| Do nothing..................... | 1.50 | — | 0.55 | — | 0.55 | 0.95 |
| **Post-blackjack oak rangeland:** | | | | | | |
| **Cow-calf operation:** | | | | | | |
| 2,4,5-T........................ | 10.20 | 2.68 | 7.44 | -1.00 | 9.12 | 1.08[d/] |
| Silvex......................... | 10.20 | 2.93 | 7.44 | -1.00 | 9.37 | 0.83[d/] |
| Do nothing..................... | 4.01 | — | 3.71 | — | 3.71 | 0.30 |

continued

Table 24—Average per-acre returns to land, overhead, risk, and management with and without 2,4,5-T, Silvex, and Dicamba on weed and brush-infested rangeland in the Southern Rocky Mountains, Pacific Southwest, Southwest, and Great Plains regions a/ (continued)

| Area & alternative | Gross returns b/ | Production costs: Herbicide treatment b/ | Production costs: Beef c/ | Production costs: Livestock-handling labor b/ | Production costs: Total | Returns to land, overhead, risk, & management |
|---|---|---|---|---|---|---|
| | Dollars | | | | | |
| Stocker operation: | | | | | | |
| 2,4,5-T........................ | 31.22 | 2.68 | 27.31 | -1.00 | 28.99 | 2.23 d/ |
| Silvex......................... | 31.22 | 2.93 | 27.31 | -1.00 | 29.24 | 1.98 d/ |
| Do nothing..................... | 16.25 | -- | 14.56 | -- | 14.56 | 1.69 |
| Sand-shinnery oak rangeland: | | | | | | |
| 2,4,5-T........................ | 9.63 | 1.24 | 4.48 | -- | 5.72 | 3.91 d/ |
| Silvex......................... | 9.63 | 1.31 | 4.48 | -- | 5.79 | 3.84 d/ |
| Do nothing..................... | 5.01 | -- | 2.99 | -- | 2.99 | 2.02 |

a/ Returns to land, overhead, risk, and mangement were estimated assuming ceteris paribus conditions with respect to price and production levels.

b/ Taken from tables 1, 11, and 13, columns 9 and 12.

c/ Texas Agricultural Extension Service, Texas A&M University, College Station Texas. Mimeographed livestock production budgets, 1977-78. Adjusted to 1973-79 average.

d/ User treats to improve range conditions to have a cover of forage grass to reduce top soil erosion and sedimentation of steams and reserviors.

SOURCE: Natural Resource Economics Division, Economics, Statisitics, and Cooperatives Service, U.S. Department of Agriculture, Corvallis, Oregon.

consider in determining if controlling woody plants is profitable to the particular operation. These items are:

1) Improving wildlife habitat by selectively controlling woody plants, which in turn increases big game hunting lease income in all areas. In mesquite areas of two, three, and six, controlling woody plants also increases ground game bird populations and game bird hunting oportunities.

2) Maintainance of natural renewable rangeland resources by improving range conditions.

3) Keeping a herbaceous cover on the soil surface to reduce soil erosion and resulting sedimentation of reservoirs.

4) Controlling brush, growing forage, and keeping ranch-raised stocker cattle to utilize excess forage and allow marketing heavier livestock at a time when prices are more favorable.

5) Maintaining the ranch in a productive state for future generations.

If woody plants are not controlled, their density increases and as the brush-grass ratio becomes greater, livestock numbers must be reduced to maintain the herbaceous cover and proper use of forage plants. The operation may become unprofitable .

Without 2,4,5-T, landowners in the post-blackjack rangeland could not produce excess forage to carry out stocker operations with the calves from their cow-calf operations. Stocker operations allow landowners to carry animals to heavier weights, thus increasing overall returns to the total operation.

## LIMITATIONS

The lack of a historical data base on some of the uses of 2,4,5-T and other herbicides on pasture and range, especially the uses on eastern pastures, fence rows, cactus, yucca, hardwoods, poisonous plants, desert shrub, and miscellaneous woody plants limited the completeness of this analysis. Collection of more complete herbicide use data on the many pasture and range problems is needed. Without these data, a full economic impact of canceling 2,4,5-T uses on herbaceous and woody plant problems on the approximately 1 billion acres of pasture and range can not be estimated. The inability to estimate the economic impacts on the majority of pasture and range acres indicates that the total impact of the loss of 2,4,5-T presented in this report is certainly understated.

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

## SUMMARY

The ribbon corridors of rights-of-way criss-crossing this nation form an interlocking network which literally enables this nation and its people to carry out their daily productive functions. Rights-of-way serve in the transport of people's needs: energy, fuel, food, communications--innumerable goods and services. The safe, continuous uninterrupted flow of goods and services over these right-of-way systems is a universal objective of those responsible for managing them. Vegetation-management programs are inherent to the accomplishment of that objective.

Major right-of-way types include railroads, highways, pipelines, and electric transmission lines. Estimated total right-of-way acreage associated with each of these are: railroads - 2.4 million acres; highways - 21.7 million acres; pipelines - 2.2 million acres; and electric utilities - 5 million acres; for a U.S. total of 31.3 million acres (approximately 1 percent of the total U.S. acreage). More than half this acreage occurs in the eastern third of the U.S. Acres treated annually with 2,4,5-T for each type are approximately 127 thousand for railroads, 22 thousand for pipelines, 68 thousand for highways, and 465 thousand for electric. About 4.1 million pounds of 2,4,5-T are applied to these 682,000 acres, annually. These acres are not usually treated with 2,4,5-T alone (14 percent), but rather 2,4,5-T in combination with other herbicides.

With 2,4,5-T applications, broadcast foliar ground treatment is most utilized by railroads and highways. Pipeline rights-of-way are predominantly treated with aerial methods. Aerial and selective basal are the dominant application methods for electric rights-of-way.

The Eastern United States where most of the right-of-way acreage is located, is dominated by deciduous woody plant species which also are susceptible to 2,4,5-T. The drier climate of the Central Plains and

Rocky Mountain region restricts woody plant growth, thus reducing need for intensive management. The abundant rainfall of the Pacific Northwest enables rapid plant growth which necessitates intensive rights-of-way vegetation-control programs.

The use of 2,4,5-T or any other chemical, mechanical, or manual methods will alter floristic composition. Resultant changes in plant communities may be beneficial to some organisms such as wildlife, and detrimental to others. For example, removal of mast-producing tree species in right-of-way clearance or periodic vegetation maintenance may be detrimental to squirrel habitat, and in contrast, the more diverse and dense vegetation cover resulting from vegetation management may be beneficial to deer, birds, and small mammals. This obvious relationship occurs under natural as well as man-induced changes in the environment. The magnitude of plant community change due to 2,4,5-T treatment is related to application technique. Selective methods cause the least disturbance to nontarget vegetation and community composition. Even with severe plant community alterations resulting from broadcast application methods, the ground layer of lesser vegetation may return to original composition over a period of years.

Habitat diversity created by use of 2,4,5-T generally enhances wildlife activity on rights-of-way. Because of rapid revegetation and the lack of site disturbance, there are minimal amounts of soil erosion and compaction following 2,4,5-T treatment. The aquatic environment receives little impact from 2,4,5-T usage. Water exposure is very limited.

The degree of control of many plant species is an important criteria in the selection of any herbicide treatment. 2,4,5-T is more effective on more species than 2,4-D, dichlorprop, or silvex. 2,4,5-T is less costly and less persistent than dicamba. It is not as corrosive to equipment as ammonium sulfamate (AMS), nor as persistent as picloram and, in contrast to glyphosate, does not kill all vegetation; i.e., 2,4,5-T is more selective.

Fire is essentially unused as a right-of-way management tool. Mechanical and manual methods generally are much more expensive than an application of 2,4,5-T and must be repeated more frequently. In many instances 2,4,5-T is used because mechanical and manual methods are physically impossible.

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

## INTRODUCTION

Rights-of-way in this section will be used to denote those lands managed to insure the safety, security, and reliability of rights-of-way systems. These lands are a necessary part of the system, but are not the dominant theme of that system. Highways, railroads, pipelines, and electric utilities need these right-of-way lands to support roads, rails, pipelines, and towers, and the lands must be managed so as to contribute to the system for which acquired.

