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CHAPARRAL CONVERSION POTENTIAL IN ARIZONA

Part II: An Economic Analysis

by Thomas C. Brown
Paul F. O'Connell
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ABSTRACT

Is chaparral conversion on National Forests in the Salt-Verde Basin economical? An inventory revealed 139 chaparral areas totaling 332,796 acres meet certain crown cover, slope, and managerial criteria for conversion. The costs of converting portions of these areas to grass and maintaining the conversion over a 50-year period were compared with the benefits to society in terms of increased water yield and forage for livestock, and reduced firefighting costs. Using fire as the main conversion tool, 96 areas have a benefit-cost ratio greater than 1; using a soil-applied herbicide, 72 areas meet that economic criterion. Proper management should favorably affect soil movement, wildlife habitat, and esthetics. Recreation use would be unaffected in most areas.

Keywords: chaparral control, multiple use, economic evaluation, cost estimation

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Part II: An Economic Analysis

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INTRODUCTION

The 8.4 million acre Salt-Verde Basin includes the Salt and Verde River Watersheds of central Arizona above Granite Reef Dam (fig. 1). The Basin supplies most of the water for the Phoenix Valley, in addition to providing timber harvesting, grazing, mining, recreation, and hunting opportunities. As the human population of central Arizona increases, demand for these products also increases. The familiar question — what should the product mix be? — continually becomes more pressing.

Fifty-nine percent of the Salt-Verde Basin is managed by the U.S. Forest Service. The 850,000 acres of chaparral on National Forest lands in the Salt-Verde Basin are the subject of this study. The Forest Service position in managing these lands is set forth in the Southwestern Region's Multiple Use Management Guide:[2]

> Management emphasis in the Chaparral Zone will be directed towards increasing water yield, reducing fire hazard, and improving forage for wildlife and livestock. In the establishment of ground cover, palatable forage species for livestock and wildlife will be given preference to the extent they will not be detrimental to the watershed. Soil stabilization measures will be included in all treatment prescriptions.

The Region's *Chaparral Management Position Statement*[3] adds that "the Forest Service objective is to achieve the full potential of the chaparral type through carefully designed modification and control of the ecosystem."

Conversion of chaparral to grasses and forbs is generally considered the main means of reaching the Forest Service objective. This involves control or complete removal of dense

[2] *U.S. Dep. Agric., For. Serv. Multiple-use management guide. For. Serv. Handbook, R-3, p. 340.3. Albuquerque, N. Mex. 1967.*

[3] *U.S. Dep. Agric., For. Serv. Chaparral management position statement, Southwestern Region. Albuquerque, N. Mex. 1972.*

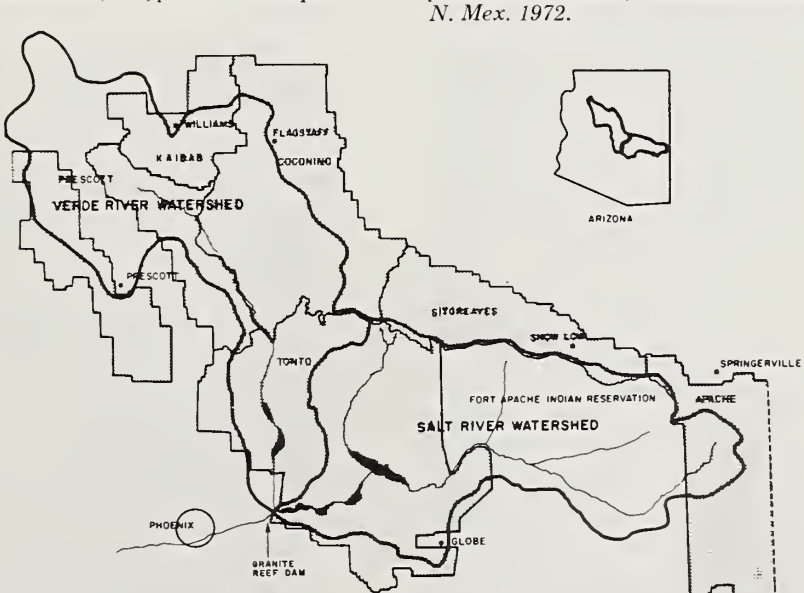


Fig. 1. — The Salt-Verde Basin includes parts of the Prescott, Kaibab, Coconino, Tonto, and Apache - Sitgreaves National Forests.

patches of chaparral, seeding the treated areas with grasses and forbs, and subsequent maintenance of the conversion for as long as benefits are desired.

Part I (Hibbert, et al 1974) of this two-part series describes the chaparral vegetation type, methods used for its modification, and the effect of such methods on water, soil, and wildlife. This part is an economic evaluation of the application of such methods on National Forest land in the Salt-Verde Basin. The study method was as follows:

1. Delineate chaparral areas meeting certain criteria for conversion.
2. Estimate costs of conversion.
3. Determine effects of conversion on yields of water, forage, and sediment, as well as impacts on fire hazard, recreation use, esthetics, and wildlife habitat.
4. Develop value criteria for quantifiable effects and impacts.
5. Integrate costs and measurable benefits into an economic framework using benefit-cost analysis.

Our primrary objective was to put the potential of chaparral conversion on National Forest lands in the Salt-Verde Basin in perspective. The conclusions drawn about the economic feasibility of conversion are based on the individual consideration of 139 separate chaparral areas within the Basin. Some details about the individual areas are found in the Appendix.

Primary costs and benefits of treatment and maintenance were estimated over a 50-year study period. Full employment of capital and labor were assumed. The two primary objectives of public investment listed by the U.S. Water Resources Council (1973) — to enhance national economic development and to enhance environmental quality — were evaluated. Adverse effects on these objectives (such as funds diverted from other uses to implement conversion) were considered *costs*; beneficial effects (such as increased forest productivity) were termed *benefits*.

To fully account for the primary benefits, all returns were identified to whomever they may accrue. Chaparral conversion increases U.S. Treasury revenue through additional grazing fees and reduced firefighting costs. Primary benefits also accrue to water users, ranchers, and recreationists. Constant 1972 dollars were assumed over the 50-year evaluation period. Inflation is assumed to have similar relative impacts on benefits and costs. The streams of benefits and costs are expressed as present value (PV), which is defined as:

$$PV = \sum_{t=1}^{50} [Y_t / (1+i)^t] \quad [1]$$

where Y_t is the annual cost or benefit, i is the discount rate, and t is time in years. In this study, i is 6-7/8 percent, as presently recommended by the U.S. Water Resources Council (1973).

The "with and without" evaluation procedure (U.S. Senate 1962) was used, where "without" signifies a continuation of present management and "with" denotes the conversion alternatives evaluated here.

Alternatives to conversion for reaching the same ends are not dealt with. Alternative methods of increasing runoff and reducing fire hazard might, for example, be more efficient than conversion. Likewise, methods of financing the investment are not considered. One alternative is for the entire financial burden to be paid from tax revenues. In line with more recent thinking (U.S. Water Resources Council 1973), however, water users, ranchers and the public sector could all play a part in the financing, commensurate with the benefits which would directly accrue to each.

CHAPARRAL INVENTORY

An inventory of all National Forest chaparral in the Salt-Verde Basin delineated 139 areas that could be considered for conversion to grass. The criteria, method, and results of the inventory are described in this section.

Criteria

Because of the large study area, a detailed on-site inventory of physical characteristics and managerial considerations for all chaparral land was unrealistic. The lack of reliable, uniform secondary data limited the criteria for delineation to the following three:

1. Vegetation. The chaparral cover (vertical crown projection) must be at least 30 percent, since clearing less than 30 percent cover would have minimal effects on runoff, forage, and fire hazard. Furthermore, an area of chaparral which supports more than a 30 percent overstory of pinyon-juniper or ponderosa pine cover should be classified as the overstory species.
2. Slope. The slope of the delineated area should not be greater than 60 percent (31 degrees). Potential erosion hazard, uncertainty of establishing grass, cattle grazing habits, and conversion methods are the main reasons for this constraint. (The 60 percent cutoff is, of course, arbitrary. The appropriate cutoff point would actually vary from site to site depending on soil, grazing, and other conditions.)

3. Operational considerations. The proximity of a conversion area to wilderness areas, private land, recreational facilities, and travel and water influence zones must be evaluated. Chaparral in the following areas was not considered convertible: (1) within designated wilderness areas, (2) within one-quarter mile of a designated wilderness area (providing a buffer zone for the wilderness), and (3) on private land within a forest boundary. In most cases, the effect of conversion on recreation areas and influence zones can only be determined by careful on-site examination; areas that might fall into this category were included.

These criteria enabled us to delineate the maximum chaparral acreage that could be considered for conversion. A more detailed examination of these areas would also consider soils, parent material, access, wildlife habitat, fire hazard, and livestock grazing management.

Methods and Data Sources

The following three sources provided the primary information about the vegetation and its density: (1) the Pacific Southwest (PSW) — I hydrologic unit inventory covering all National Forest land in the Salt-Verde Basin[4], (2) the comprehensive Hydrologic Surveys done on approximately 50 percent of the dense chaparral on the Tonto National Forest, and (3) the vegetative type map of the Tonto National Forest.[5]

The PSW survey, completed 5 years ago by the Pacific Southwest Hydrologic Study Team of the U.S. Forest Service, was the most useful because it covered all chaparral areas and also gave some estimates of percent cover. The vegetation delineations, which were based almost exclusively on aerial photographs, proved quite accurate for most areas; the only major discrepancies were due to different definitions of chaparral.

The Comprehensive Hydrologic Surveys were completed by the Forest Service Salt-Verde Study Team. The surveys included in-depth inventories of the vegetation and soils of the following areas: (1) the Mazatzal hydrologic subprovince, including individual reports on the Sycamore Creek and East Mazatzal planning units; (2) the Cherry Creek and Salome Creek planning units and Connor Canyon and Turkey Creek-Bear Head Canyon project areas of the Sierra Ancha hydrologic subprovince; and (3) the Upper Salt River, Pinal, Pinto Creek, San Carlos, Spencer, and Sixshooter project areas of the Globe hydrologic subprovince.

A complete vegetative inventory of the Tonto National Forest was developed from aerial photos, personal observation, and aid from the district personnel. The inventory does not delineate percent vegetative cover, but was helpful in outlining the general vegetation.

The information provided by the above sources was verified at the Ranger District level. District personnel were asked to comment on all chaparral areas in an attempt to correct any inconsistencies.

Slope data were taken directly from U.S. Geological Survey topographic maps. Wilderness boundaries and access routes were taken from Forest Service maps. Information about access problems, recreation use, and other management considerations was obtained from discussions with Forest personnel.

Delineation of Chaparral

Chaparral in general. — Over 90 percent of the chaparral in Arizona lies in a wide band stretching across the central part of the State to the south and west of the ponderosa pine belt. The Salt and Verde Rivers and their tributaries drain approximately half of this chaparral. That portion of the major band of chaparral not in the Basin lies northwest of Phoenix.

Nearly all of the chaparral on the Tonto National Forest is also in the Basin. The Prescott has close to 400,000 acres of chaparral, but only about 30 percent drains into the Verde River. While the chaparral on the Coconino lies in the Basin, there are less than 30,000 acres, and only isolated small patches of more than 30 percent cover. The Kaibab National Forest, while partially in the Basin, has no chaparral. Some chaparral is found on the Apache National Forest south of where the Salt River drains the Apache.

Chaparral areas suitable for further consideration. — Of the 850,000 acres of National Forest chaparral in the basin, 82 percent is on the Tonto, 15 percent is on the Prescott, and 3 percent is on the Coconino National Forest. Some 200,000 acres in wilderness areas and 263,000 acres with less than 30 percent brush cover were eliminated from consideration. A total of 43,621 additional acres were eliminated because of slope and operational criteria. The remaining 347,967 acres are contained in 139 areas: 108 are on the Tonto (fig. 2) and 31 are on the Prescott (fig. 3). Also outlined in figure 2, but not included in the acreage totals, is previously

[4] *The maps and accompanying data are maintained at the Southwestern Regional Office, U.S. Forest Service, in Albuquerque, New Mexico.*

[5] *The hydrologic surveys and vegetative map are maintained at the Tonto National Forest Supervisor's Office, U.S. Forest Service, Phoenix, Arizona.*

converted Brushy Basin (area T40). If the 9,171 acres of private land scattered throughout the areas are subtracted , 332,796 acres of National Forest land remain (table 1).

The 139 areas range in size from 88 to 12,160 acres; the mean size is 2,440 acres. Smaller areas were outlined solely on the basis of the criteria stated. Larger areas were sometimes divided to make them easier to consider. Where possible, the division line conforms to a district boundary, watershed boundary, or allotment fence.

