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Managing Interior Northwest Rangelands: The Oregon Range Evaluation Project

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Abstract

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This report is a synthesis of results from an 11-year study of the effects of increasing intensities of range management strategies on herbage production, water resources, economics, and associated resources—such as wood fiber and recreation—in Grant County, Oregon. Four intensities of management were studied on Federal land (19 grazing allotments) ranging from no grazing to intensive management aimed at improving livestock distribution and forage production by applying cultural treatments. On private land (21 cooperating ranches), an additional strategy aimed at maximizing commodity production was tested. During the course of the project, more than 1000 range improvement practices were installed on 350,000 acres.

Baseline herbage production information was developed for 51 resource units that comprise 10 major ecosystems. Effects of increasing intensities of management on herbage production were determined. The resultant increase in carrying capacity was determined, and the allocation—by ecosystem—of animal unit months within pastures was determined. The most intensive strategy on both Federal and private land was generally the economically optimal strategy. Effects of increasing intensity of management on water resources was tested only on Federal land. Baseline information on water yield and timing, storm runoff, pollution indicator bacteria, dissolved chemicals, and temperature was generated. Changes in the measured water parameters in response to increasing intensity of management were measured. The only parameter that could be related directly to increasing intensity of management and increased cattle use was bacterial quality.

More than 100 publications and reports were developed. Predictive models for water yield, stream temperature, and animal unit months outputs were developed. A handbook on specifications for range improvement practices was produced, and costs of these practices were determined.

Results provide state-of-the-art information for managing rangelands in the interior West, with understanding of the economic consequences and effects on related resources.

Keywords: Range improvement, range management strategies, range economics, herbage production, forage production, range carrying capacity, animal unit month allocation, range watersheds, water yield, stream discharge, stream temperature, pollution indicator bacteria, fecal coliforms, fecal streptococcus, stream chemistry.

Preface

This book represents the successful culmination of an 11-year research and management program that involved 21 private landowners and 7 State of Oregon and Federal Agencies. The Forest Service is proud to have been a partner in this effort. The coordinated resource management planning used in this project is an example of how we will be doing business in the future as we implement new Forest Management Plans and revise Allotment Management Plans to incorporate new standards, guidelines, and management requirements. This planning process emphasizes multi-resource and interdisciplinary management. A full range of natural resource and economic values was incorporated and integrated as a result of this effort. Included were forage production, livestock use, wildlife habitat and riparian enhancement, environmental quality, rural community stability, and economic development to maintain and enhance a diverse and healthy economic base in eastern Oregon.

A framework for quality management of rangelands is provided in this book. Of more lasting importance, however, is the cooperation that was fostered through the program, as agencies and private individuals worked toward common goals. Both the economies of Grant County and eastern Oregon and their natural resource base have benefited from this effort. The future direction of natural resource management has been enhanced by the Oregon Range Evaluation Project.

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1 Developing and Implementing the Project

H. Reed Sanderson

The Oregon Range Evaluation Project (EVAL) was developed as a result of a 1970 review of the range resources in the 48 adjacent United States. Information from this review was used to construct and model alternative sets of goals and to evaluate the minimum cost of each alternative under different political, social, environmental, and economic targets (Forest-Range Task Force 1972). This review led to the Accelerated Range Program, which included Evaluation Areas. Information from the Evaluation Areas was to be used to make adjustments in implementing the Accelerated Range Program.

Since the early 1960's, the Grant County (Oregon) Resource Council, the Grant County Commissioners, and other resource groups in Grant County have worked diligently to find ways to develop and maintain their natural-resource-based economy. County groups saw the Accelerated Range Program and the Evaluation Area concept as an opportunity to improve the County's critical economic situation and to obtain additional information on the social, environmental, and economic impacts of alternative management strategies in different forest-range ecosystems. As a consequence, the Grant County Resource Council proposed to the Pacific Northwest Regional Forester and the Pacific Northwest Research Station Director that Grant County be designated as an Evaluation Area. In October 1974, the Regional Forester and Station Director submitted a report to the Chief of the Forest Service nominating a portion of the Blue Mountains in Oregon as an Evaluation Area.

The Grant County Resource Council organized support from 31 groups throughout Oregon, and Resource Council members testified before the Senate and House Interior Subcommittees. The Resource Council promoted the Oregon Evaluation Area and requested necessary funding. Congress appropriated 1.4 million dollars to begin the Oregon Range Evaluation Project in January 1976.

The USDA Forest Service defined eight major objectives: (1) to identify range management practices that influence herbage production; (2) to identify combinations of ecosystem, productivity, and condition class that can be expected to increase herbage production under various range management practices; (3) to apply range management practices on public and private land; (4) to evaluate costs of implementing range management practices; (5) to evaluate herbage production as a result of implementing range management practices; (6) to evaluate related resource outputs after practice implementation; (7) to inform and involve local landowners, managers, officials, agency representatives, and interested citizens; and (8) to provide periodic feedback of results.

Description of the Area

The Oregon Range Evaluation Area in east-central Oregon included the northern half of Grant County plus small portions of Umatilla and Wheeler Counties on the northwest and west boundaries (fig. 1-1). About half of the 1.5 million acre area is in public ownership, primarily the Malheur National Forest (fig. 1-2) (appendix A, table 1).