These ribbon corridors traverse varied soil, topographic, and climatic conditions. The vegetation occurring thereon pose differing management problems depending both on the dominant and secondary use of the rights-of-way. Rights-of-way traversing state gamelands, for example, may also be managed to conform with regulations of a state wildlife agency.

The level of use of 2,4,5-T as a vegetation-management tool within the right-of-way area reflects: (1) the presence of vegetation susceptible to the herbicide, (2) the extent to which this vegetation is a problem, and (3) the geographic occurrence of this vegetation across the U.S. While this report will cover rights-of-ways of different types, it should be clear from the outset that vegetation management is accomplished in distinctly different ways on different kinds of right-of-way and the use of 2,4,5-T will vary with type of rights-of-way and geographic location usually the areas where 2,4,5-T is used on rights-of-way resemble forest and range sites in topography, soils, climate factors, and vegetation complexes. Thus rights-of-way, and forest and range sites have many ecological and environmental properties in common.

In this section, four general types of rights-of-way will be of primary interest:

1. Electric lines - electric transmission.

2. Pipelines - transmission of oil, natural gas, and coal slurry.

3. Highways - rural roads, including Interstate, primary, and secondary roads.

4. Railroads.

THE NUMBER AND LOCATION OF RIGHTS-OF-WAY IN THE UNITED STATES

Right-of-way occurrence can be illustrated by arbitrarily dividing the United States into four regions. This division is based on vegetation types according to Bailey's ecoregions (1976), and will be further explained in a succeeding section. For discussion purposes, the four regions are as follows (fig. 1):

1. Eastern Region (all states east of and including Minnesota, Iowa, Missouri, Arkansas, and Louisiana).

2. Central Plains and Rocky Mountain Region (all states east of and including Idaho, Nevada, and Arizona, and excluding the Eastern Region).

3. West Coast Region (Washington, Oregon, and California).

4. Alaska and Hawaii Region.

Using these regions, i.e., grouping of states, data were compiled to illustrate the occurrence of rights-of-way across the United States (table 1). Some of the information was available by states, some by industries, and some by both. Where possible, the data are presented by region of occurrence. Regionalization of data was necessary for two reasons. First, 2,4,5-T would only tend to be used where susceptible vegetation occurs. Second, it was evident early in this assessment


Figure 1. Arbitrary regions of the U.S.

Table 1--Location of rights-of-way (ROW) by type and U.S. region

| ROW type | Eastern region | Central Plains & Rocky Mountain region | West Coast region | Alaska & Hawaii | Total U.S. |
|---|---|---|---|---|---|
| Area (sq. miles)[a] | 1,197,047 | 1,506,348 | 323,866 | 592,862 | 3,613,123 |
| Percent of U.S. area | 33% | 42% | 9% | 16% | |
| Railroads (miles)[b] | 124,199 | 59,485 | 15,057 | 670 | 199,411 |
| Percent of U.S. area | 62% | 30% | 8% | 1% | |
| Highways--rural (miles)[c],[d] | | | | | |
| Interstate[e] | 18,242 | 12,159 | 2,505 | 15 | 32,921 |
| Primary[f] | 222,505 | 147,293 | 36,525 | 4,210 | 410,533 |
| Secondary[g] | 1,572,146 | 970,844 | 260,835 | 6,746 | 2,765,571 |
| Total rural highways | 1,767,893 | 1,130,296 | 299,865 | 10,971 | 3,209,025 |
| Percent of U.S. miles | 55% | 35% | 9% | 1% | |
| Pipeline-interstate (miles)[h] | | | | | |
| Oil & coal slurry | 64,017 | 107,107 | 2,869 | 79 | 174,072 |
| Percent of U.S. miles | 37% | 62% | 2% | 1% | |
| Natural gas[i] | 68,745 | 115,017 | 3,081 | 84 | 186,927 |
| Total pipelines | 132,762 | 222,124 | 5,950 | 163 | 360,999 |
| Electric transmission | | | | | |
| REA[j] (circuit miles) | 36,120 | 32,851 | 2,083 | 758 | 71,812 |
| Public utilities[k] (circuit miles) | 5,076 | 11,459 | 5,853 | 34 | 22,422 |
| Federal projects[l] (circuit miles) | 17,515 | 13,999 | 14,645 | 87 | 46,246 |
| Total circuit miles | 58,711 | 58,309 | 22,581 | 879 | 140,480 |
| Circuit miles converted to structure miles[m] | 49,904 | 49,563 | 19,194 | 747 | 119,408 |

continued

Table 1--Location of rights-of-way (ROW) by type and U.S. region

| ROW type | Eastern region | Central Plains & Rocky Mountain region | West Coast region | Alaska & Hawaii | Total U.S. |
|---|---|---|---|---|---|
| Private utilities[n] | | | | | |
| (structure miles) | | | | | |
| 31 KV | 5,522 | 1,872 | 143 | 85 | 7,622 |
| 31-50 KV | 47,780 | 16,911 | 400 | 560 | 65,651 |
| 51-131 KV | 79,889 | 35,863 | 22,482 | 308 | 138,542 |
| 132-188 KV | 37,860 | 17,555 | 904 | 117 | 56,436 |
| 189-253 KV | 18,408 | 5,699 | 8,056 | - | 32,163 |
| 254-400 KV | 12,370 | 5,925 | - | - | 18,295 |
| 401-600 KV | 4,669 | 1,845 | 2,343 | - | 8,857 |
| 601-850 KV | 1,415 | - | 290 | - | 1,705 |
| Total private structure miles | 207,913 | 85,670 | 34,618 | 1,070 | 329,271 |
| Total electric structure miles | 257,817 | 135,233 | 53,812 | 1,817 | 448,679 |
| Percent of U.S. miles | 57% | 30% | 12% | 1% | |
| Overall summary | | | | | |
| Total miles of ROW | 2,283,017 | 1,548,107 | 375,341 | 13,537 | 4,218,114 |
| Percent of ROW in U.S. | 54% | 37% | 9% | 1% | |

a/ Source: The Hammond World Atlas, Superior Edition. Hammond, Inc., Maplewood, NJ 184 p. 1975.

b/ Source: Handy Railroad Atlas of the United States. Rand McNally and Co. Chicago. 1978.

c/ Source: U.S. Dept. of Transportation News Release. Feb. 13, 1978.

d/ Rural roads are all roads except those within incorporated places, densely populated New England towns and certain of the more populous unincorporated areas. This includes the Interstate system.

e/ Source: U.S. DOT News Release of Feb. 13, 1978. Table FM-1.

f/ Source: U.S. DOT News Release of Feb 13, 1978. Table M-1. Primary highway miles = Col. 2 + Col. 4 - Interstate miles for state from Table FM-1.

g/ Source: U.S. DOT News Release of Feb. 13, 1978. Table M-1. Secondary highway miles = Col. 3 + Col. 9 + Col. 10.

h/ Source: Inter. Commerce Comm. 1978. Transport statistics in the U.S. for the year ended December 31, 1976. Part 6. Pipelines. (These data obviously do not include the recently completed Alaska pipeline).

i/ Source: Fed. Power Comm. 1974. Statistics of interstate natural gas pipeline companies. (Gas pipeline mileage apportioned to regions in same ratio as oil pipeline mileage).

j/ Source: 1976 Annual Statistical Report, Rural Electric Borrowers, Calendar Year Ended December 31, 1976. REA Bull. 1-1.

k/ Source: Federal Power Comm. 1976. Statistics of publicly owned electric utilities in the U.S. 1974.

l/ Source: See footnote k. Comment: Eastern region includes TVA and 1/2 Southwestern Pow. Admin.; Alaska and Hawaii region include Alaska Pow. Admin.; West Coast Region includes Bonn. Power Admin., Columbia River Basin Project, 1/2 Colorado River Station Project, and Central Valley Project; all others included in Central Plains and Rocky Mountain region.

m/ For private utilities, the ratio of structure miles to circuit miles for lines greater than 132 KV = 0.85. Since all the circuit miles data are for transmission lines, this same conversion factor was assumed for REA, public utilities and federal projects.

n/ Source: Fed. Power Comm. 1976. Statistics of privately owned electric utilities in the U.S. 1974. Classes A and B companies.

preparation that the different classes of right-of-way do not occur in equal ratio across the nation.