Seven areas on the Tonto National Forest (fig. 2), totaling 15,950 acres, are presently held under special agreements which may make intensive management infeasible; five areas (T41, 42, 47, 48, and 50) are in the Three Bar Game and Fish Agreement area in the Mazatzal Mountains, area T84 is on the Sierra Ancha

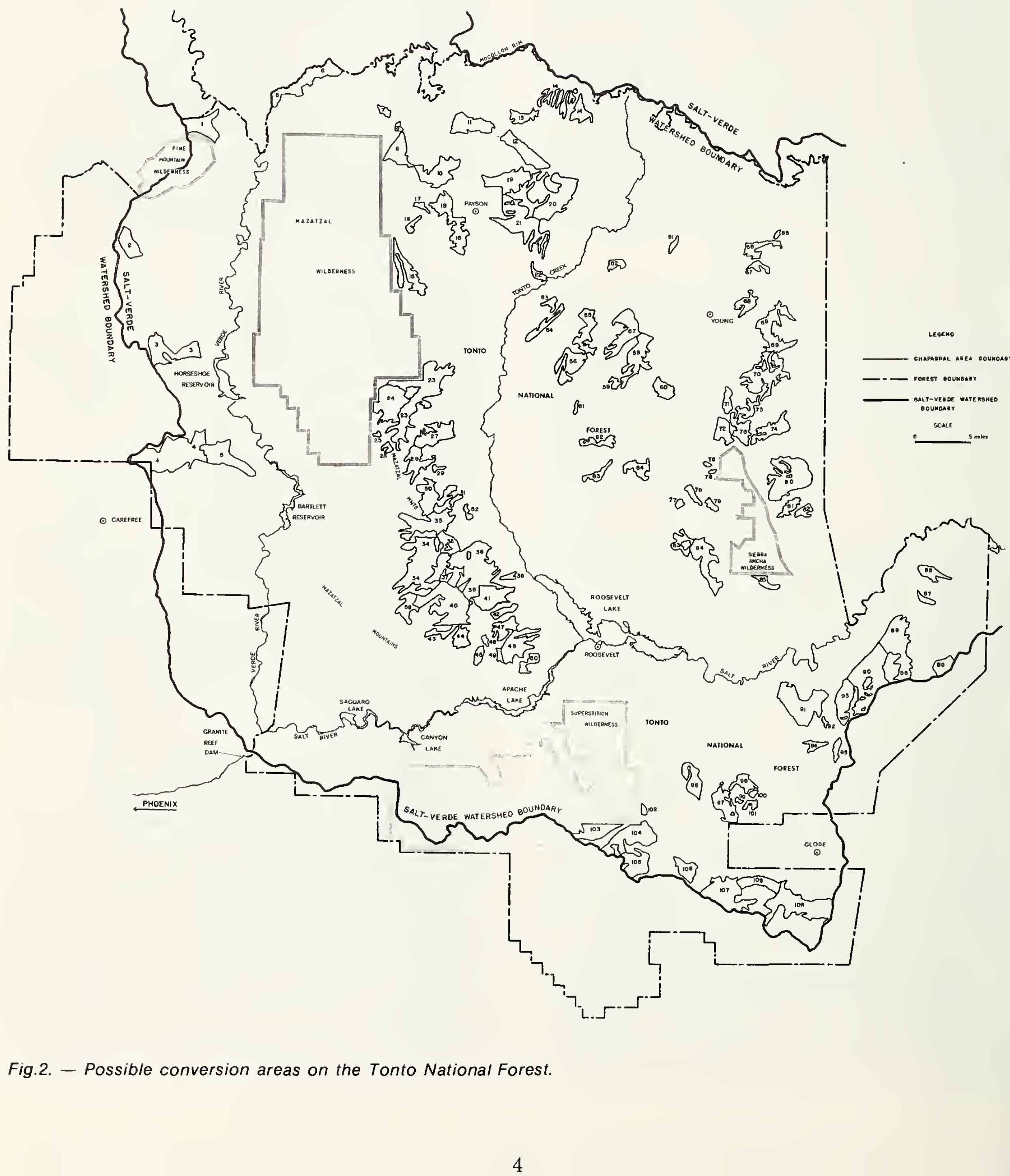


Fig.2. — Possible conversion areas on the Tonto National Forest.

Experimental Forest, and area T19 includes the Tonto Forest Seismological Observatory near Payson. Although grazing is not presently permitted on six of the areas, grazing was assumed as if the area were not under the special management.

Pattern of Conversion

Decision makers have the option of converting all or only part of a chaparral area. Although complete conversion yields maximum increases in water runoff and forage, partial conversion (leaving unconverted patches within the general area) is more favorable to wildlife, probably is more esthetically pleasing, and, in addition, leaves the steeper slopes untreated.

Table 1.--Summary of possible chaparral conversion areas, Salt-Verde Basin, Arizona

Ranger District	No. of areas	Nat'l Forest land[1]	Percentage on slopes--		Possible conversion portion[2]	
			<30%	Between 30% & 60%	Size	% of total
		Acres			*Acres*	*Percent*
Tonto						
Cave Creek	5	21,137	16	76	10,196	48
Globe	24	56,909	35	59	27,033	48
Mesa	15	37,083	10	78	22,250	60
Payson	17	44,560	47	47	23,514	53
Pleasant Val.	30	47,203	28	66	24,856	53
Roosevelt	17	28,423	14	72	16,936	60
Sub-total	108	235,315	28	64	124,786	53
Prescott						
Chino Valley	2	4,447	67	32	2,668	60
Thumb Butte	10	11,744	62	35	4,333	37
Verde	7	31,832	21	68	15,770	50
Walnut Creek	12	49,458	57	42	28,355	57
Sub-total	31	97,481	46	49	51,126	52
Total	139	332,796	33	60	175,912	53

[1]A total of 9,171 acres of private land have been subtracted.
[2]A maximum of 60 percent of the delineated areas was considered convertible; a lesser conversion rate was slated for 42 areas.

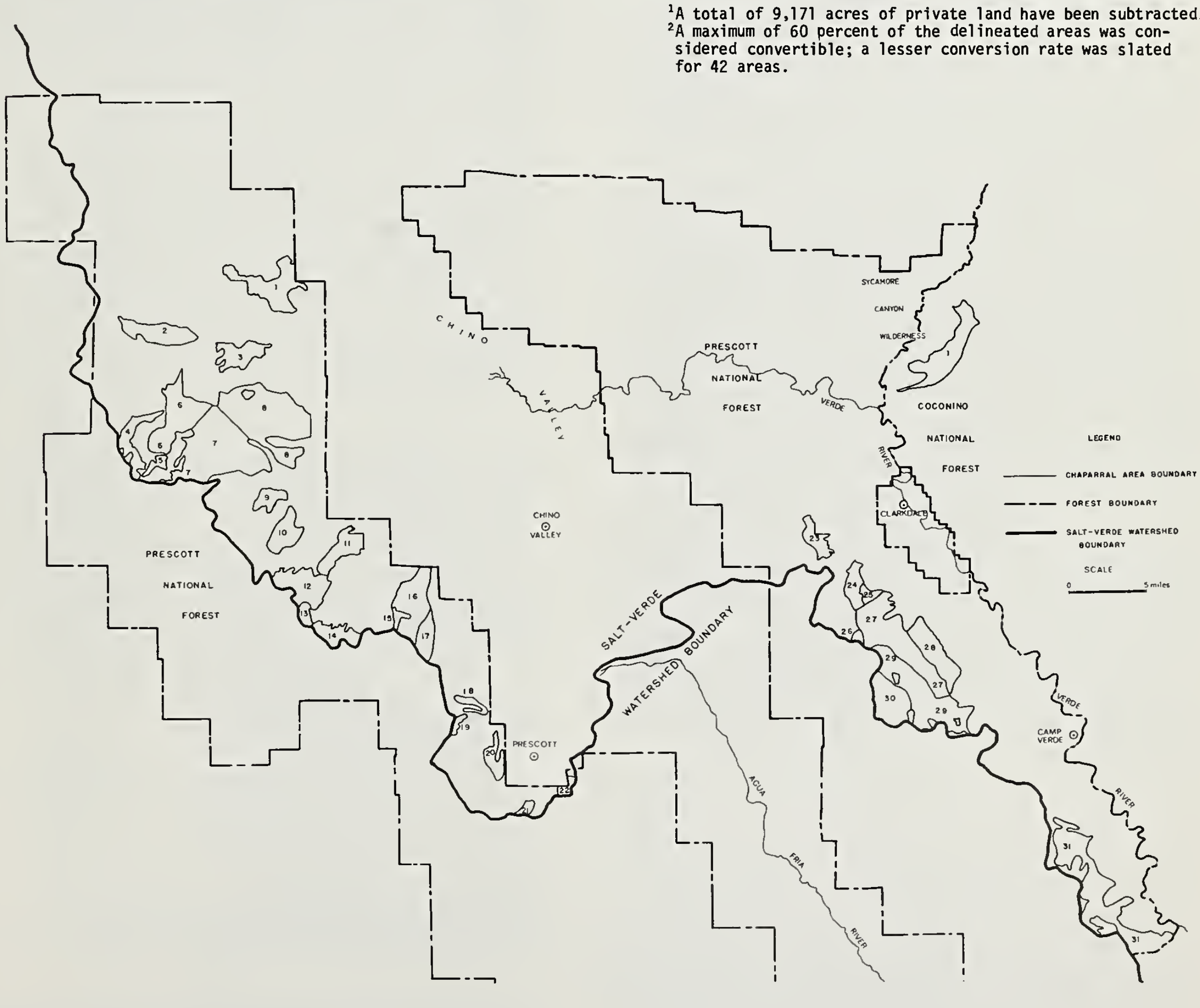


Fig. 3. — Possible conversion areas on the Prescott National Forest.

Currently the Forest Service favors partial conversion. The *Chaparral Management Position Statement* of the Southwestern Region states:

> Cultural practices, when appropriate, will be used to re-establish irregular patterns of different chaparral age classes, intermixed with forb, grass, and timber types to establish as nearly as possible a natural fire-induced ecological phenomenon. Such practices will be applied on areas culturally improved by design and also areas which have been devastated by uncontrolled wildfires.

We assumed the maximum allowable conversion of any given chaparral area to be 60 percent; thus, at least 40 percent of the area would remain as patches of chaparral within the conversion area. The 60 percent conversion maximum is a compromise between the water user and rancher on the one hand, and those concerned with wildlife and esthetics.

Because of the gross scale of the data utilized in the inventory, some of the 139 delineated areas contain small patches covered by (1) chaparral of less than 30 percent cover, (2) other vegetation types, or (3) slopes greater than 60 percent. Where any combination of these three situations exists on more than 40 percent of a delineated area, less than 60 percent of the area can be converted. Examination of each of the 139 areas, based on this qualification, resulted in a reduction of the maximum allowable conversion for 43 areas (Appendix).

The actual conversion acreage was thus reduced to 175,912 acres, or 53 percent of the total acreage of the delineated areas (table 1, the two right-hand columns). This is the maximum possible acreage which could be converted based on (1) the vegetation, slope, and operational criteria, (2) the inclusion of seven areas presently under special management, and (3) a conversion pattern which preserves portions of the original stand.

CONVERSION COSTS

Two treatment and maintenance models were evaluated. Conversion Alternative I consists of an initial burn followed by periodic maintenance burns and broadleaf herbicide applications; Alternative II consists of an initial soil-applied herbicide followed by maintenance burns.[6] Refer to Part I for descriptions of several herbicides used in brush treatment. A maximum of 60 percent of each area is to be converted with both alternatives. If more than 60 percent of an area were inadvertantly burned under Alternative I, the excess portions would be allowed to return to brush through exclusion of seeding and herbicide. For Alternative II, predetermined patterns should be easily created.

The alternative conversion models were developed to determine costs; their use here should not be considered an endorsement. While individual readers may question the timing, amounts, or actual inclusion of particular items in the conversion schemes, small changes should not significantly affect the computed present value costs.

The cost models simulate treatment and maintenance costs for all 139 areas, assuming conversion began in 1972 and is maintained for 50 years. Inputs to the cost models were derived from information collected at the Forest and

Table 2.--Unit costs of conversion[1] (1972 dollars)

Item	Cost	Unit
Personnel		
Crewman	$ 3.31	hr.
Caterpillar operator	5.19	hr.
Per diem		
Camping	10.00	day
In town	19.00	day
Equipment		
Helicopter lease (450.00 minimum)	150.00	hr.
Helicopter helper	0.25	mi.
Tractor, D-7 type		
Haul	336.00	r. trip
Lease	17.14	day
Operate	25.80	day
Pickup, 1/2-ton, 4-wheel-drive		
Lease	2.59	day
Operate	0.07	mi.
Pickup, 3/4-ton, 4-wheel-drive		
Lease	4.14	day
Operate	0.135	mi.
Carryall, 1/2-ton, 4-wheel-drive		
Lease	2.59	day
Operate	0.075	mi.
Bus, 20-passenger		
Lease	4.82	day
Operate	0.21	mi.
Pumper, slip-on ECO pump	0.50	day
Supplies		
Seed (weeping lovegrass)	1.25	lb.
Herbicide		
Broadleaf	2.02	lb. active
Soil-applied	6.00	lb. active
Burning	0.06	acre
Other		
Rootplowing	18.21	acre
Overhead		
10 percent of listed cost.		

[1]Source: U. S. General Services Administration rental rates, and communication with Forest Service personnel.