MILES OF RIGHTS-OF-WAY

The Eastern Region accounts for 33 percent of the area of the U.S., the Central Plains and Rocky Mountain Region 42 percent, the West Coast Region 9 percent, and Alaska and Hawaii 16 percent (table 1). However, of the nearly 200 thousand miles of railroads in the U.S., 62 percent is located in the Eastern Region. The nation's pipeline system is more concentrated in the Central Plains and Rocky Mountain Region, 62 percent, with three-fourths of this located in Kansas, Oklahoma, and Texas. Natural gas lines were apportioned to the regions in the same ratio as oil pipelines since mileage was not available by states. The nation has some 3.2 million miles of rights-of-way in its rural highway system, with 55 percent located in the Eastern Region. This includes the Federal Interstate system. Electric transmission rights-of-way are also more concentrated in the Eastern Region, with nearly 60 percent.

There are approximately 4.2 million miles of railroad, pipeline, highway, and electric rights-of-way of various widths in the U.S. Fifty-four percent of this total occurs in the eastern one-third of the U.S., percent in the mid-section of the nation, and nine percent in the West Coast states. The small size of Hawaii and the vast wilderness of Alaska essentially eliminate these two states from the national rights-of-way picture. The importance of eastern U.S. in rights-of-way reflects the concentration of people. The dominant use of these rights-of-way is the transport of peoples' needs.

RIGHTS-OF-WAY ACREAGE

Table 2 presents the estimated acreage of rights-of-way by types for the four regions of the U.S. There are an estimated 2.4 million acres of railroad rights-of-way in the U.S. Of the total railroad rights-of-way, exclusive of yards and sidings, 80 percent (1.9 million acres) is

Table 2—Rights-of-way (ROW) acreage by type and region in the U.S.

| ROW type | Assumed ROW width | Eastern region | Central Plains & Rocky Mountain region | West Coast region | Alaska & Hawaii | Total U.S. |
|---|---|---|---|---|---|---|
| | feet | | | | | |
| **Railroad** | | | | | | |
| Total ROW | 100[a/] | 1,505,442 | 721,030 | 182,509 | 8,121 | 2,417,102 |
| Brush control area (excludes road bed) | 80[b/] | 1,204,354 | 576,824 | 146,007 | 6,497 | 1,933,682 |
| **Highways-rural**[c/] | | | | | | |
| Interstate | | | | | | |
| Total ROW | 300 | 663,345 | 442,145 | 91,091 | 545 | 1,197,127 |
| Vegetation area | 220[d/] | 486,453 | 324,240 | 66,800 | 400 | 877,893 |
| Primary | | | | | | |
| Total ROW | 75 | 2,022,772 | 1,339,028 | 332,046 | 38,272 | 3,732,118 |
| Vegetation area | 27[e/] | 728,198 | 482,050 | 119,536 | 13,778 | 1,343,562 |
| Secondary | | | | | | |
| Total ROW | 50 | 9,255,430 | 5,883,903 | 1,580,818 | 40,885 | 16,761,036 |
| Vegetation area | 18[f/] | 3,331,955 | 2,118,205 | 569,095 | 14,719 | 6,033,973 |
| Total highway ROW | | 11,941,547 | 7,665,076 | 2,003,955 | 79,702 | 21,690,280 |
| Total highway vegetation area | | 4,546,606 | 2,924,495 | 755,431 | 28,897 | 8,255,428 |
| **Pipelines** | 50[g/] | 804,618 | 1,346,206 | 36,061 | 988 | 2,187,873 |
| **Electric transmission**[h/,i/] | | | | | | |
| REA, public utilities and Federal projects | 100[j/] | 604,897 | 600,763 | 232,654 | 9,055 | 1,447,368 |
| Private utilities[k/] | | | | | | |
| <31 KV | 40 | 26,773 | 9,076 | 693 | 412 | 36,955 |
| 31-50 KV | 50 | 289,576 | 102,491 | 2,424 | 3,394 | 397,885 |
| 51-131 KV | 75 | 726,264 | 326,027 | 204,382 | 2,800 | 1,259,473 |
| 132-188 KV | 110 | 504,800 | 234,067 | 12,053 | 1,560 | 752,480 |
| 189-253 KV | 125 | 278,909 | 86,348 | 122,061 | - | 487,381 |
| 254-400 KV | 150 | 224,909 | 107,727 | - | - | 332,636 |
| 401-600 KV | 180 | 101,869 | 40,254 | 51,120 | - | 193,244 |
| 601-850 KV | 225 | 38,591 | - | 7,909 | - | 46,500 |

Continued.

Table 2— Rights-of-way (ROW) acreage by type and region in the U.S. (Continued)

| ROW type | Assumed ROW width | Eastern region | Central Plains & Rocky Mountain region | West Coast region | Alaska & Hawaii | Total U.S. |
|---|---|---|---|---|---|---|
| | feet | | | | | |
| Total Electric ROW | | 2,796,588 | 1,506,753 | 633,296 | 17,221 | 4,953,858 |
| Overall summary | | | | | | |
| Total ROW acres | | 17,048,195 | 11,239,065 | 2,855,821 | 106,032 | 31,249,113 |
| Percent of ROW in U.S. | | 55% | 36% | 9% | 1% | |
| Total vegetation acres | | 9,352,166 | 6,354,278 | 1,570,795 | 53,603 | 17,330,842 |

a/ ROW width based on discussions with railroad weed control contractors.

b/ Excludes 20 feet for road bed which is generally treated with soil sterilants rather than 2,4,5-T.

c/ ROW widths based on discussions with highway department officials in Indiana and Maryland, and Federal Highway Administration.

d/ Excludes two lanes, each consisting of 24' road, 12' and 4' shoulders or 40' per lane of divided highway.

e/ Excludes a 24' road and two 12' shoulders.

f/ Excludes a 24' road and two 4' shoulders.

g/ Source: 1975. U.S. Dept. Interior. The need for a national system of transportation and utility corridors. Table VIII-2.

h/ Only mileage designated as transmission considered. Assumes most distribution mileage occurs in populated areas or often on shared ROW with others such as rural roads; or generally of such low voltage that only narrow ROW required which tends to be trimmed rather than treated with herbicide. This eliminates 1.7 million miles of REA distribution lines.

i/ Transmission miles or structure miles = circuit miles x 0.85. This ratio derived from comparison of circuit miles and structure miles of private utility lines greater than 132 KV.

j/ ROW width suggested as average width for REA by REA official.

k/ ROW widths are assumptions made after discussions with electric utility and other knowledgeable personnel.

actually available for brush-control treatment or treatments where 2,4,5-T could be involved. The remaining 20 percent is in the roadbed ballast area and tends to be treated with soil sterilants for total vegetation control.

The rural highway system is divided into Interstate, primary, and secondary roads to better account for the differences in right-of-way width associated with each class of road. Assuming a 300 foot right-of-way for the Interstate system, there are 1.2 million acres included in Interstate right-of-way. Discounting paved surfaces and shoulders, only 73 percent of this Interstate right-of-way is actually available for vegetation treatment. Similarly, 36 percent of the primary and secondary rights-of-way is actually available for vegetation-control treatment. Within the U.S., rural highway rights-of-way account for more than 21 million acres. Of this, slightly more than half is located in the Eastern Region of the U.S.

Interstate pipeline systems account for 2.2 million acres of right-of-way which are largely concentrated in the Central Plains and Rocky Mountain Region. Electric transmission rights-of-way occupy nearly 5 million acres. Of this, approximately 56 percent is located in the Eastern Region.

In summary, rights-of-way utilize more than 31 million acres of land in the U.S. Of this, 17.3 million acres are located such that they could be potentially treated with 2,4,5-T. As has been the consistent trend throughout the data assimilation on rights-of-way, the Eastern Region, which accounts for only one-third of the U.S. area, accounts for greater than one-half of the right-of-way acreage.