[6]*Another possible alternative consists of initial burning with biological maintenance (goat grazing for example). Because of lack of experience with biological control, this alternative was not evaluated.*

District level of the Tonto and Prescott National Forests. Table 2 lists the unit costs for the inputs in 1972 prices.

In an attempt to include all possible conversion costs and to anticipate the unexpected, three precautions were taken. (1) Use of a large — 31 man — crew was assumed for the initial burning of all areas in Alternative I. (2) A generous application of soil-applied herbicide is assumed for Alternative II. (3) A maintenance seeding of 20 percent of each area was included in case grass does not catch in certain portions of the conversion. On the other hand, we assumed there would be no costly escapes from prescribed burning.

Conversion Schedule

We assumed a maximum of 600 acres in any one area would be converted each year. In areas with more than 600 acres to be converted, conversion would proceed in annual stages of 500 acres. Area T13, for example, contains a total of 1088 acres, 60 percent (653 acres) of which is to be converted; 500 acres would be treated the first year and 153 acres the second year. If 2027 acres of area T30 were to be converted (60 percent of 3379 total acres), 500 acres would be treated in each of the first three years, with 527 acres treated the fourth year. While on-the-ground situations may suggest somewhat different annual staging procedures than used here, they should not greatly affect costs.

Conversion Alternative I. — An environmental impact statement for the proposed treatment must first be completed and reviewed. In the first year of the conversion schedule, access problems are solved, fuelbreaks and firelines are installed, and the first portion of the area to be converted (the entire area if less than 600 acres are converted) is burned and seeded. The following maintenance schedule follows initial treatment of each portion:

- Year 2 - herbicide spray
- Year 4 - maintenance burn and 20 percent maintenance seed
- Year 5 - herbicide spray
- Year 7 - maintenance burn
- Year 10 - maintenance burn
- Year 11 - herbicide spray
- Years 13-50 - a 12-year cycle beginning in year 13 of maintenance burns the first, fifth, and ninth years and herbicide spray the tenth year.

In addition, access improvements are maintained every three years beginning in year 5. For area T13, 500 acres would follow the schedule in the years stated, while the remaining 153 acres would follow the schedule one year later.

Conversion Alternative II. — An environmental impact statement must be completed prior to conversion. In the first year of the soil-applied herbicide alternative, access problems are solved and the herbicide and seed are applied to the first portion of the area to be converted. The conversion is maintained with a burn the third year and every four years thereafter. A 20 percent maintenance seed immediately follows the first burn. A fireline is installed around the upper half of each portion to be burned at the same time as the burn. Access improvements are maintained every three years.

Cost of Conversion — Alternative I

This section describes Alternative I in detail, concluding with an example of the individual costs of a 50-year conversion scheme for a particular area. Conversion Alternative II is subsequently described, but only briefly.

Environmental impact statement. — Environmental impact statements have only recently been required for Forest Service vegetation management. Based on limited Region 3 experience, we assumed that 20 areas would be included in one statement (combining has previously been allowed) at a cost of $200 per acre. The cost of the environmental analysis, an input to the statement, is covered in overhead. The weighted (for area size) average per-acre cost of the impact statement for all 139 areas is 16 cents. The average unit costs of this and other cost categories are listed in table 3.

Access. — Vehicular access to each area was examined to determine whether improvements would be necessary to allow movement of men and equipment. We assumed that new or improved roads would remain open for public use and be periodically maintained.

Areas with access problems were sorted into two categories, (1) areas presently lacking access routes, and (2) areas served by primitive roads that need improvement (not all primitive roads need improvement). Within the first category, four classes were established reflecting the difficulty likely to be encountered in installing a road. Classes A, B, C, and D require 2, 6, 10, and 12 days, respectively, to install one mile of road. Within the second category, two classes (A and B) were established, requiring 1.3 and 3.0 days, respectively, per mile of improvement.

The crew for providing and maintaining access for all classes in both categories requires

Table 3.--Average undiscounted unit costs of converting 139 chaparral areas, Salt-Verde Basin, Arizona (1972 dollars)

Category	Cost	Unit
Environmental impact statement	$ 0.16	acre[1]
Install road		
A (2 days/mi)	971.39	mile
B (6 days/mi)	1,801.18	"
C (10 days/mi)	1,884.78	"
D (12 days/mi)	2,390.28	"
Improve primitive road		
A (1.3 days/mi)	423.04	"
B (3.0 days/mi)	696.76	"
Maintain access improvements	291.93	"
Rootplowing	18.21	acre[1]
Mechanical preparation for burning		
Fuelbreaks (25% of perimeter)	3.38	"
Firelines (50% of perimeter)	0.57	"
Burning		
Initial (fuelbreaks, firelines, area)	10.99	"
Maintenance (per application)	0.21	"
Seeding		
Initial	3.85	"
Follow-up (20% of area)	8.75	"
Aerial herbicide application		
Broadleaf spray (per application)	3.31	"
Soil-applied	33.01	"

[1]The weighted (by area size) average per-treated-acre cost.

the following men, equipment, and supplies:[7]

2 crewmen
1 tractor, D-7 type
1 tractor operator
1 pickup (1/2 ton, 4-wheel drive)
seed for road shoulders (4 pounds per acre)

[7]*Based on communication with Joy J. Baldwin, Timber, Fire, and Watershed Staff Officer, Tonto National Forest, Phoenix, Arizona, 1972.*

Engineer's time necessary to mark the right-of-way for the new access is included in overhead. For the Tonto National Forest, the crew comes from Payson, Pleasant Valley, or Globe, whichever is closer. The crew comes from Prescott for the Prescott National Forest. The men either return home each night or camp at the site, whichever is less expensive. Costs of hauling the caterpillar (table 2) and transporting the crew are included. Average costs per mile of providing and maintaining access, as figured for those areas where it is necessary, are listed in table 3.

Fuelbreaks and firelines. — We assumed fuelbreaks and firelines were a necessary prerequisite for burning. For areas without natural fuelbreaks, we assumed that one fourth of the perimeter would be made a fuelbreak, one half a fireline, and the remaining one fourth left as is. Where areas have adjacent boundaries or can otherwise utilize the same breaks or lines, the cost is shared. The fuelbreaks are 132 yards wide (48 acres per mile) and the firelines are one tractor-width wide. Estimates of the acres per hour which a D-7 tractor can clear in California (Green, et al 1963) were utilized to determine time requirements:

Chaparral	Days per mile for installation	
density	Fuelbreak	Fireline
Medium	10	0.8
Heavy	16	1.4

The crew and its origin are the same as those for providing access. Table 3 lists average per-acre installation costs. The fuelbreaks and firelines are later burned by the burning crew.

Rootplowing.— Although burning is the major initial treatment method of Alternative 1, rootplowing is also utilized. Forest personnel delineated 5,560 acres within the 139 areas where rootplowing is feasible. The average cost of rootplowing on the Prescott National Forest from 1969 through 1971 — $18.21 per acre in 1972 prices — was applied to the 5,560 acres.

Burning.— The time necessary for burning the fuelbreaks, firelines, and initial acreage is 5 days for 400 to 600 acres, 4 days for 200 to 400 acres, and 3 days for less than 200 acres. Subsequent (interior) portions require less time because the lines and breaks are already available. The time necessary is 4 days for 400 to 600 acres, 3 days for 200 to 400 acres, and 2 days for less than 200 acres. These requirements will naturally vary with circumstances. The burning crew, which is the same for all areas and size burns, includes the following:

- 31 crewmen
- 1 pickup (1/2 ton, 4-wheel drive)
- 3 pickups (3/4 ton, 4-wheel drive)
- 3 slip-on pumpers
- 1 carryall
- 1 bus
- burning supplies

Crew composition was based on the number of firefighters historically available at each district. Crews consist of men from the local district plus,if necessary, men from neighboring districts. Transportation and per diem costs were calculated for all crewmen. A followup crew of two men with a pickup and pumper remains at the scene for 2 days after each burning operation. The average per-acre cost over all 139 areas of the initial burn is $10.99 (table 3), slightly higher than the $10.00 per-acre cost estimated by Duran and Kaiser (1972, p.11) for chaparral burning.

Maintenance burns are important in controlling sprouting chaparral species and maintaining a vigorous grass stand. The maintenance burn crew consists of two men with a three-quarter ton pickup, a pumper, and burning supplies. The average cost over all areas is $0.21 per acre (table 3).

Seeding. — We assumed two pounds of weeping lovegrass, at $1.25 per pound, would be seeded per acre. Per-acre costs of combinations of grasses and forbs, such as a mixture of weeping lovegrass, Lehmann lovegrass, and yellow-blossom sweet clover, would be similar. All areas are seeded following initial burning. Anticipating that grass may not become established in some portions of the treatment area, we also assumed a 20 percent followup seeding after the first maintenance burn.

The seed is applied by helicopter (except for the rootplowed areas, which are initially seeded during the rootplowing) at a rate of 372 acres per hour. The helicopter and helper come from Phoenix for the Tonto National Forest and Marana for the Prescott National Forest. The ferry charge ($150.00 per hour at an average flying time of 50 miles per hour) and the helper's charge ($0.25 per mile) are assumed to be split between three areas. In addition, a three-man seeding crew (1) transports the seed from the Forest headquarters to the area in a three-quarter ton, 4-wheel drive pickup, (2) loads the seed, and (3) calibrates the seeder. The average per-acre cost of seeding the 139 areas is $3.85 for initial seeding and $8.75 for followup seeding (table 3).

Herbicide application. — Broadleaf herbicides are used in the second year to control sprouting chaparral species and provide a more favorable environment for establishment of a grass stand, and periodically during the remainder of the study period as maintenance. The spray is applied at a rate of 10 gallons per acre (a 10 percent active mixture) and costs $2.00 per acre. Helicopter and crew costs are similar to the seeding costs except for the addition of a slip-on pumper to the pickup. The average per-acre cost of broadleaf herbicide application over all areas is $3.31 (table 3).

Overhead. — The normal overhead used by the Forest Service is at least 30 percent, but much of this would be incurred whether or not areas are converted. The additional planning and supervision costs which would be incurred *with* conversion are assumed to be 10 percent of conversion costs.

Complete costs of converting one area — an example. — Area T13 (fig.2) is located about 10 miles north of Payson on the Payson Ranger District of the Tonto National Forest. The majority of the chaparral ranges from 40 to 60 percent cover, which is considered "medium." Sixty percent of T13 (653 acres) will hypothetically be converted. Except for small isolated exceptions, the slopes are less than 60 percent. There is sufficient access to the area. The perimeter of T13 is 7.8 miles, one-fourth (1.94 mi.) of which will be a fuelbreak and one-half (3.9 mi.) of which will be a fireline. Nearly 23 working days will be necessary to install the fuelbreaks and firelines: (1.95 mi.) (10 days/mi.) +(3.9 mi.) (0.8 day/mi.) = 22.62 days.A permanent tractor crew maintained in Payson will install fuelbreaks and firelines, and will return to Payson each night. The burning crew consists of 10 men from Payson, 6 from Pleasant Valley, and 15 from Globe. The 10 men from Payson will return there each night, but the other 21 men will camp at the site due to the distance from their homes and the travel time involved. After the burning operations, two men will remain for two more days with a pickup and pumper to watch for fires. After the areas are burned and seeded, they are maintained with periodic herbicide sprays and burns. Table 4 lists the individual costs of the complete conversion and maintenance of T13 over 50 years.