MINOR RIGHTS-OF-WAY

There are also rights-of-way which are difficult to firmly quantify in terms of potential herbicide usage, but sheer magnitude demands mention (table 3). For lack of a better term, these might be considered as

Table 3--Additional miles and acres of "minor" rights-of-way (ROW) types

| ROW type | Assumed ROW width (ft) | Eastern region | Central Plains & Rocky Mountain region | West Coast region | Alaska & Hawaii | Total U.S. |
|---|---|---|---|---|---|---|
| REA-distribution | | | | | | |
| Structure miles a/ | | 1,018,177 | 645,307 | 33,722 | 4,611 | 1,701,817 |
| ROW acres | 30 b/ | 3,702,462 | 2,346,571 | 122,625 | 16,767 | 6,188,425 |
| Telephone | | | | | | |
| Structure miles c/,d/ | | 855,260 | 178,250 | 155,492 | 2,848 | 1,191,850 |
| ROW acres | 10 | 1,036,679 | 216,061 | 188,475 | 3,452 | 1,444,667 |
| Pipelines - natural gas | | | | | | |
| Field miles e/ | | 20,442 | 34,254 | 1,105 | - | 55,248 |
| ROW acres | 50 f/ | 123,891 | 207,600 | 6,697 | - | 334,836 |
| Totals | | | | | | |
| miles | | 1,893,879 | 857,811 | 190,319 | 7,459 | 2,948,915 |
| acres | | 4,863,032 | 2,770,232 | 317,797 | 20,219 | 7,967,928 |

a/ Source: 1976 Annual Statistical Report, Rural Electric Borrowers, Calender Year Ended December 31, 1976. REA Bull. 1-1.

b/ ROW width suggested by REA official.

c/ Source: Statistics of Communications Common Carriers. Federal Communications Commision. 1976.

d/ Mileage estimated by proportioning the number of poles in the U.S. (42,187,906) to each state in accordance with the percent of miles of aerial cable and wire. Assumed span distance of 150 feet between poles and ROW width suggested by official of Chesapeake and Potomac Telephone Company of Virginia.

e/ Source: Fed. Power Comm. 1974. Statistics of interstate natural gas pipeline companies. (Gas pipeline mileage apportioned to regions in same ratio as oil pipeline mileage).

f/ Same width as used for interstate gas transmission.

"minor" right-of-way types although, in terms of potential miles or acres, they may be far from minor. The rights-of-way considered in tables 1 and 2 are almost totally rural. REA distribution lines ( <34.5 kv), 1.7 million miles (table 3), are almost four times the total electrical structure miles (table 1) and 25 percent greater than total transmission acreage (table 2). Portions of these lines are known to be treated with herbicides, but manual tree trimming is also very important. These lines obviously integrate into urban conditions, and may occur as shared rights-of-way with highways and telephones, all in uncertain ratios.

Similarly, based on the number of telephone poles in the U.S. (42.2 million), there are approximately 1.2 million miles of telephone pole lines in this nation. Assuming a 10 foot right-of-way width, there are almost 1.5 million acres of telephone right-of-way. Again, unknown proportions are shared with highways, railroads, and electric, and unknown proportions are in urban locations.

There are an additional 55,248 miles of natural gas field lines. However, the proportion of multiple lines and actual amounts of unshared rights-of-way are unknown.

There also are extensive areas of drainage ditches, canals, channels, and other waterways where brush control is necessary. While these water-related rights-of-way are not currently treated with 2,4,5-T, as rights-of-way they are subject to vegetation management and were potentially treatable with 2,4,5-T until current restrictions were imposed prohibiting the use of 2,4,5-T for these purposes.

## MANAGEMENT GOALS VERSUS VEGETATION PROBLEMS

One common goal throughout the various types of rights-of-way is maintenance of the security and reliability of the right-of-way system. The electrical transmission lines must transport electricity and railroads must transport goods safely. Pipelines must transport petroleum products and the highways must provide safe transportation for the users. For all of these systems, vegetation -- often woody and sometimes grass and herbaceous vegetation -- poses particular problems. Also common to all rights-of-way management is the maintenance of an aesthetically pleasing appearance, control of noxious weeds required by law, and soil stabilization.

Right-of-way vegetation management may, on the surface, appear to be a simple problem, particularly since crop residues are not involved. However, excluding total vegetation control in the ballast portion of railroads, selective and adequate vegetation control is the primary objective for all rights-of-way. The control program must be geared to the dominant problem plant or plant complex in each locale. This management program must fit within the management objectives and budgetary constraints of the industry concerned, be it electric, highway, pipeline, or railroad. As the problem vegetation changes with treatment, topography, soils, or climate, the specific control program must change accordingly.

All of the undesirable vegetation on a right-of-way site must be controlled. There is no single herbicide that will selectively and adequately control all undesired species, especially woody plants, with the species complex on a site. It is therefore necessary to have several herbicides available that can be used to supplement the main herbicide of choice for the confronting problem. Where a herbicide does not adequately control the vegetation or has undesired attributes, other herbicides or management methods are used to maintain the right-of-way site. Each of these also has advantages and disadvantages.

## ELECTRIC TRANSMISSION

Vegetation problems for electric transmission systems center largely on tall-growing woody vegetation. Vegetation in the conductor security zone or in contact with the transmission lines will cause power outages. This disrupts service to homes and industries and can cause fires. Woody vegetation also hinders access for line and structure inspection and maintenance. The primary purpose for vegetation management on electric utility rights-of-way is for safe and uninterrupted transmission of electrical power. These problems are encountered over a variety of terrain conditions from flat to very steep and from uninterrupted forests to wooded lands interspersed with agricultural croplands. Development of low dense cover for wildlife habitat enhancement can be an important secondary objective.

RAILROADS

Because of the nature of railroad use, the control of vegetation on railroad rights-of-ways serves essential transportation purposes. Safety of train movement requires maintenance of sound track foundations. Uncontrolled weeds, vines, and brush will penetrate and undermine track structures and make them hazardous. Rights-of-way must be cleared of fire hazards created by the presence of weeds, vines, and brush.

Uncontrolled vegetation impedes visibility. Visibility along rights-of-way, especially on curves, and visibility of signals must be maintained in the interest of safe operations. Visibility must be maintained at highway grade crossings for the safety of motorists and train crews. There are 25,000 public crossings at grade in the United States. Uncontrolled vegetation at grade crossings seriously impairs visibility.

Rights-of-way must be cleared of vegetation to enable communications and signal systems to operate properly and to be maintained. These systems are essential to railroad transportation. Railroad employees need safe working conditions and the control of vegetation is necessary for that purpose. The control of vegetation on or adjacent to roadbeds is a duty imposed on railroads by Federal regulations (Welsh 1974).

## HIGHWAYS

Vegetation problems along highway rights-of-way are similar to those of railroads. Control of vegetation on highway rights-of-way is essential for safety of vehicle movement and visibility along rights-of-ways especially at curves and road crossings. From table 1, 86 percent of our nation's highway system (2.8 million miles) is in the secondary road class with typically narrow rights-of-way. Vegetation control is necessary to prevent brush encroachment into the driving lanes, thus reducing visibility, to permit drainage ditches to function as intended, to reduce snow drifting, and to reduce shading, permitting more rapid drying of the road surface which reduces road maintenance costs as well as increasing safety. Vegetation control must be accomplished by some method which can be used on highly erodable cut and fill slopes, where stones and stumps or rock outcroppings may exist.

Highway rights-of-way are unique among the various rights-of-way because of the necessity for herbaceous weed control. Roadsides must be pleasing in appearance and must be free of noxious plants. Examples of noxious or otherwise undesirable weeds include Canada thistle, hemp, milkweed, chicory, leafy spurge, common mullin, field bindweed and poison ivy.

## PIPELINES

Vegetation control on pipeline rights-of-way principally concerns reliability of the system. Woody plant control is necessary for visual inspection of the lines as well as access for maintenance.