Cost of Conversion — Alternative II

Environmental impact statement and access costs are identical to those for Alternative I. Soil-applied herbicide at a rate of 5 pounds active material per acre has shown promise of eliminating chaparral growth on experimental plots. Assuming a 5 pound rate, at a cost of $6.00 per pound of active ingredients, the herbicide will cost $30.00 per acre. Because the herbicide is in solid form rather than liquid, the aerial application costs are similar to those for seeding in Alternative I. The total average cost of the herbicide application is estimated to be $33.01 per acre (table 3). The first maintenance burn,

Table 4.--Complete costs for Alternative I conversion of area T13 (1972 dollars, undiscounted)

Item	Cost
I. Environmental impact statement	$200.00
II. Access	0.00
III. Fuelbreaks and firelines (23 days)	
2-man crew ($26.48/day/man)	1,218.08
Cat operator ($48.99/day)	1,126.77
Cat hauling	336.00
Cat lease ($17.14/day)	394.22
Cat variable ($25.80/day)	593.40
Half-ton pickup lease ($2.59/day)	59.57
Transportation (20.4 mi. round trip)($0.07/mi)	32.84
Overhead (10%)	376.09
Total	4,136.97
IV. Rootplowing	0.00
V. Burning	
A. Year 1 (500 acres plus lines, 5 days)	
31-man crew ($26.48/day/man)	4,104.40
3 three-quarter ton pickup lease ($4.14/day/truck)	62.10
3 pumpers lease ($0.50/day/pumper)	7.50
Bus lease ($4.82/day)	24.10
Carryall lease ($2.59/day)	12.95
Transportation	
3 pickups ($0.135/truck/mi.) (176 mi. round trip from Phoenix)	71.28
Bus ($0.21/mi.) (170.8 mi. round trip from Phoenix via Globe, Payson)	35.87
Bus ($0.21/mi.) (20.4 mi. round trip from area to Payson) (4days)	17.14
Carryall ($0.075/mi.) (204.3 mi. round trip from Phoenix via Pleasant Valley, Payson)	15.32
Burning supplies ($0.06/acre) (500 acres)	30.00
Per diem ($10.00/day/man to camp) (21 men) (4 days)	840.00
Post fire watch (2 days)	
Pickup lease ($4.14/day)	8.28
Pumper lease ($0.50/day)	1.00
2-man crew ($26.48/day/man)	105.92
Per diem ($10.00/day/man) (2 men)	40.00
Overhead (10%)	537.59
Total	5,913.44
B. Year 2 (153 acres, 2 days) A similar operation to year 1. Total	2,404.11
VI. Seeding	
A. Year 1 (500 acres)	
3-man crew ($26.48/man)	79.44
Helicopter ferry ($150 hr) (3.16 hrs flight time round trip from Phoenix) (1/3)	158.00
Helicopter helper ($0.25/mi) (176 mi round trip) (1/3)	14.67
Seeding ($150/hr) (500/372 hrs)	201.61
Seed ($2.50/acre) (500 acres)	1,250.00
Pickup, three-quarter ton lease ($4.14/day)	4.14
Transportation ($0.135/mi.) (176 mi.)	23.76
Overhead (10%)	173.16
Total	1,904.78
B. Year 2 (153 acres) Similar to year 1. Total	796.62
VII. Herbicide (phenoxy compounds)	
A. 500 acres in years 2, 5, 11, 22, 34, 46	
3-man crew ($26.48/man)	79.44
Helicopter ferry ($150/hr) (3.16 hrs) (1/3)	158.00
Helicopter helper ($0.25/mi.) (176 mi.) (1/3)	14.67
Spraying ($150/hr) (500/372 hrs)	201.62
Spray ($2.02/acre) (500 acres)	1,010.00
Pickup lease ($4.14/day)	4.14
Pumper lease ($0.50/day)	0.50
Transportation ($0.135/mi.) (176 mi.)	23.76
Overhead (10%)	149.21
Total per year	1,641.33
B. 153 acres in years 3, 6, 12, 23, 35, 47 Total per year	716.39
VIII. Maintenance burn	
A. 500 acres in years 4, 7, 10, 13, 17, 21, 25, 29, 33, 37, 41, 45, 49	
2-man crew ($26.48/man)	52.96
Pickup, three-quarter ton lease ($4.14/day)	4.14
Pumper lease ($0.05)	0.50
Burn supplies ($0.06/acre) (500 acres)	30.00
Transportation ($0.135) (20.4 mi. round trip from Payson)	2.75
Overhead (10%)	9.04
Total per year	99.39
B. 153 acres in years 5, 8, 11, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50 Total per year	76.48
IX. Followup seed (20%)	
A. 100 acres in year 4 Similar to seeding except for lighter application Total	804.72
B. 31 acres in year 5 Total	406.02

including the burning of firelines around part of the perimeter of the burn, will be completed by a 20-man crew. Time necessary is 4 days for 400 to 600 acres, 3 days for 200 to 400 acres, and 2 days for less than 200 acres. The seeding and subsequent maintenance burns are similar to those for Alternative I.

CONVERSION EFFECTS

Conversion impacts fall into two basic groups. The first group includes those benefits which can, with relative ease, be measured and predicted and to which a monetary value can be assigned. Increases in water runoff and forage and reduced fire hazard belong to this group. The other group includes the following less-easily quantified impacts (benefits or costs): changes in recreation use, esthetics, and wildlife habitat; soil savings or losses; and possible herbicide residue. A model will be presented for estimating yields in the first group, and a qualitative understanding will be offered for the effects in the second group.

Water Runoff

Projections of water yield increases from conversion were based on the following relationship (described in Part I) between mean annual increase in runoff ($\overline{\Delta R}$) and mean annual precipitation ($\overline{P}$):

$$\overline{\Delta R} = 0.74\overline{P} - 12.53. \qquad [2]$$

A modification of this equation was necessary, however, to account for the difference between the five experimental watersheds upon which Equation 2 is based and the average conversion project. Two differences are contemplated. First, runoff increases are likely to be greater for the experimental conversions because of the more extensive and selective use of herbicides in both initial treatment and maintenance. Over 90 percent of the brush cover was removed in the experimental treatments; this study assumes a minimum of three-fourths removal of the brush in the converted portions. Second, Equation 2 represents 100 percent conversions of delineated areas, whereas a maximum of 60 percent of the 139 areas is hypothetically converted. If the untreated portion lies downslope from the converted portion, part, or possible all, of the increase may be lost to remaining chaparral plants.

Average annual water yield increase for the 139 areas was estimated by:

$$\overline{\Delta R} = 0.59\overline{P} - 10.02, \qquad [3]$$

which represents 80 percent of the increase predicted in Equation 2. Mean annual precipitation ($\overline{P}$) was estimated from the map *Normal Annual Precipitation (1931-1960)* for the State of Arizona, published cooperatively by the Arizona Agriculture Experiment Station and the University of Arizona Institute of Atmospheric Physics. For example, area T13 (fig. 2), with a mean annual precipitation of 25 inches, will be expected to yield about 4.73 inches of additional runoff per year on site. If 60 percent of area T13 (1088 acres) is converted, an on-site runoff increase of 257 acre-feet is expected (0.60 x 1088 acres x 4.73 in./12 in. = 257). The average mean annual precipitation for all 139 areas is 22 inches, yielding an average on-site runoff increase for all areas of about 3 inches.

Projection Equations 2 and 3 would not apply if maintenance herbicide treatments were eliminated from Conversion Alternative I. The more tenacious sprouting species, which are found in abundance in most dense chaparral stands, can be suppressed, but not eradicated, with periodic burns (Pond and Cable 1960). Anderson and Leven predict substantial reductions in runoff as brush regrows.[8]

A portion of runoff increases is lost to evaporation and downstream vegetation. Following Hibbert and Ingebo's (1971) estimate, we assumed that 80 percent of the increased runoff would reach storage reservoirs downstream. Very little of this 80 percent is lost en route from reservoirs to actual points of use because the additional water will not measurably increase the surface area of the water traveling in the rivers or canals.

Although the hydrologic model projects average annual runoff increases, runoff increase will actually vary significantly from year to year, as does total Basin runoff. Thus, in an exceptionally dry year, the converted areas will yield little runoff increase, while in an exceptionally wet year the increase will be far above average. In the event that the downstream reservoir and canal system capacity is exceeded (which happened five times — 1941, 1965, 1966, 1968, and 1973 — in the past 50 years), and water is spilled into the Salt River, runoff increases from conversion would be lost to the full extent of the release. Furthermore, such a loss would naturally occur in a year of above average runoff. Additional storage capacity — in the form of the proposed Orme Dam, for example — would alleviate this situation.

[8]*Anderson, David A., and Andrew A. Leven. Hydrologic analysis procedures; east fork Sycamore Creek chaparral position statement. U.S. Dep. Agric., For. Serv., Southwestern Region, Albuquerque, N. Mex. Unpublished manuscript, 35 pp. 1970.*

Places of valuation. — Increases in runoff from chaparral management in the Salt-Verde Basin can be valued at three locations: (1) in streams leaving the treated watersheds, (2) at hydroelectric dams downstream, and (3) at final points of use in the Phoenix Valley or Chino Valley.

Not only greater flows, but flows for more extended periods, were observed on the Three Bar and Whitespar Experimental Watersheds following brush removal (Hibbert and Ingebo 1971). Because stream channels leaving most chaparral watersheds are dry most of the year, extending flow duration, or actually making an intermittent stream perennial, should have value to livestock and wildlife. Furthermore, additional streamflow for longer duration may enhance the recreation quality of an area. Although potentially significant, the on-site value of these runoff increases was not estimated in dollar terms.

Because part of the runoff from chaparral areas travels below the surface for some distance, the hydrologic nature of several portions of the Salt-Verde Basin is not well understood. Runoff from areas P19-P22 (fig.3) near Prescott flows into Watson Lake or Willow Creek Reservoir and is used for irrigation in Chino Valley. It seems reasonable to assume that runoff from the remaining 135 areas reaches storage reservoirs on the Salt and Verde Rivers, from where it is released to Granite Reef Diversion Dam, the outlet point for the Basin and the place where water is diverted to the agricultural, municipal, and industrial users in the greater Phoenix area. In addition, runoff increases from some areas on the Tonto National Forest flow into Roosevelt, Apache, Canyon, and Saguaro Lakes on the Salt River (fig. 2) and become available for power production as the water passes the hydroelectric dams. The methods used for determining the dollar value of the water yield increases are explained below. Irrigation water in Chino Valley is assigned the same value as water reaching the Phoenix Valley.

Value of additional water in producing power. — Additional flow through hydroelectric dams has value in replacing the most costly alternative power source. Although oil is presently the most costly alternative, coal will soon replace oil in Salt River Project power production. For this analysis we assume that the additional runoff replaces coal.

The increased runoff from 84 of the 139 chaparral areas passes through all four dams (Theodore Roosevelt, Horse Mesa, Mormon Flat, and Stewart Mountain) and has a value of $2.48 per acre-foot (1972 prices), based on data supplied by the Salt River project:

Hydroelectric dam	Value of an acre-foot of additional water
Theodore Roosevelt	$0.68
Horse Mesa	0.90
Mormon Flat	0.45
Stewart Mountain	0.45

In addition, water from two areas passes through the lower three dams, and the water from two areas passes through only Stewart Mountain Dam. The remaining 52 areas are in the Verde River Watershed.

Value of additional water below Granite Reef Dam. — The primary user of any additional water in the Phoenix Valley is the agricultural sector — there is some unmet demand for water to irrigate low-valued feed grain and forage crops. All other, higher valued demands are already met. The marginal value of additional water to the farms was $7.50 per acre-foot in 1967 (Mack 1969). Projecting to the year 2000 and assuming an increase in municipal and industrial water use of 215,000 acre-feet (O'Connell 1972a), additional water would still go to low-valued crops at a marginal value of $11.20 per acre-foot (1972 prices) (that is, the most the farmer could pay for the additional water and still pay variable costs would be $11.20).

The Salt River Valley Water User's Association (SRP) administers much of the water supply for the Phoenix Valley. Any portion of the increase not used for additional crops has value to the SRP in replacing pumped water. It would reduce pumping costs (power, operation, and maintenance costs), reduce depreciation on investment, and slow the rate of groundwater depletion. Initial increases were worth $10.30 per acre-foot in 1972 (O'Connell 1972a).

If the increase were not used for either additional crops or replacement of pumped water, it would recharge the ground water supply (as, for example, when reservoir storage capacity is exceeded), thus avoiding, to some extent, future costs of sinking wells deeper. The SRP estimates this value to be 76 cents per acre-foot. We assume for this analysis the maximum value: that all runoff increases are used to produce additional crops at a value of $11.20 per acre-foot.

Forage

Most of the 139 chaparral areas are grazed by cattle. There is evidence that these sites can produce substantial grass yields where the chaparral is successfully controlled (Pond 1961a, b; Lavin and Pase 1963; Pase and Ingebo 1965; Tiedemann and Schmutz 1966). Chaparral-to-grass conversions may aid ranching operations on these areas in three ways: they reduce labor costs of herding by providing easier access, support more animal units per acre, and stimulate faster weight gains per animal (Pond 1967).

Lovegrasses (see Part I) are commonly used for seeding burned chaparral areas, not so much for their forage value as for the relative ease with which they become established and the watershed protection they provide. Nevertheless, if managed properly, lovegrass can be a valuable addition to many grazing allotments which rely primarily on chaparral and scattered native grasses and forbs.

Estimating increases in carrying capacity. — Each of the 139 chaparral areas was examined to estimate the value of increased cattle grazing capacity which would result from conversion to grass. Range specialists on the National Forests estimated the present grazing capacity in animal units per year (AUY) per section, and the potential forage production following conversion in pounds of forage per acre per year. These estimates corresponded with the limited results of experimental studies.

The following assumptions were necessary to estimate increases in cattle grazing with conversion:

- Forage production reaches estimated levels within three years and is maintained thereafter.
- Additional forage can be converted to pounds of beef. If the allotment is not presently overstocked, additional forage will allow an increase in the number of cattle permitted on the allotment. If the allotment is presently overstocked, additional forage will avoid a reduction in the number of cattle permitted.
- If necessary, additional fencing and water facilities will be installed to allow proper management of the converted areas.
- Since the grazing schedule is coordinated with the maintenance schedule, the converted areas will be grazed two of the first six years, four of the following six years, and 28 of the remaining 38 years (three of every four years) in the 50-year study period.
- Fifty percent of the annual growth in a chaparral pasture is utilized on slopes of less than 30 percent, while 20 percent of the annual growth is utilized on slopes of from 30 to 60 percent. Utilization by cattle of any additional forage on slopes above 60 percent is assumed to be nil.
- A 14 to 1 cow/bull ratio is maintained for any additional cattle. Furthermore, a 77 percent calf crop is assumed, with 14 percent of the cows culled each year and replaced by part of the calf crop.
- An animal unit consumes 30 pounds of air-dry forage daily.