## BIOLOGY AND ECOLOGY OF PLANT COMMUNITIES

With the constraints of herbicide effectiveness or species susceptibility, and management intensity, the United States can be divided into relevant ecoregions (Bailey 1976, fig. 2 and table 4). This division was explained previously in the discussion of rights-of-

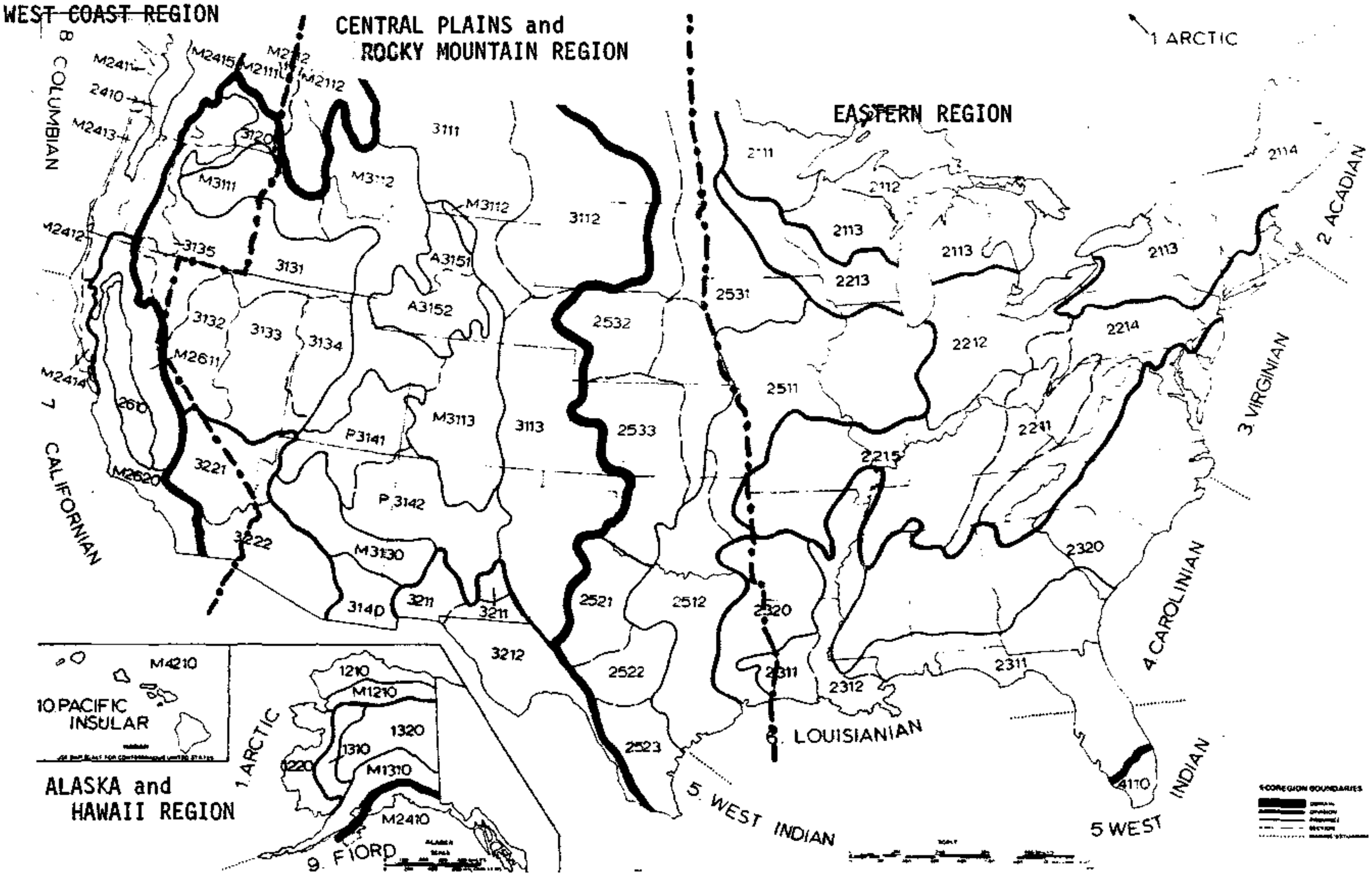


Figure 2. Relationship of ecoregions and arbitrary U.S. regions designated in Figure 1. (See table 3 for explanation of numerical symbols.

Table 4--Explanation of ecosystem numbers from figure 2 by U.S. regions

## Eastern Region

Laurentian Mixed Forest

2211 Spruce-fir forest
2112 Northern hardwoods-fir forest
2113 Northern hardwoods forest
2114 Northern hardwoods-spruce forest

Eastern Deciduous Forest

2211 Mixed mesophytic forest
2212 Beech-maple forest
2213 Maple-basswood forest and oak savanna
2214 Appalachian oak forest
2215 Oak-hickory forest

Outer Coastal Plain Forest

2311 Beech-sweetgum-magnolia-pine-oak forest
2312 Southern flood plain forest

2320 Southeastern Mixed Forest

Prairie Parkland

2511 Oak-hickory-bluestem parkland

Tall-Grass Prairie

2531 Bluestem prairie

4110 Everglades

## Central Plains and Rocky Mountain Region

Columbia Forest

M2112 Cedar-hemlock-Douglas-fir forest

Prairie Parkland

2512 Oak-bluestem parkland

Prairie Brushland

2521 Mesquite-buffalograss
2522 Juniper-oak-mesquite savanna
2523 Mesquite-acacia savanna

Continued.

Table 4— Explanation of ecosystem numbers from figure 2 by U.S. regions (Continued)

Tall-Grass Prairie

2531 Bluestem prairie
2532 Wheatgrass-bluestem-needlegrass
2533 Bluestem-grama prairie

Great Plains Short-Grass Prairie

3111 Grama-needlegrass-wheatgrass
3112 Wheatgrass-needlegrass
3113 Grama-buffalograss

Intermountain Sagebrush

3131 Sagebrush-wheatgrass
3132 Lohantan saltbush-greasewood
3133 Great basin sagebrush
3134 Bonneville saltbush-greasewood

3140 Mexican Highlands Shrub Steppe

Rocky Mountain Forest

M3111 Grand fir-Douglas-fir forest
M3112 Douglas-fir forest
M3113 Ponderosa pine-Douglas-fir forest

M3130 Upper Gila Mountains Forest

Colorado Plateau

P3141 Juniper-pinyon woodland + sagebrush-saltbush mosaic
P3142 Grama-galleta steppe and juniper-pinyon woodland mosaic

Wyoming Basin

A3151 Wheatgrass-needlegrass-sagebrush
A3152 Sagebrush-wheatgrass

Chihuahuan Desert

3211 Grama-tobosa
3212 Tarbush-creosote bush

American Desert

3221 Creosote bush
3222 Creosote bush-bur sage

Continued.

Table 4--Explanation of ecosystem numbers from figure 2 by U.S. regions (Continued)

## West Coast Region

Columbia Forest

M2111 Douglas-fir forest

Willamette-Puget Forest

2410 Willamette-puget forest

Pacific Forest

M2411 Sitka spruce-cedar-hemlock forest
M2412 Redwood forest
M2413 Cedar-hemlock-Douglas-fir forest
M2414 California mixed evergreen forest
M2415 Silver fir-Douglas-fir forest

2610 California Grassland

M2611 Sierran Forest

M2620 California Chaparral

3120 Palouse Grassland

Intermountain Sagebrush

3131 Sagebrush-wheatgrass
3135 Ponderosa shrub forest

Rocky Mountain Forest

M3111 Grand fir-Douglas-fir forest

American Desert

3221 Creosote bush
3222 Cretosote bush-bur sage

## Alaska and Hawaii

1210 Artic Tundra
1220 Bering Tundra

M1210 Brooks Range

1310 Yukon Parkland
1320 Yukon Forest

Continued.

Table 4--Explanation of ecosystem numbers from figure 2 by U.S. regions (Continued)

| | |
|---|---|
| M1310 | Alaska Range |
| M2410 | Pacific Forest |
| M4210 | Hawaiian Islands |

way occurrence. The compilation of the states by selected regions was based on major vegetational boundaries. Obviously 2,4,5-T will not be used in areas where nonsusceptible species make up the major plant communities, or where 2,4-D or other herbicides can attain the same objective more effectively or at a lower cost. Also, 2,4,5-T is not likely to be used in semi-arid, prairie, or other regions where woody plants do not grow rapidly or abundantly.

Woody vegetation, of particular concern on rights-of-way, develops in response to climatic, edaphic, and physiographic factors. Eastern U.S., as defined here, includes Minnesota, Iowa, Missouri, Arkansas, Louisiana, and all states east. Forest is the climax vegetation. The West Coast states include California, Oregon, and Washington where both forest and grasslands occur. The remaining contiguous states in the continental 48 will be referred to as the Central Plains and Rocky Mountain Region. Here grasslands predominate but woody plants are found at high elevations or other sites where climate and site conditions will support them.

One important ecoregion province included in the Eastern Region is the Laurentian Mixed Forest (Bailey 1976). The region covers 224,700 square miles across the northern portion of the Lake States, the Adirondacks, and New England Highlands. The woody plant communities in this province are transitional between the boreal forests of Canada and the deciduous forests to the south. Bailey recognized four sections in this province.