Value of increases in grazing capacity. — Additional grazing capacity can be valuated several ways; the Forest Service grazing fee, the private lease rate, and the capitalized value are all possibilities (O'Connell 1972b). We used the "with and without" procedure, however, because it allowed area-by-area consideration of fixed cost increases. The value was defined as the difference in expected net return from cattle grazing on the areas with and without conversion.

The areas were individually examined by range specialists on the National Forests to determine if any additional fences, cattle guards, or water developments (fixed costs) would be necessary to properly manage the converted areas for grazing. Costs of these improvements depended on the characteristics of the area; the average costs were $1200 for a

mile of fence, $500 for a cattle guard, $600 for a spring development or a horizontal well, and $5000 for a vertical well (1972 prices). These improvements would be installed at the beginning of the study period. The annual annuity payment was figured using a 6-7/8 percent interest charge.

Variable costs will increase for any rancher who adds additional cattle to his operation. Costs of the following inputs or losses can be expected to increase with an increase in the size of the herd: labor, feed, veterinary services and supplies, cattle taxes, machine operation, cattle depreciation, animal death loss, and interest for the purchase of the additional animals. Costs which would not increase proportionally with additional cattle are property tax, insurance, utilities, and building depreciation. The additional variable cost of operation for an average size allotment on the Tonto National Forest — $2.94 per animal unit month (AUM) (O'Connell 1972a) — was applied to each of the 139 areas where grazing increases would be expected.

The ultimate value of additional forage is derived from the market value of the cattle produced (table 5) less transportation and sales costs. Based on ranching experience, we assumed a transportation cost of 2.5¢ per head per mile and a sales commission of $3.00 per head.

The net present value of the additional forage is the present value of the marginal annual revenues minus marginal annual variable costs and annuity on the fixed costs stemming from increased (marginal) cattle production over the 50-year study period. For the 122 areas which have a positive net present value, an average of 11 more animal units could be added per section of converted land, resulting in an average annual yield of $1.57 per converted acre and an average value per additional AUM of $6.54.

Table 5.--Estimated market value of cattle in Arizona (1972 prices)

Cattle	Average weight	Price/cwt.	Total value
	Pounds	*Dollars*	
Yearling steers	560	34.92	195.55
Yearling heifers	550	33.97	186.84
Cull cows	850	23.90	203.15

[1]Source: Prices Received by Farmers, Arizona Crop and Livestock Reporting Service, USDA and Univ. of Arizona, 5405 Federal Bldg., Phoenix, Arizona. Prices do not include transportation or sales commission.

Fire

From 1962 to 1972, 420 chaparral fires were reported on the Tonto National Forest, 137 on the Prescott. Modern quick attack techniques, utilizing air tankers that drop fire retardant on-target regardless of on-the-ground access problems, held most fires to small size. A few, however, escaped initial attack and required a large, expensive suppression effort. The Battle Fire (1972) on the Prescott National Forest, which began in dense chaparral, is a stark example. Even with the aid of essentially unlimited funds and modern equipment and firefighting techniques, the Battle Fire raged uncontrolled for 6 days, burning 14,000 acres of chaparral plus 13,500 acres of pine and mixed pine and chaparral. The suppression cost was $1.4 million dollars.

Attack methods are continually improving. The more effectively fires are controlled, however, the more fuel accumulates over time. Without significant increases in fuel management or changes in wildfire suppression policy, additional large, expensive fires are therefore likely.

Chaparral conversion, by reducing available fuels, is one positive way of reducing the chance of large, costly fires. Proper grazing and periodic maintenance burns can effectively control accumulations of cured grasses and forbs in converted areas, reducing available fuels and lowering the average annual fire start rate. And when fires do start in converted areas, such grass fires are generally easier and less costly to control than dense chaparral fires. It should also be easier to quickly contain fires which start near converted areas, for conversions improve access and provide fuelbreaks. See Brown and Boster (1974) for a more detailed discussion of these points.

Effect of conversion on firefighting costs. — The "fire benefit" in this study is the reduction in firefighting costs as a result of conversion. Another possible benefit of fewer or smaller fires, not considered here, is a reduction in resource damages.

The model for estimating the fire benefit (Brown and Boster 1974) calculates annual firefighting cost (C) for each area (i) for the with and without conversion situations:

$$C_i = N_i \sum_k p_k c_k \qquad [4]$$

where N_i = average annual number of fires for area i

k = Forest Service fire size classes A, B, C, D, and E (all classes larger than E are included in E[9])

p_k = average proportion of fires in size class k for the 139 areas

c_k = average suppression cost of a class k fire for Basin chaparral or grass fires.

[9]*The fire size classes are defined as follows: A (up to 1/4 acre), B (1/4-10 acres), C (10-100 acres), D (100-300 acres), and E (300 acres and larger).*

The "without" minus the "with" situation gives an estimate of the average annual cost savings from conversion, which is the fire benefit. Although limitations make use of this model for estimating cost savings for individual areas risky, it is the best approach available.

One of the more likely alternatives postulated by Brown and Boster is considered here. It assumes a $45 per-acre cost of fighting class D and larger fires, and the following changes with conversion: a 20 percent reduction in fire starts, and a 50 percent reduction in the incidence of Class E and larger fires (i.e., 50 percent fewer fires will reach Class E size).

The estimated per-acre annual fire benefit for the 139 areas ranges from 3¢ to $2.00, with a mean of 31¢ and a median of 12¢. The skewed distribution of fire benefits reflects the fact that some areas have had exceptionally high fire start rates.

Recreation

Nearly all recreation use in Arizona chaparral is dispersed; developed campsites or other recreational facilities other than roads are virtually non-existant. Activities include hunting, hiking, camping, picnicking, rock hunting, sightseeing, birding, fishing, horseback riding, and driving four-wheel-drive and other vehicles for pleasure. Driving for pleasure and hunting are likely the most popular of these activities. Use is highest during the spring and fall when the climate is most agreeable.

Few chaparral areas receive much use other than hunting. Exceptions, such as Brushy Basin and Bloody Basin, are somewhat unique. Brushy Basin, part of which was converted, is accessible from Phoenix by sedan. The drive passes from southern desert shrub through chaparral to ponderosa pine. The panorama is unique, and the presence of several washes with riparian-type vegetation and the cooler pine area at the top add to the experience. Bloody Basin is part of a rugged scenic drive which includes desert shrub, chaparral, woodland, and grassland, and is also accessible by sedan. Both areas provide opportunities for hunting, camping, birding, rock hunting, and picnicking.

Except for hunting, which is spread out by the permit system, use of chaparral areas is highly dependent on the access factors — distance, travel time, and vehicle accessibility. Accessible chaparral areas relatively close to Phoenix and Globe receive considerable use since these are the closest areas providing climatic relief. More distant chaparral areas on the Tonto National Forest are used less because of the equally accessible, but more popular, ponderosa pine areas. On the Prescott National Forest, even the closest chaparral areas are no closer than the pine to the population center (Prescott), which places the chaparral areas in a secondary position for most activities.

Effect of conversion on recreation. — Three of the factors which determine recreation use — travel time and distance from population centers, vehicle accessibility, and recreational opportunities (Clawson and Knetsch 1966, p.60) — may be affected by conversion.

Vehicle accessibility increases wherever access improvements are necessary for conversion. The total supply of accessible chaparral increases if new roads are required. Travel time and distance must be considered in relation to the major sources of demand for chaparral-based recreation (Phoenix and to a lesser extent Globe). Access improvements relatively close to

these populated areas may decrease travel time to chaparral sites.

Recreational opportunities may be increased several ways. (1) If conversion improves wildlife habitat, the area may become more popular with hunters because of increased game and improved access and visibility. (2) Since conversion has been known to increase the quantity and duration of streamflow, riparian sites which receive the increased flow may experience additional recreation use. (3) In areas where chaparral is bordered by ponderosa pine, careful conversion may both provide foot access to the pine and clear the understory sufficiently to provide an attractive recreation site. (4) Conversion also opens up an area of dense brush making hiking and rock hunting more feasible.

An increase in recreation use of any particular area is either a transfer or new demand. A transfer results if an increase in visitor days for one area is offset by a decrease in visitor days at other areas. New demand represents new recreationists or an increase in recreation by former recreationists. Because of the large supply relative to demand for dispersed recreation in chaparral, much of the increase will be transfers.

Estimating change in recreation following conversion. — The District Rangers were asked their opinion of the effect of conversion on recreation use. In light of their opinions and the above considerations, the areas were ranked according to the following three categories:

1. Areas relatively close to a population center which have potential for an increase in visitor days and which also would benefit from an improvement in accessibility.
2. Areas relatively close to a population center which have potential for an increase in visitor days but need no access improvement.
3. Areas not expected to receive an increase in visitor days for one or more of the following reasons: a) lack of recreation potential, b) distance from popultion centers, c) no need for access improvements.

The 139 areas were categorized as follows:

Category:	1	2	3
Number of areas	3	7	129

The 10 areas in categories 1 (areas T33, 34, and 35) and 2 (areas T23, 24, 36, 97, 98, 100, and 109) may experience some increase in new demand as a result of conversion; demand on the other 129 areas would probably be unaffected. Area T33 (fig.2), for example, which falls in category 1, is only 48 miles from Phoenix and would require at least 3.5 miles of road improvement. Improved access would make the west side of T33 one of the closest accessible chaparral sites offering climatic relief from the desert. Increased surface runoff would improve the attractiveness of springs in the area.

Increased recreation use should be considered in any decision about conversion. The value of such an increase would have to be balanced with increased road and grounds maintenance costs caused by heavier recreation use.

Soil Loss

Some soil loss is common on most chaparral slopes. The chance of erosion is normally highest following chaparral wildfire, which not only eliminates overstory, but also reduces soil wettability and consumes much organic matter on the soil surface (see Part I).

Initially, chaparral conversion also increases the chance of erosion, but probably not as much as wildfire. Chemical and mechanical eradication should have less effect than prescribed burning.

Present evidence suggests two conclusions about the effect of conversion on soil loss (based on Part I). (1) Conversion to grass should not allow more erosion than natural chaparral, assuming a good grass stand is established. (2) In the long run, conversion should reduce erosion because the wildfire cycle will be interrupted and heavy post-fire erosion avoided. Both conclusions require that management after conversion must insure both maintenance of the grass stand and proper grazing procedures.

Wildlife

Most wildlife specialists agree that carefully planned and executed conversions can improve wildlife habitat. Part I lists the following improvements as possible results of conversion: (1) Space is provided for animal movement by opening up dense brush stands, (2) abundance and quality of browse and forage are augmented, and (3) variety of food is increased.

The following three qualifications are often listed by wildlife specialists regarding chaparral conversion (Part I): (1) Conversions should be limited to the more dense, continuous stands, especially those dominated by relatively unpalatable species such as shrub live oak, (2) a maximum of 50 percent of a stand should be converted, and (3) the converted portions should be small and spread throughout the original stand.

The 60 percent conversion postulated here for most areas is more extensive than that generally recommended by wildlife specialists. While not ideal, however, such conversions would alter the more dense chaparral stands which presently impede animal movement, and, if properly executed and maintained, should create a desirable patchwork of converted and non-converted areas.

Esthetics

The esthetic appearance of a conversion project is, of course, a matter of opinion and time. The important opinion is that of the public, and, unfortunately, nothing has yet been reliably determined about public perception of chaparral conversion. Research is needed to set down guidelines for the most esthetically pleasing design. The time factor affects all vegetation management practices. Is the public willing to put up with a temporary, say 5-year, degradation to receive a long-term improvement?

The following variables influence the esthetic appearance of a conversion:

- The size of the converted area.
- The area's shape — how well the shape fits the topography.
- The spacing of various clearings.
- The well-placed presence of small relict areas within a larger conversion.
- The area's proximity to roads and fences.

It is easier to create a pleasing pattern (assuming landscape architects can design one) with rootplowing or herbicides than with fire. In rootplowing, the topograpohy, depth of soil, and presence of large rocks are the only constraints, while with carefully applied herbicides there are essentially no constraints. Particular bushes, clumps of bushes, or large areas can either be removed or left standing. Fire, however, is not as easily controlled. As the desired pattern becomes more meticulous, the cost of the burning increases, with no definite guarantee that a relict area will actually be saved.

In this study a somewhat more realistic approach is taken in Conversion Alternative I. Larger portions are burned than would be ideal from the esthetic standpoint. The fire will determine which areas, if any, will initially be left within broad boundaries consisting of from 100 to 600 acres. Selective seeding and maintenance will later be used to establish a desired pattern. If a patch is not seeded or sprayed, the brush will soon take over and the patch will not readily burn for many years. Thus, while the desired pattern is not immediately created, it develops with time.

No attempt will be made to quantify the effect of conversion on esthetics. It does appear, however, that a properly planned conversion will make the landscape more attractive within a few years.

Herbicide Use

Although experience suggests that herbicides are necessary for successful chaparral conversions, their future use will depend on forthcoming Environmental Protection Agency regulations governing herbicide use.