1. Spruce-fir forest
2. Northern hardwoods-fir forest
3. Northern hardwoods forest
4. Northern hardwoods-spruce forest

A second important ecoregion in Eastern U.S. is the Eastern Deciduous Forest, 367,800 square miles. Only a small part of this ecoregion lies outside Eastern U.S. as defined here. The Eastern Deciduous Forest Region extends from the New England lowlands through the Appalachian

Region to the Ozarks on the west. It also includes the southern portions of the Lake States. Five sections in this ecoregion are:

1. Mixed mesophytic forest
2. Beech-maple forest
3. Maple-basswood forest plus oak savanna
4. Appalachian oak forest
5. Oak-hickory forest

A third ecoregion province of importance in Eastern U.S. is the Outer Coastal Plain Forest. This province covers 150,100 square miles, most of which is in Eastern U.S. as herein defined. This ecoregion covers the extreme southern part of the Southeastern U.S., including nearly all of Florida, southern Georgia, Alabama, Mississippi, Louisiana, and extending up the Mississippi River to southern Missouri. Two distinct sections of this province are:

1. Beech-sweetgum-magnolia-pine-oak forest
2. Southern flood plain forest

A fourth province in this region is the Southeastern Mixed Forest Province covering 257,000 square miles across Southeastern U.S. The forests in this region are dominated by various southern pines with common hardwood associates such as oak, hickory, sweetgum, black gum, red maple, and winged elm.

Also of importance in the Eastern U.S. Region is the Prairie Parkland Province. A section of this province is the oak-hickory-blue stem parkland. This section occurs predominantly in Illinois, Iowa, and northern Missouri. Most of this section is included in the Eastern Region. It is the only part of the Eastern Region not characterized exclusively by woody climax vegetation.

An important segment of the Central Plains and Rocky Mountain Region as used in this discussion is the Prairie Division along the eastern edge of this region. The prairies of the U.S. extend from Texas to the northern U.S. border in a broad belt. This is a transitional zone between two forested areas. Moisture tends to be limiting for tree growth. The natural vegetation of the prairies is tall grasses with subdominant broadleaved herbs. Trees and shrubs occur only as occasional patches usually in river bottoms and drainage areas. While part of the Prairie Parkland Province is included in the Eastern U.S. region, one section, the Oak-Bluestem Parkland, occurs in the Central Plains and Rocky Mountain region.

Mixed hardwood-conifer stands occur across the northern and southern portion of the Eastern Region. Forests in the central part of the Eastern Region tend to be dominated by hardwood species. The Eastern Region also includes a transitional zone in Iowa and Illinois where hardwoods occur in mixture in parks and savannas with grasses. The climate is sufficient in the Eastern Region to support fairly lush woody plant growth and herbaceous vegetation throughout most of the region.

The Central Plains Region grades from tall and short grass prairies into the Pinyon-Juniper-Sagebrush communities of the Rocky Mountains. The Central Plains and Rocky Mountain Region can be generally characterized as having a net moisture deficit, limited occurrence of broadleaf species, often fairly sparse vegetation and woody plant vegetation which is typically very slow growing.

The West Coast Region east of the Cascade and Sierra Nevada Mountains is, for the most part, typified by vegetation types and growth conditions similar to the Rocky Mountain Region. The western third of Oregon, Washington, and northwestern California is an area greatly influenced by the Pacific Ocean. Lush, rapid growing woody vegetation is dominant throughout the coastal zone. This vegetation is typified by coniferous species; numerous broadleaf, deciduous hardwood species are also characteristic of the forest species in this particular area.

Following the initial disturbance necessitated by installation of a right-of-way system, natural plant successional trends constantly tend to convert the disturbed or right-of-way area back to naturally occurring seral woody vegetation. In the Eastern Region and Pacific Northwest, this leads to encroachment by broadleaf woody vegetation into rights-of-way. Woody vegetation would tend to occur to various degrees in the Central Plains and Rocky Mountain Region, but the climatic extremes, particularly moisture availability, generally cause development to be very slow.

## IMPACT ON COMMODITY YIELD

Within the right-of-way area the nature of land management is totally different from that associated with crop production where yields and yield reductions as a function of weeds and weed growth can be reasonably well defined. On rights-of-way weed and brush control is either satisfactory or it is not. It does not involve a commodity that can be measured in terms of board feet, metric tons, or animal units, but rather uses such as power or fuel transmission and transportation which impact all of the U.S. or major segments of the country when serious problems arise. Therefore, a major objective of vegetation management on rights-of-way is to prevent plant growth from interfering with these functions which are the "commodities" in this case.

## MANAGEMENT STRATEGIES

The ultimate objective for right-of-way managers is to maintain the reliability of the right-of-way system. Strategy, in the simplest terms, is to maintain that right-of-way in operable condition for the lowest costs per acre or mile of right-of-way. This involves vegetation manipulation to (1) prevent tall-growing woody plants from entering the conductor security zone on electric transmission rights-of-way, (2) provide visibility and reduce interference with vehicles and carriers on transportation rights-of-way, (3) reduce interference with fuel movement on pipeline rights-of-way, and (4) provide access for inspection and maintenance on all rights-of-way.

## POTENTIAL SOLUTION OF THE PROBLEM

There are a variety of methods available to the right-of-way manager for controlling vegetation. In the broadest sense, these include chemical, mechanical, hand labor, fire, or a variety of combinations of these methods. Each method has advantages and disadvantages which may enhance or exclude its use in a particular locale, types of rights-of-way, or type of vegetation. Certainly all of these methods have associated costs and impacts on vegetation, wildlife, and services which must be continuously considered by the right-of-way manager in the selection of the particular method or combination of methods. Throughout the remaining portion of this report, the major methods will be compared, especially herbicides, mechanical, and hand labor.

Fire is seldom used in rights-of-way vegetation management. Managing small ribbons of land crossing a variety of soils, climates, physiographic features, and adjacent crop and noncrop situations severely limits the use of fire as a tool for controlling right-of-way vegetation. Not only are there problems with smoke emission, but also severe managerial problems associated with maintaining fire within very strict and narrow confines while also maintaining a fire of sufficient intensity to accomplish the prescribed objective, especially if this objective is woody plant control.

## ALTERNATIVES FOR PROBLEM SOLUTION

### 2,4,5-T

#### Patterns of Use

During the summer of 1978, Asplundh Environmental Services surveyed the major right-of-way sectors that are actively involved in major vegetation management programs, i.e., railroads, pipelines, highways, and electric utilities. This survey was specifically designed to determine the role of 2,4,5-T in vegetation-management programs of these right-of-way groups. The survey results are based on responses from 469 electric utilities, 25 railroads, 66 pipeline companies, and 31 highway departments.

The estimated acres treated annually by rights-of-way type and method of application are presented in table 5. Electric utilities treat the greatest number of acres with 2,4,5-T annually, 465,339 acres or 68 percent of the total acres treated annually with 2,4,5-T. Railroads annually treat 127,425 acres or 19 percent, highways treat 68,167 or 10 percent, and pipelines 22,026 or 3 percent.

Railroads are heavily dependent on broadcast foliar treatments applied by ground equipment. This method of application accounts for more than 75 percent of treated railroad acres. Broadcast aerial application accounts for nearly 90 percent of the pipeline acreage treated. Broadcast foliar ground applications are most important for highway rights-of-way management, 86 percent of the treated acreage. One-half of the treated electric right-of-way acreage is treated with a selective basal treatment. An additional 34 percent of electric rights-of-way acreage is treated with broadcast aerial foliar application.

The acres treated annually with 2,4,5-T are relatively small when compared to the total right-of-way acres. Railroads treat only 7 percent annually, pipelines and highways only 1 percent annually and electric, 9 percent. However, if an average treatment cycle of 4 to 5 years is assumed, i.e., the number of years before the same acre is retreated, the importance of 2,4,5-T to rights-of-way management becomes more realistic. Pipelines and highways manage 4 to 5 percent of their rights-of-way with 2,4,5-T. Electric utilities depend on 2,4,5-T as a management tool for more than 40 percent of their rights-of-way and some 30 percent of railroad rights-of-way are managed with 2,4,5-T.

## Methods of Application

The methods of application listed in table 5 have some elements of commonality as well as unique features when utilized on the different types of right-of-way. Foliar applications are generally best in situations having a high density of target species (Barnhart et al. 1975). Foliar applications are made during the growing season after full leaf development and until the target species cease active growth. This period may encompass May to September, depending on location. Basal treatments are applied to the bark and can be done year round, climate permitting.