None of the soil-applied herbicides which have been tested for brush control are presently registered for management use. Also, it is not known how new regulations covering the use of broadleaf herbicides presently registered for range use will affect their use on watershed lands. (See the pesticide precautionary statement on the inside back cover). New regulations should set standards to guard against unacceptable levels of environmental contamination. Any environmental damage due to herbicide usage, however, would represent a cost of conversion over and above application costs.

INTEGRATION OF BENEFITS AND COSTS

Benefit-cost analysis (Howe 1971), which was used to compare the present values of the quantified benefits and costs, provides two fundamental indices of project worth, the benefit-cost ratio (B:C) and the benefit-cost difference (B-C). B:C is a measure of the economic feasibility of a proposed project; an area is economically feasible for conversion if the ratio of the present value of its benefits (B) to the present value of its costs (C) is greater than 1.0. B-C gives a measure of the magnitude of the net benefit, or loss, obtainable from the project. As explained in the introduction, present values were calculated using a 6-7/8 percent discount rate.

Results for Conversion Alternatives I and II

The benefit-cost analysis of Alternative I (initial burn with maintenance burns and herbicide sprays) indicates that conversion is economically feasible on 96 of the 139 areas, which contain 82 percent (273,383) of the total delineated acres and 83 percent (147,118) of the actual conversion acres (table 6). Seventy-eight of the economically feasible treatment areas are on the Tonto National Forest and 18 are on the Prescott. Most feasible treatment acreages are on the Globe, Mesa, Payson, Pleasant Valley, Roosevelt and Walnut Creek Ranger Districts (table 7).

For Alternative II (initial soil-applied herbicide treatment with maintenance burns), conversion is economically feasible on 72 of the 139 areas (table 6), which encompass 58 percent of the total acreage and 60 percent of the actual conversion acreage. The greater initial treatment costs for Alternative II, as compared with Alternative I, resulted in fewer areas meeting the economic criterion.

Benefit-cost ratios for Alternative I range from 0.1 to 6.4. Forty-seven areas have a B:C greater than 2.0 and 15 areas have a B:C greater than 3.0 (table 7). The range for Alternative II is considerably narrower — from 0.1 to 3.2, and only nine areas have a B:C greater than 2.0. Benefit-cost ratios and differences for each area are listed in the Appendix.

Of the three conversion benefits which we quantified, water runoff increases proved the most significant economically. Runoff increases yielded more, in present value terms, than forage or fire benefits on 98 of the areas. Forage benefits yielded most return on 29 areas, and fire benefit on 12 areas. Assuming Alternative I, estimated runoff increases actually cover conversion costs for 61 areas, while forage increases cover costs on 21 areas and reductions in wildfire suppression costs cover costs on eight areas.

Table 6.--Portion of total delineated acreages with a benefit-cost ratio[1] greater that 1.0 for alternative conversion schemes, 139 chaparral areas, Salt-Verde Basin, Arizona

Alternatives	Areas		Size	
			Total	Actual conversion[2]
	Number	*Percent*	*Acres*	
Alternative I				
Best estimate	96	69	273,383	147,118
Low estimate[3]				
Water runoff	94	68	264,210	143,703
Forage production and utilization	81	58	208,709	113,664
Fire benefit	89	64	264,431	144,233
Combined low estimate	64	46	186,993	103,740
Alternative II	72	52	192,796	106,543

[1]Constant 1972 dollars over 50-year planning horizon discounted at 6-7/8 percent.
[2]The 60 percent or less of each area which was considered the part actually treatable.
[3]Each of the three quantified benefits were individually reduced to their lowest reasonable estimate (one yield was reduced while the other two remained at the "best estimate" level).

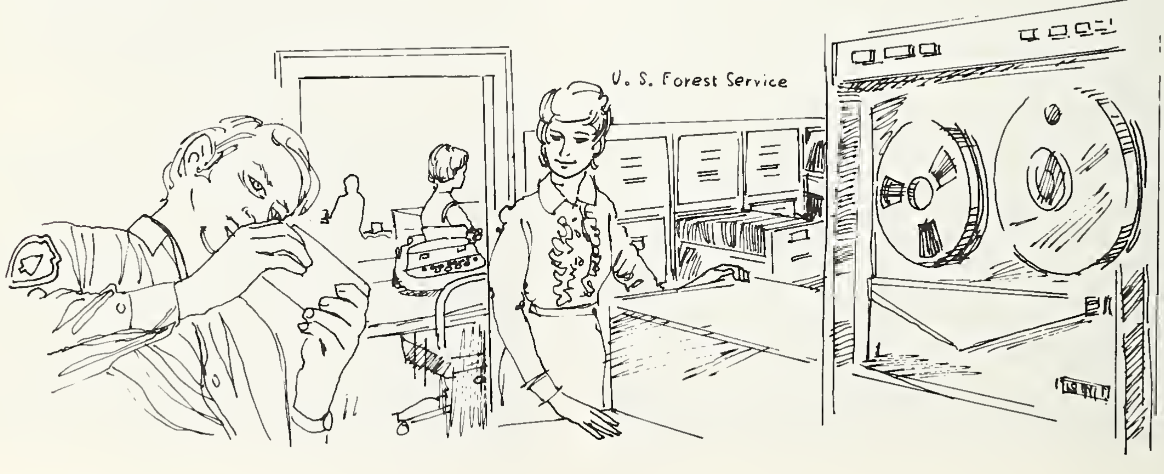
Table 7.--Distribution (by Ranger District for Conversion Alternative I) of areas economically feasible for conversion, Salt-Verde Basin, Arizona

Forests and Districts	Areas with benefit-cost ratio[1] greater than--					
	1.0		2.0		3.0	
	No.	*Acres*[2]	*No.*	*Acres*[2]	*No.*	*Acres*[2]
Tonto						
Cave Creek	4	8,569	1	1,382	-	-
Globe	12	22,288	8	12,867	1	2,695
Mesa	10	14,725	4	10,900	1	1,579
Payson	15	23,015	12	20,131	6	10,688
Pleasant Val.	23	22,714	15	78,236	6	6,298
Roosevelt	14	22,895	7	18,238	1	1,477
Sub-total	78	114,206	47	81,754	15	22,737
Prescott						
Chino Valley	1	2,552	-	-	-	-
Thumb Butte	6	2,988	-	-	-	-
Verde	2	1,336	-	-	-	-
Walnut Creek	9	26,036	4	12,538	1	6,797
Sub-total	18	32,912	4	12,538	1	6,797
Total	96	147,118	51	94,292	16	29,534

[1]Constant 1972 dollars over 50-year planning horizon discounted at 6-7/8 percent.
[2]Actual conversion acreage (a maximum of 60 percent of each area).

Modification of Benefits for Conversion Alternative I

The results of the benefit-cost analysis of Alternatives I and II are based on the best estimate of expected changes in runoff, forage production and utilization, and incidence of large wildfires following conversion. Because



these benefits are less than certain, however, we also calculated the benefit-cost analysis of Alternative I using the lowest reasonable estimates of the above benefits. Specifically, (1) runoff increases were estimated to be 30 percent less than those experienced on experimental watersheds, rather than 20 percent; (2) maximum lovegrass production was assumed to be 900 pounds per acre, rather than 1500 pounds, and forage utilization was lowered from 50 percent to 35 percent on slopes less than 30 percent, and from 20 percent to 10 percent on slopes of from 30 to 60 percent; and (3) the proportion of Class E and larger fires remains the same with conversion as without, rather than being reduced by 50 percent.

Separate incorporation of the low estimates of the water, forage, and fire yields (reducing one yield while maintaining the other two at the "best estimate" level) reduced the number of areas with B:C greater than 1.0 from 96 to 94, 81, and 89 respectively. If the low estimates are assumed for all three yields, conversion is economically feasible for only 64 areas (table 6 and Appendix).

Maximum Potential Benefits

We do not suggest that all areas found here to be economically feasible for treatment should actually be converted. Each area must be examined in detail. Economic efficiency is not the sole determinant in land management decisions. Nevertheless, it is instructive to examine the range of feasible benefits from conversion.

If all 96 areas with B:C greater than 1.0 (Alternative I) were converted (an actual conversion of 147,118 acres, table 6) an average of 30,443 acre-feet of additional water would become available for downstream users each year. In addition, cattle grazing capacity would increase by an average of 35,520 AUM per year, and average annual firefighting costs should be reduced by $90,289. The gross annual benefits would be less under Alternative II, or the reduced version of Alternative I (table 8).

These values should be compared with averages of 1.2 million acre-feet of runoff which annually reaches storage reservoirs in the Salt-Verde Basin, 980,000 AUM annually carried by the Basin, and about $3 million annually spent for fire protection and suppression in the Basin. In other words, actual conversion of 147,118 acres of chaparral (1.8 percent of the Basin) could potentially increase Basin runoff reaching reservoirs by 2.5 percent, increase cattle grazing capacity 3.6 percent and reduce Forest Service firefighting costs in the Basin by 3.0 percent.

Subtracting the annuity[10] of the 50-year conversion and maintenance cost stream for an area from the annuity of the 50-year benefit stream for that area gives the net annual return from conversion. The total net annual return from conversion of all areas with a benefit-cost ratio greater than 1.0 (Alternative I) would be $369,347 (table 8).

Table 8.--Total impacts of conversion[1] of all areas with benefit-cost ratio[2] greater than 1.0, Salt-Verde Basin, Arizona

Impacts	Alt. I (best estimate)	Alt. I (low estimate)[3]	Alt. II
Average annual benefits			
Water			
Increase in off-site[4] runoff (acre-feet)	30,443	24,010	27,281
Value to agric. ($)	340,960	268,907	305,551
Value to power ($)	43,494	36,721	41,766
Total water value ($)	384,454	305,628	347,317
Forage			
Increase in grazing capacity (AUM)	35,520	5,883	25,608
Value ($)	265,710	26,146	189,076
Fire			
Value ($)	90,289	35,082	76,775
Annuity of benefits ($)	661,182	346,503	552,660
Annuity of costs ($)	291,835	202,238	352,660
Net annual benefits ($)	369,347	144,265	199,687

[1]Changes due to conversion, measured by the "with minus the without" technique.

[2]Constant 1972 dollars over 50-year planning horizon discounted at 6-7/8 percent.

[3]Alternative I reduced by using low estimates of yields of water runoff, forage production and utilization, and fire benefits.

[4]Eighty percent of the estimated on-site runoff increase.

Average Conversion Impacts

If all 96 chaparral areas economically feasible for treatment under Alternative I were actually converted, a yearly average of 0.21 foot per acre of additional downstream runoff could be expected from the converted portions. Likewise, an average annual increase of 0.24 AUM per acre and a decrease of $0.34 in firefighting costs per acre could be expected. These three impacts yield a gross average annual (annuity) return of $4.49 per acre. Subtracting average per-acre (annuity) conversion costs of $1.98 leaves a net average annual return of $2.51 per acre. The range of this net return for all 96 areas is from $0.04 to $6.89 (table 9).

Assuming the low estimates of runoff, forage, and fire benefits for Alternative I, conversion of the 64 areas economically feasible for treatment would yield a gross average annual return of $3.34 per acre. The annuity of average per-acre costs for these areas is $1.95, and the net average annual return is $1.39 per acre (table 9).

[10]*Annuity* $= PV\,[i(1+i)^t/((1+i)^t-1)]$, *where PV is present value, i is the discount rate, and t is time in years.*

Assuming Alternative II (and the best estimates of the benefits), gross average annual return is $5.18 for the 72 economically feasible treatment areas. The annuity of average per-acre costs, however, is also higher — $3.53 — leaving a net average annual per-acre return of $1.87 (table 9).

The non-value-determined impacts of conversion are less easily predicted. Recreation use should increase for some areas, but will probably be unaffected on most. With proper grazing management, long-term soil loss should lessen with conversion or be similar to without conversion; with improper grazing, soil loss would probably increase. Careful treatment and maintenance should create a wildlife habitat superior to dense chaparral. Conversion without regard for pattern, however, may harm wildlife habitat. Finally, depending on the particular qualities of the chaparral area and the care taken in creating patterns, conversion will either improve or harm the area's esthetic appearance (table 9).

Importance of Some Major Assumptions

Numerous assumptions were necessary to estimate conversion costs and benefits. Six important assumptions — concerning the discount rate, the effects of inflation, conversion on steeper slopes, access requirements, fire policy, and areas under special agreements — are examined here.

Discount rate. — Although the Water Resources Council is presently recommending use of a 6-7/8 percent discount rate, it has also recognized that the real rate of return on non-Federal investment is about 10 percent (U.S. Water Resources Council 1971). Use of the lower rate in evaluating projects with large investment costs may show a benefit-cost ratio greater than 1.0 while use of the higher rate would not. Many economists argue (Cicchette, et al. 1973, for example) that the higher rate, being the opportunity cost of Federal investment, is more appropriate. Implementation of a project efficient at a 6-7/8 percent discount rate but inefficient at a 10 percent rate in effect represents a regional subsidy.

Increasing the discount rate from 6-7/8 to 10 percent reduces the number of areas economically feasible for Alternative I conversion (best estimates of the benefits) from 96 to 79. These 79 areas encompass 229,727 total acres and 126,944 possible conversion acres.