### Broadcast Foliar - Air

Aerial application is the most economical method of treating dense stands relatively inaccessible to conventional ground equipment. Size and density of brush have little effect on the volume of herbicide and carriers applied and the cost of applications (Barnhart et al. 1975). The volume of solution applied ranges from 15 to 25 gallons per acre with water or water-oil mixture as the carrier.

A typical aerial spray crew will include a pilot, two groundmen and possibly a mechanic (fig. 3). Equipment will include the helicopter and its maintenance truck, and a tank truck to store, mix and transfer the spray solution to the helicopter (Barnhart et al. 1975). Actual applications are generally restricted to the early morning and late afternoons -- periods of calm air. The nature of and actual accomplishment of aerial application is fairly standard, regardless of right-of-way type (fig. 4). Highways do not apply 2,4,5-T aerially (table 5).

### Broadcast Foliar - Ground

Broadcast foliar ground applications are made during the growing season, as with aerial foliar treatments, but the actual application method will

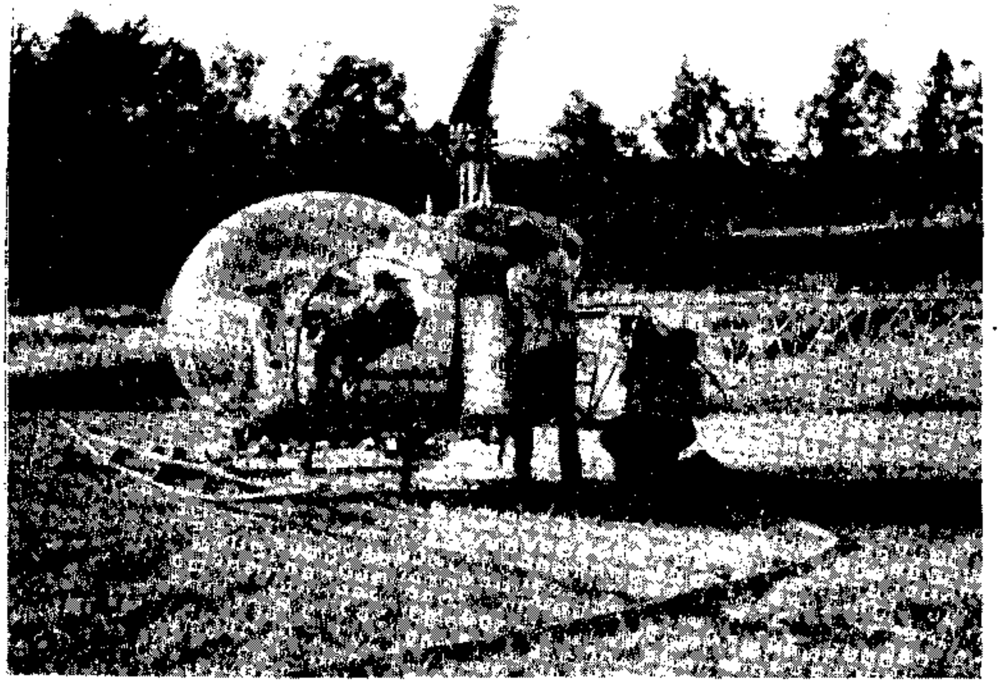

Figure 3. Herbicide mixture is pumped from mix truck to waiting helicopter.

Figure 4. Special equipment or spray additives produce large droplets which minimize drift. Aerial application controls woody plants in right-of-way and side-trims trees on the edge.

Table 5—Acres treated annually with 2,4,5-T by rights-of-way type and method of application[a/]

| ROW type | Total treated annually | Broadcast foliar-air | Broadcast foliar-ground | Selective foliar | Selective basal | Stump spray after cutting |
|---|---|---|---|---|---|---|
| Railroad | 127,425 | 27,386 | 99,996 | 0 | 43 | 0 |
| Pipeline | 22,026 | 19,391 | 0 | 2,635 | 0 | 0 |
| Highway | 68,167 | 0 | 58,447 | 5,614 | 733 | 3,373 |
| Electric | 465,339 | 159,479 | 43,927 | 21,151 | 234,254 | 6,528 |
| Total acres | 682,957 | 206,256 | 202,370 | 29,400 | 235,030 | 9,901 |

a/ Source: Asplundh Environmental Services 1978.

vary by rights-of-way type in response to differing physical constraints. Railroad and highway applications are somewhat similar in that it is possible for the equipment to drive along the right-of-way. However, highly specialized equipment is used for treating railroad rights-of-way.

Railroad brush control is accomplished with spray trains and Hyrail units. Spray train units are highly adapted railroad cars. These cars are self-contained with all necessary pumps, valves, controls, booms, and nozzles. Tank cars containing the major herbicides or herbicide mixtures separate the spray car from the locomotive engine. The entire unit is pushed by the engine with the spray car in front. Herbicide solution is pumped from the attached tank cars as the application is made. Tank cars or tanks in the spray car may contain specific undiluted herbicides which can be injected into the spray stream as needed for specific vegetation problems. These trains are used for road ballast as well as brush-control treatments. Nozzle configurations and types enable treatment across the right-of-way. A typical crew would consist of four people. Usually three handle the actual application and one supervisor monitors speed and pressures and looks out for sensitive crops. Herbicide mixtures are usually applied in a total volume of 300 gallons per acre with water as the carrier.

Railroad brush control is also done with Hyrail units, trucks modified with the addition of hydraulically operated rail wheels (fig. 5). These units can travel on highways as well as on railroads. A typical crew consists of two people - one to drive and one to operate a mobile boom. These units are particularly important for woody plant control on branch lines whereas spray trains tend to be used for treating mainlines. Herbicide solution is usually applied in a total volume of 25 gallons per acre with water as the carrier. Each unit is accompanied by a railroad employee as a safety precaution.

Highway rights-of-way by their very nature afford a certain degree of access which can facilitate herbicide application. Truck or trailer

Figure 5. Versatile Hyrail units increase flexibility in railroad vegetation control programs.

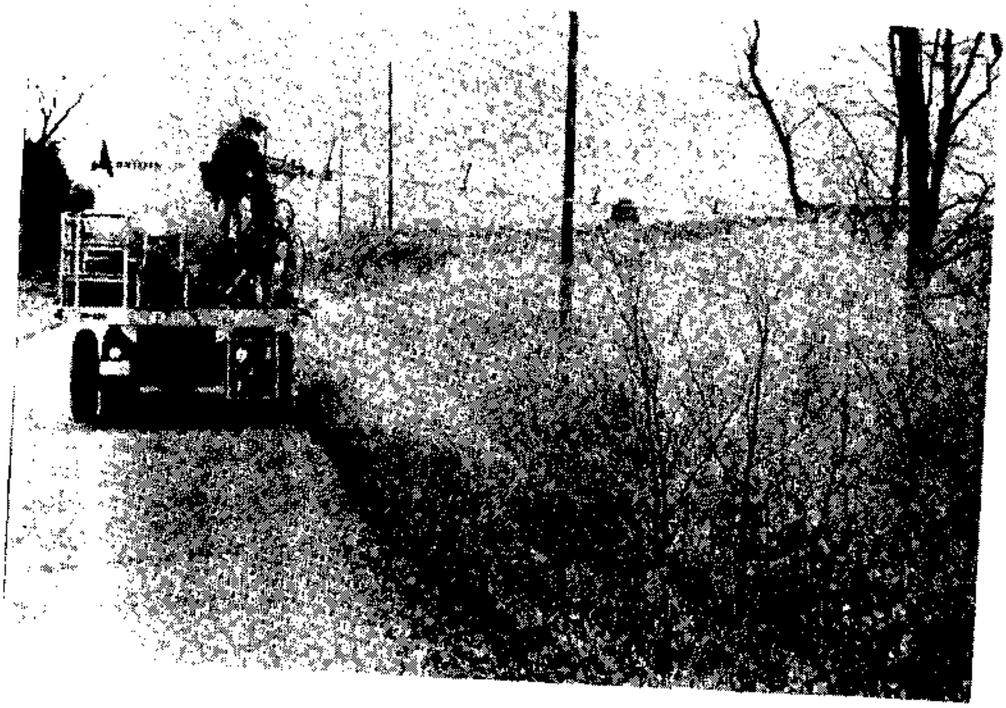

Figure 6. A highway application utilizing mobile boom and off-center nozzles.

mounted spray units can often treat adjacent vegetation with off-center nozzles (fig. 6). The road construction operation often creates broad areas which are readily accessible to tractor mounted sprayers with boom or boomless nozzles such as on the Interstate rights-of-way. However, this is probably a relatively small percentage of the total highway vegetation acreage—less than 10 percent. A typical crew with each spray unit would be two people—one to operate the sprayer and one to drive the equipment.