Probable effects of inflation on study results. — In the introduction we assumed that inflation would have similar relative impacts on benefits and costs. In the past year (1973), however, prices of food products and fuel rose considerable faster than all other commodities. Specifically, prices of feed grains and feeder cattle rose 50 percent faster than farm production costs or conversion costs (U.S. Dept. of Commerce 1974). Is this relative advantage merely temporary, or a long-term change?

Table 9.--Average annual impacts of conversion[1] for chaparral areas with a benefit-cost ratio[2] greater than 1.0, Salt-Verde Basin, Arizona

Impacts	Alternative I (best estimate)		Alternative I (low estimate)		Alternative II	
	Average	Range[3]	Average	Range[3]	Average	Range[3]
Value-determined impacts (per converted acre)						
Water (acre-feet off-site)	0.21	0.00- 0.43	0.23	0.11-0.35	0.26	0.03- 0.43
Forage (AUM)	.24	.00- .45	.06	.00- .16	.24	.07- .38
Fire ($)	.34	.02- 2.00	.19	.01-1.49	.40	.02- 2.00
Economic effects[4]						
Gross return ($)	4.49	1.92-10.91	3.34	1.75-7.64	5.18	2.35-10.91
Cost ($)	1.98	1.28- 8.84	1.95	1.25-5.97	3.31	2.66- 9.62
Net return ($)	2.51	.04- 6.89	1.39	.10-3.34	1.87	.03- 5.74
Non-value-determined impacts[5]						
Recreation	----------------some areas +, others 0--------------------					
Soil	0 or + with proper management, - with improper management					
Wildlife habitat	+ with proper management, - with improper management					
Esthetics	--------------------could be + or minus--------------------					

[1]Refers to the change with conversion, i.e., the with minus the without case.
[2]Constant 1972 dollars over 50-year planning horizon discounted at 6-7/8 percent.
[3]For some cases, extreme points were not reported.
[4]Expressed as annuity.
[5]Long-term average impacts.

Past experience suggests that this relative difference, in large part at least, will be short-lived. First, both wage earners and the business community have already begun to regain their former relative economic position by seeking wage and price increases. This means that the cost of labor, equipment, and materials to the farmer and rancher, as well as those to implement chaparral conversion and maintenance, will increase relative to feed grain and feeder cattle prices. Second, the farm products industry should, as it has in the past, respond to relative increases in the prices of its products with increased production, thereby diminishing the short-term price increases.

The new increase in foreign demand for our agricultural products, concurrent with devaluation and rising affluence abroad, was in part responsible for domestic price increases in farm products. It is impossible to determine the future course of foreign demand accurately. The best prediction at this time is that a large portion of the 50 percent increase in farm product prices relative to all other commodities will dissipate in the long run.

Since the net benefit of fire hazard reduction was based on differences between costs of conversion and costs of fire suppression, the relative difference should remain constant. The same conclusion applies to water if the replacement value of pumping is used, rather than ability to pay.

Conversion on steeper slopes. — The steeper the slope, the more difficult access becomes, the greater the potential for soil loss, and the smaller the increase in cattle carrying capacity. Conversion has been quite successful on the Three Bar Experimental Watersheds on slopes near 60 percent, however, and potential soil loss from a prescribed burn is generally less than from a wildfire. Nevertheless, the gentler slopes should receive preference.

Only 33 percent of the 332,796 acres covered by the 139 chaparral areas is on slopes of less than 30 percent. A reduction in the slope steepness criterion from 60 to 30 percent would affect some areas very little (such as those in Chino Valley and Thumb Butte Ranger Districts), but the treatable acreage on others, with a large portion of relatively steep slopes (such as those in Mesa and Roosevelt Ranger Districts), would be reduced considerably (table 1). The estimated treatment acreage in the 96 areas economically feasible for Alternative I conversion would be reduced by 37 percent to 93,235 acres.

Access requirement. — The lack of vehicular access to some of the possible conversion areas may influence the decision of whether or not to convert an area. Although accesss improvements increase firefighting efficiency, they also increase the chance of man-caused fire starts. In some cases, access improvements may conflict with the overall management plan for the area.

Several National Forest "roadless areas" have recently been proposed that include 10,720 acres in 13 of the 139 delineated chaparral areas. Exclusion of these areas from consideration for conversion would eliminate all or part of 10 of the 96 areas with B:C greater than 1.0 (Alternative I).

Limitations on access improvements could significantly restrict conversion possibilities. Half of the 96 areas with a B:C greater than 1.0 (Alternative I) require some accesss improvement for conversion. Eleven of these areas require a stretch of new road and nine additional areas require extensive primitive road improvements.

Fire policy. — Calculation of the "fire benefit" assumed continuation of present fire suppression and fuel management practices. In light of concerted fire suppression and minimal fuel management, conversion can significantly alleviate hazardous fuel situations and reduce firefighting costs. A change in suppression practices which allowed more fires to burn themselves out would reduce firefighting costs, and with them the estimated fire benefit.

Increases in prescribed burning, without subsequent efforts to maintain a grass stand and suppress shrub regrowth, would also affect the fire benefit. Less expensive than conversion, it would be more effective in reducing firefighting costs and would also be more acceptable to wildlife interests. If prescribed burning for fuel management were extensively practiced, the "fire benefit" of conversion would be minimal.

Experimental watersheds. — Seven of the 139 chaparral areas are presently held under special agreements. All had B:C ratios greater than 1.0. Their exclusion from consideration for conversion would reduce the number of areas economically feasible for Alternative I conversion to 89.

SUMMARY AND CONCLUSIONS

Chaparral covers approximately 850,000 acres on National Forest land in the Salt-Verde Basin. Over 500,000 acres have no potential for conversion because they are (1) in or adjacent to wilderness areas, (2) of less than 30 percent cover, or (3) on slopes greater than 60 percent. On the basis of specified cover, slope, and operational criteria, 332,796 acres, in 139 designated areas, were considered worthy of consideration for conversion.

The 139 areas were analyzed on the following operational premises:

- Herbicide use for conversion is acceptable (only time will tell if this premise is valid).
- Areas are successfully converted to grass.
- Proper grazing management follows conversion (thereby avoiding undue erosion).

To allow for establishment of a pattern of chaparral and grass acceptable from the wildlife and esthetics standpoints, we assumed that a maximum of 60 percent of a delineated area could actually be converted to grass. This assumption reduced the maximum acreage considered for conversion to 175,912 acres. Of this, 124,786 acres (71 percent) are on the Tonto and 51,126 (29 percent) are on the Prescott National Forest.

The 139 delineated chaparral areas represent the maximum chaparral available for conversion on National Forest land in the Salt-Verde Basin. Additional criteria — physical (soil, slope, or wildlife habitat), managerial (access requirements or grazing management problems), or economic (efficiency or budgetary constraints) — will reduce the maximum. We evaluated the economic efficiency of converting the 139 areas by means of benefit-cost analysis.

Costs and benefits of converting each of the 139 delineated areas were estimated for a 50-year time horizon. Treatment and maintenance costs were estimated for two conversion alternatives based on Forest Service experience. Costs of an Environmental Impact Statement, providing access, installing fuelbreaks and firelines, rootplowing, burning, seeding, and maintaining the conversion with burning, broadleaf herbicides, and partial seeding were calculated for Alternative I. Alternative II is similar to Alternative I, but modifies the fuelbreak-fireline requirement, replaces initial burning with a soil-applied herbicide, and eliminates herbicide maintenance. On the benefit side, the effects of conversion on runoff, forage production, and firefighting costs were estimated. A monetary value was put on the incremental yields, and the present values of the benefits and costs were compared in a benefit-cost ratio.

Three important assumptions were made for the economic analysis. First, a 6-7/8 percent discount rate was used. Second, we assumed that all increased runoff reaching the Phoenix Valley would be used for increasing agricultural production. Third, we assumed that the relative position of prices would not change over the long run.

For Alternative I, chaparral conversion was found to be economically feasible (benefit-cost ratio greater than 1.0) for 96 of the 139 delineated areas. These 96 areas contain a total of 273,383 acres on the Tonto and Prescott National Forests, 54 percent of which (147,118 acres) was considered the amount actually convertible. For Alternative II, costs increase such that only 72 areas, encompassing 106,543 actual conversion acres, are economically feasible for conversion.

Conversion Alternative I was also evaluated with the low, rather than the best, estimates of water, forage, and fire benefits. In this case 64 of the 139 areas, containing a total of 103,740 actual conversion acres, were found economically feasible for conversion.

If all 96 economically feasible areas were to be converted by Alternative I, the following average annual benefits could be expected: 0.21 foot of additional runoff downstream from each converted acre, 0.24 additional animal unit months per converted acre, and a 34 cent reduction in firefighting costs per converted acre. The

average per-acre annuity benefit ($4.49) minus the annuity cost ($1.98) leaves a net average annual return of $2.51 per converted acre. The total yields from conversion of 96 areas could potentially increase Basin runoff by 2.5 percent, increase Basin cattle carrying capacity by 3.6 percent, and decrease Basin firefighting costs by 3 percent. These yield increases are based on the best estimates of the benefits. Results for Alternative II, or for Alternative I with the low estimates of the benefits, are less optimistic.

Several non-quantified, non-value-determined impacts were also examined. Recreation use should increase in a few areas following conversion, but will probably be unaffected in most areas. Effects on soil movement, wildlife habitat, and esthetics will depend on the manner in which treatment and maintenance are carried out; proper management should favorably affect these values.

Although chaparral conversion was shown to be economically beneficial for some areas, this does not necessarily mean that they should be converted. More detailed analyses, utilizing additional criteria and on-site investigation, are of course required on a per-area basis. Furthermore, future consideration of benefits or costs, either primary or secondary, which were not quantified in this analysis, may change the results. Also, and most far-reaching, this study deals only with conversion; opportunity costs were not considered. Other uses of limited funds may supercede their use for chaparral conversion.

A comprehensive economic analysis such as this helps put the potential of chaparral conversion in perspective. By comparing all chaparral lands in the entire study area, the possibilities of future chaparral conversion in general are presented for the land manager and others to view. The rough estimates of the costs and benefits discourage both over-optimistic and over-pessimistic views of the program. Such a broad perspective is often very useful in determining the directions of future policy.

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APPENDIX

Table 10.--Location, size, and benefit-cost results for 139 chaparral areas in the Salt-Verde Basin, Arizona.

Area[1/]	Ranger[2/] District	Size: Total[3/]	Size: To be [4/] convert.	Benefit-Cost ratio 5/: Alt.I 6/ (best estimate)	Benefit-Cost ratio 5/: Alt.I 7/ (low estimate)	Benefit-Cost ratio 5/: Alt.II 8/	Benefit minus cost 9/ (best estimate)
		----Acres------					$
T 1	CC	3,203	1,922	1.02	0.59	0.58	1,141
T 2	CC	2,304	1,382	2.04	1.13	1.11	87,294
T 3	CC	3,200	1,920	1.92	1.14	1.13	51,668
T 4	CC	8,354	3,342	1.22	.74	.65	16,064
T 5	CC	4,076	2,446	.79	.04	.29	-22,152
T 6	P	4,160	2,496	1.36	.65	.78	22,538
T 7	P	512	307	2.53	1.57	1.80	18,940
T 8	P	200	120	1.09	.76	.93	772
T 9	P	2,592	1,555	2.16	1.52	1.22	50,465
T 10	P	3,281	1,969	2.56	1.69	1.43	78,479
T 11	P	2,746	1,648	3.05	1.89	1.84	98,019
T 12	P	3,136	1,882	2.80	1.65	1.71	95,463
T 13	P	1,088	653	3.41	1.95	2.21	55,177
T 14	P	3,238	1,943	6.40	4.13	3.21	243,171
T 15	P	2,429	1,457	2.72	1.73	1.63	70,899
T 16	P	448	269	1.16	.75	1.05	2,635
T 17	P	189	113	.54	.38	.50	-5,850
T 18	P	3,789	2,273	2.69	1.64	1.60	94,725
T 19*	P	3,564	1,426	3.19	1.81	1.80	83,960
T 20	P	6,183	2,473	3.88	2.34	2.04	165,550
T 21	P	6,365	2,546	3.15	1.87	1.67	126,774
T 22	P	640	384	.49	.38	.39	-12,521
T 23	M,R	7,751	4,651	2.59	1.80	1.47	165,903
T 24	M	5,180	3,108	2.08	1.56	1.17	85,121
T 25	M	250	150	.77	.67	.65	-2,145
T 26	M	384	230	1.28	.89	1.01	3,130
T 27	R	3,002	1,801	2.42	1.75	1.45	74,132
T 28	M,R	2,632	1,579	3.02	2.00	1.85	91,051
T 29	R	184	110	.44	.39	.44	-9,157
T 30	M,R	3,379	2,027	2.44	1.60	1.50	84,207
T 31	R	448	269	.67	.54	.51	-4,063
T 32	R	220	132	1.27	.87	1.35	2,890
T 33	M,R	4,995	2,997	2.47	1.66	1.49	117,628
T 34	M	6,976	4,186	2.39	1.62	1.33	134,537
T 35	M,R	1,735	1,041	1.68	1.22	1.08	24,438
T 36	R	8,418	5,051	2.61	1.87	1.41	165,214
T 37	M	352	211	1.46	.99	1.28	6,460
T 38	R	320	192	.23	.20	.21	-10,777
T 39	M	1,856	1,114	.19	.70	.73	7,074
T 40	M	-------------------Brushy Basin-------------------					
T 41*	R	2,462	1,477	4.30	2.92	2.26	118,765
T 42*	R	706	424	1.66	1.08	1.35	13,395
T 43	M	800	480	.88	.69	.74	-4,281
T 44	M	1,344	806	1.14	.82	.89	7,500