Ground foliar applications are somewhat different for electric rights-of-way since off-road capability is usually an equipment requirement and wide rights-of-way, 200 feet plus, may need to be treated. Four-wheel drive trucks, skidders, or track vehicles are preferred. These vehicles are equipped with high pressure pumps, tanks with hydraulic or mechanical agitation, 800 to 1,000 feet of hose, and two or three hand spray guns. Crew complements range from three to four men (figs. 7, 8 and 9). In some instances back-pack mist blowers may be used to treat small areas relatively inaccessible to heavy equipment (Barnhart et al. 1975) (figs. 10 and 11). The foliage and stem of the target plants are wet to the point of runoff. This is an effective and economical method for controlling medium to dense brush.

Selective Foliar

Selective foliar application is a modified broadcast foliar treatment. It is used with low to medium densities of target species. The spray is directed to the specified undesired species. In actual practice there is a constant gradation between selective and broadcast foliar treatments depending on species density.

Selective Basal

Selective basal application method is distinctly different from foliar methods. This method uses oil carriers, requires treatment of each individual stem, and can be used during any season of the year

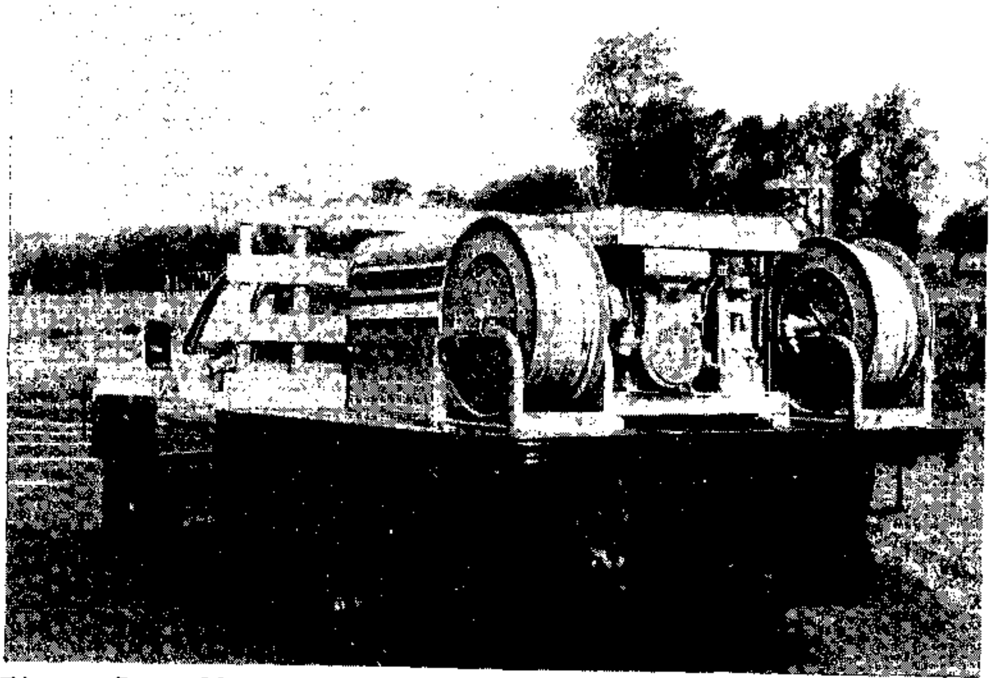

Figure 7. Off-road capability is a requirement for brush control on electric utility rights-of-way. Four wheel drive, high pressure pump and 800-1,000 feet of hose are typical equipment.

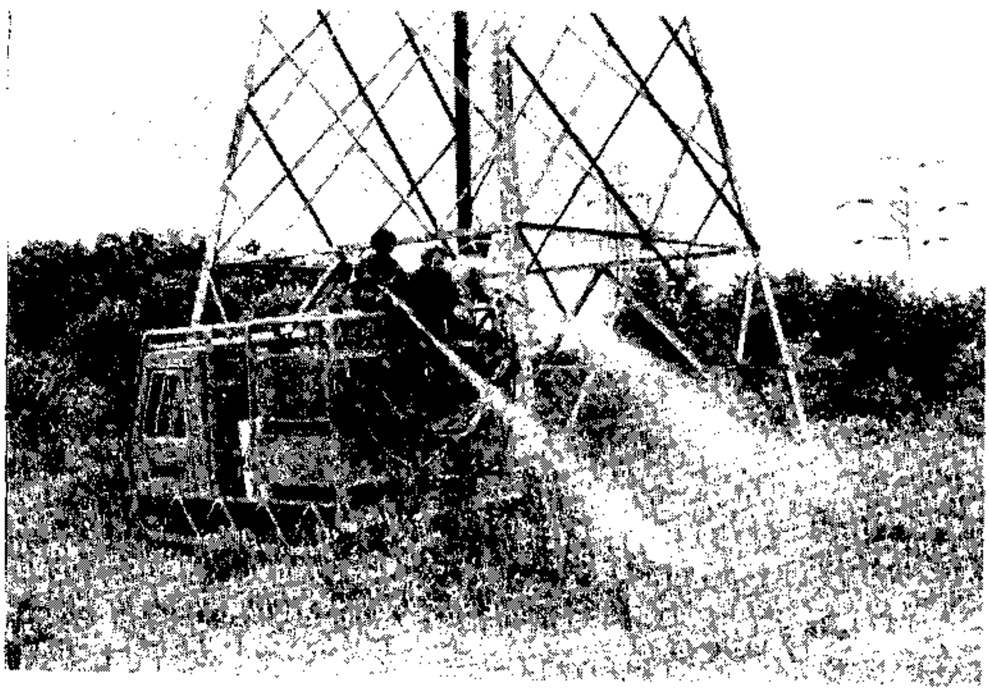

Figure 8. Tracked vehicles are necessary for some terrain conditions. Application may be made from equipment, as shown, but is more generally applied from the ground.

Figure 9. Broadcast foliar and selective foliar treatments differ only in the extent of vegetation treated. This ground application is typical of both treatments.

Figure 10. The knapsack sprayer is effective for spot treatments.

Figure 11. The backpack mist blower is modified for treating the base of stems or stumps. This equipment is used mainly for spot treatment of inaccessible areas.

(fig. 12). Although it is the most expensive per acre treatment for electric utilities, it is used on 50 percent of their treated acres annually (Asplundh Environmental Services 1978). The selective basal method is used where selective treatment of brush is desirable, where close control is necessary, and the density is such that a basal application is economical (Barnhart et. al. 1975). Stand density and stem diameter affect the volume applied and the thoroughness and cost of application. The lower 12-24 inches of each individual stem is completely sprayed to the point of runoff. The root collar area and any exposed roots are also thoroughly treated.

This treatment can be applied with a variety of equipment, from hand operated knapsack sprayers and back-pack mist blowers with special attachments to truck-mounted units such as used for other ground treatments. The personnel-carried sprayers are generally used only in light scattered brush, for spot treatments and areas with poor access (Barnhart et al. 1975).

Stump Spraying After Cutting

Stump spraying after cutting is used to prevent sprouting from the stumps of cut woody plants. This treatment is used extensively for initial rights-of-way clearing and reclearing. The same equipment and carriers used for basal treatments are used with this method to soak the cut stump (Barnhart et al. 1975). The crew complement may be much larger such as a crew of seven to eight cutters followed by two to three stump sprayers. Stand density and terrain have major impacts on productivity.

## Environmental Effects

This section considers some indirect effects of using 2,4,5-T on rights-of-way. In contrast to the direct beneficial use effects of 2,4,5-T, there are a number of potential indirect effects that should be considered where this herbicide is used for vegetation management on rights-of-way. For example, spraying with 2,4,5-T, or use of any other

Figure 12. Basal applications require individual stem treatment and can be made during any season of the year.