Table 10. continued

Area[1/]	Ranger District[2/]	Size: Total[3/]	Size: To be convert.[4/]	Benefit-Cost ratio 5/: Alt.I 6/ (best estimate)	Benefit-Cost ratio 5/: Alt.I 7/ (low estimate)	Benefit-Cost ratio 5/: Alt.II 8/	Benefit minus cost 9/ (best est.)
		---- Acres	-----				$
T 45	M	704	422	1.38	.94	1.17	10,875
T 46	M	224	134	.56	.42	.53	-8,809
T 47*	R	1,920	1,152	1.80	1.22	1.15	32,268
T 48*	R	2,902	1,741	1.75	1.06	.99	35,019
T 49	M	256	154	.83	.53	.77	-3,173
T 50*	R	650	390	1.12	.61	.81	2,298
T 51	PV	384	230	.82	.64	.74	-2,924
T 52	P,PV	704	422	.44	.34	.37	-16,238
T 53	PV	448	269	.56	.34	.48	-12,607
T 54	PV	1,088	653	.83	.60	.64	6,791
T 55	PV	2,432	1,459	2.08	1.38	1.30	53,833
T 56	R	2,432	1,459	2.31	1.64	1.42	62,774
T 57	PV	3,692	2,215	2.80	1.95	1.60	110,541
T 58	PV	3,119	1,871	2.87	1.91	1.57	90,652
T 59	PV	384	230	1.33	.97	1.16	4,963
T 60	PV	1,216	730	2.67	1.73	1.80	44,485
T 61	PV	128	79	.67	.61	.69	-4,339
T 62	PV	832	499	3.58	2.97	2.54	46,518
T 63	R	704	422	1.52	1.24	1.44	9,038
T 64	PV	1,280	768	2.55	1.68	1.72	48,253
T 65	PV	192	115	1.23	.99	1.13	3,341
T 66	PV	1,126	730	3.57	2.29	2.47	78,429
T 67	PV	635	381	3.62	2.08	2.47	36,818
T 68	PV	1,145	687	1.73	1.01	1.14	19,406
T 69	PV	3,680	2,208	3.18	1.98	1.98	99,354
T 70	PV	4,595	1,838	2.94	1.79	1.64	133,579
T 71	PV	960	576	2.46	1.68	1.74	32,392
T 72	PV	1,616	970	3.35	2.38	1.93	65,894
T 73	PV	2,816	1,408	2.63	1.74	1.55	70,856
T 74	PV	2,683	1,342	1.35	.92	.89	17,103
T 75	PV	96	58	.88	.66	.87	-1,195
T 76	PV	88	53	1.15	1.06	1.12	1,128
T 77	PV	192	77	.74	.70	.73	-3,962
T 78	PV	448	179	1.85	1.49	1.59	11,485
T 79	PV	256	154	2.04	1.87	1.89	13,401
T 80	PV	5,970	1,493	1.06	.80	.66	2,815
T 81	PV	723	434	.89	.47	.66	-2,066
T 82	PV	632	379	1.36	.71	1.05	7,629
T 83	R	1,336	802	2.61	1.70	1.78	49,741
T 84*	PV	3,745	2,247	3.15	2.18	1.84	129,356
T 85	R	792	396	1.50	1.08	1.08	7,265
T 86	G	1,280	768	.83	.40	.54	-4,777
T 87	G	448	179	.94	.89	.80	-613
T 88	G	5,632	2,253	1.30	.40	.75	16,466

Table 10. Continued

Area[1]	Ranger[2] District	Size: Total[3]	Size: To be 4/ convert.	Benefit-Cost ratio 5/: Alt.I 6/ (best estimate)	Benefit-Cost ratio 5/: Alt. I 7/ (low estimate)	Benefit-Cost ratio 5/: Alt.II 8/	Benefit minus cost 9/ (best est.)
		--- Acres	------				$
T 89	G	1,632	653	2.92	1.73	1.83	42,408
T 90	G	6,720	2,688	1.50	.48	.79	30,972
T 91	G	5,696	3,418	1.55	.58	.91	43,095
T 92	G	192	115	.64	.28	.54	-2,905
T 93	G	2,976	1,190	.11	.01	.06	-33,541
T 94	G	704	422	.46	.15	.32	-8,240
T 95	G	448	269	.46	.27	.35	-6,435
T 96	G	2,186	874	.15	.01	.09	-26,503
T 97	G	2,432	973	2.36	1.12	2.31	38,969
T 98	G	1,216	486	.78	.21	1.01	-4,490
T 99	G	128	51	.24	.11	.24	-6,911
T100	G	320	128	.74	.23	.57	-1,965
T101	G	384	154	.12	.11	.10	-10,409
T102	G	216	108	.44	.39	.40	-6,771
T103	G	2,656	1,062	1.76	1.62	1.15	29,903
T104	G	4,680	1,872	2.61	2.08	1.43	75,791
T105	G	2,480	992	2.13	1.66	1.34	38,127
T106	G	1,563	625	2.01	1.46	1.31	23,686
T107	G	4,492	2,695	3.68	2.33	2.08	177,825
T108	G	1,920	1,152	2.10	1.34	1.36	43,883
T109	G	6,508	3,905	2.71	1.43	1.59	155,747
P 1	WC	1,952	781	.21	.10	.16	-28,011
P 2	WC	3,424	2,054	2.10	.95	1.28	65,890
P 3	WC	1,523	914	.62	.04	.47	-11,837
P 4	WC	2,720	40	1.45	1.17	.99	18,298
P 5	WC	704	422	2.49	1.45	1.85	29,231
P 6	WC	5,440	3,264	2.04	1.07	1.19	88,068
P 7	WC	11,328	6,797	3.26	1.40	1.67	269,934
P 8	WC	12,160	7,296	1.59	.06	.84	76,764
P 9	WC	1,248	624	.80	.33	.53	-6,339
P 10	WC	2,611	1,306	1.72	.97	1.03	33,181
P 11	WC	2,924	1,754	1.31	.05	.70	14,569
P 12	WC	3,424	2,054	1.70	.21	.89	36,036
P 13	TB	1,024	307	.25	.07	.15	-13,062
P 14	TB	1,984	595	.43	.12	.24	-12,145
P 15	TB	352	211	.68	.19	.46	-5,006
P 16	TB	3,776	1,133	1.23	.13	1.04	8,276
P 17	TB	1,664	832	1.40	.57	.93	11,772
P 18	TB	576	230	.76	.52	.42	-3,199
P 19	TB	576	230	1.31	.81	.61	3,569
P 20	TB	704	141	1.47	.75	.82	5,680
P 21	TB	480	288	1.72	.94	.78	9,485
P 22	TB	608	365	1.56	.97	.77	10,046

Table 10. Continued

Area 1/	Ranger District 2/	Size: Total 3/	Size: To be convert. 4/	Benefit-Cost ratio 5/: Alt.I 6/ (best estimate)	Benefit-Cost ratio 5/: Alt. I 7/ (low estimate)	Benefit-Cost ratio 5/: Alt.II 8/	Benefit minus cost 9/ (best est.)
		-----Acres-----					$
P 23	V	1,536	922	1.59	1.37	.78	18,198
P 24	V	1,382	415	1.28	1.06	.59	5,474
P 25	V	384	192	.52	.41	.19	-6,199
P 26	CV	192	115	.28	.17	.13	-13,327
P 27	V	7,359	4,415	.28	.24	.13	-69,451
P 28	V	3,968	2,381	.41	.01	.21	-36,572
P 29	V	7,616	4,570	.02	.01	.01	-98,121
P 30	CV	4,255	2,553	1.10	.59	.56	6,810
P 31	V	9,581	2,876	.65	.56	.34	-27,898

1/ Numbers of areas in Fig. 2 (Tonto National Forest) are preceded by "T"; numbers of areas in Fig. 3 (Prescott National Forest) are preceded by "P". Starred (*) areas are presently held under a special management agreement.

2/ Ranger Districts on the Tonto are Cave Creek (CC), Globe (G), Mesa (M), Payson (P), Pleasant Valley (PV), and Roosvelt (R). Districts on the Prescott are Chino Valley (CV), Thumb Butte (TB), Verde (V), and Walnut Creek (WC).

3/ The total acreage of the area minus any private property in the area.

4/ The portion of the area (60 percent or less) estimated to be convertible.

5/ Discount rate is 6-7/8 percent.

6/ Conversion Alternative I: initial burn with maintenance burns and broadleaf herbicide sprays.

7/ Alternative I but based on the low, rather than the most likely, estimates of the water, forage, and fire benefits.

8/ Conversion Alternative II: initial soil-applied herbicide with maintenance burns.

9/ Present value of benefits minus present value of costs for Alternative I at 6-7/8 percent.

Brown, Thomas C., Paul F. O'Connell, and Alden R. Hibbert
1974. Chaparral Conversion potential in Arizona. Part II: An economic analysis. USDA For. Serv. Res. Pap. RM-127, 28 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

Is chaparral conversion on National Forests in the Salt-Verde Basin economical? An inventory revealed 139 chaparral areas totaling 332,796 acres meet certain crown cover, slope, and managerial criteria for conversion. The costs of converting portions of these areas to grass and maintaining the conversion over a 50-year period were compared with the benefits to society in terms of increased water yield and forage for livestock, and reduced firefighting costs. Using fire as the main conversion tool, 96 areas have a benefit-cost ratio greater than 1; using a soil-applied herbicide, 72 areas meet that economic criterion. Proper management should favorably affect soil movement, wildlife habitat, and esthetics. Recreation use would be unaffected in most areas.

Keywords: chaparral control, multiple use, economic evaluation, cost estimation

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PESTICIDE PRECAUTIONARY STATEMENT

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

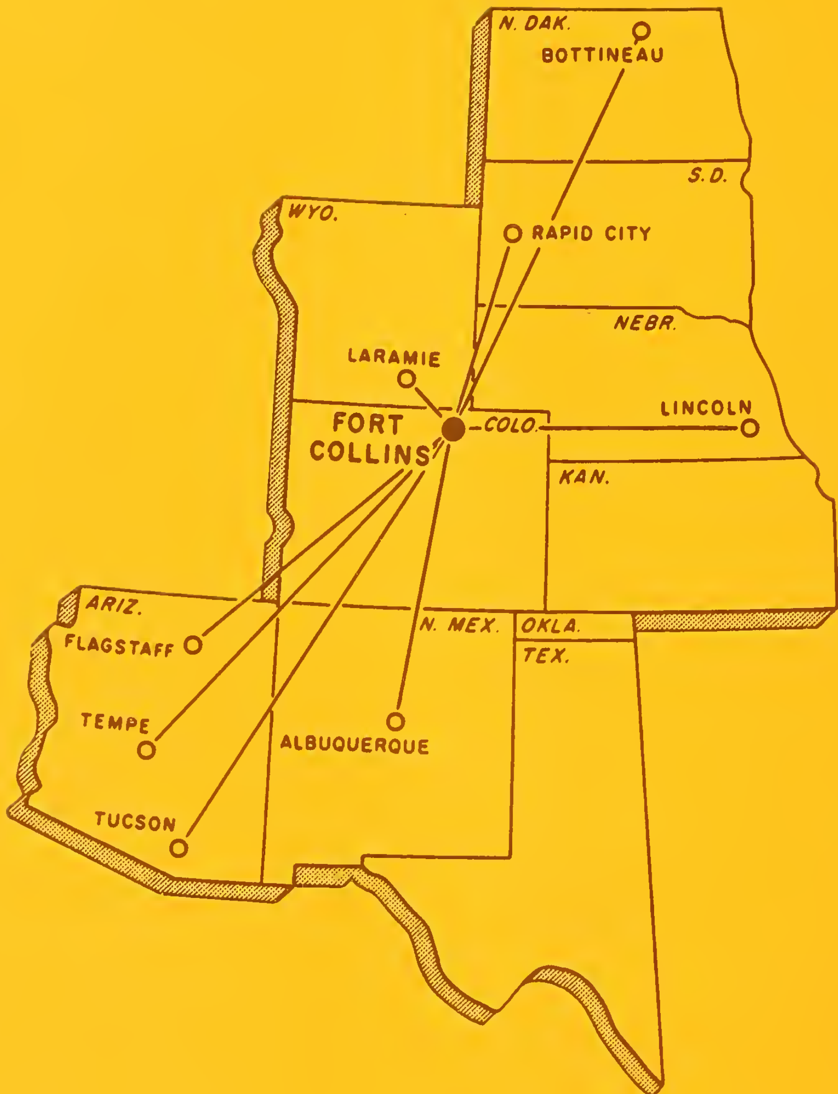
CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE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