Terrain is generally hilly or mountainous and predominantly range and forest land (fig. 1-3). Elevations range from about 2,000 to 8,000 feet. The entire area is drained by the John Day River system, and major streams are deeply entrenched. Irrigated valley land occurs along the main stem of the John Day River, the lower North Fork, and on portions of the Middle Fork.

About 350 private ranches, 115 Bureau of Land Management grazing leases, and 60 Forest Service grazing permits are included in the area. With few exceptions, these leases and permits are held by area ranchers.

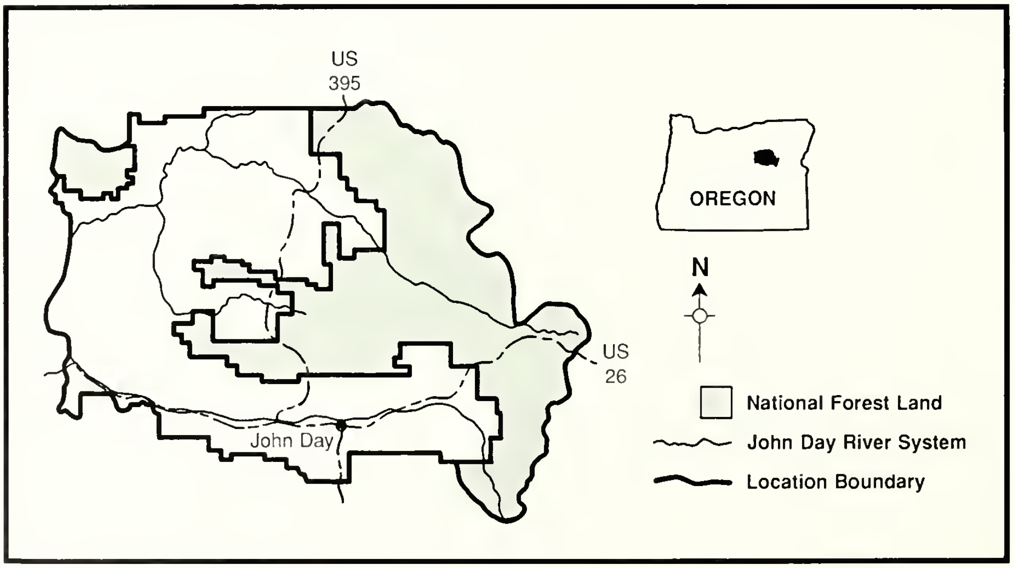

Figure 1-1—Location and boundary of the Oregon Range Evaluation Project.

Figure 1-2—Land ownership in the Oregon Range Evaluation Project.

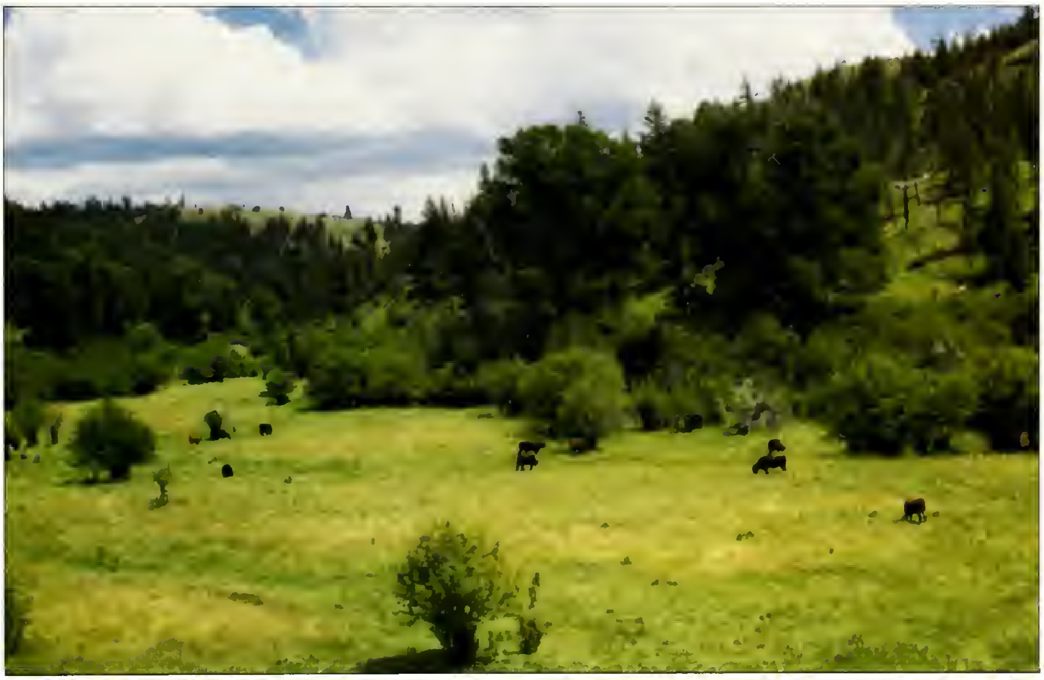

Figure 1-3—The Oregon Range Evaluation area is dominated by forest and range land.

Geology

The Oregon Range Evaluation Area is in the Blue Mountain Physiographic Province of Oregon (Dickens 1955), on the borderline of two major geologic provinces—the Columbia Plateau to the north and the Basin and Range Province to the south.

Geological formations range from Paleozoic sediments and metamorphic to Tertiary volcanic. The most varied occur in the high mountain areas where old ocean sediments have been folded, faulted, and raised above surrounding lowlands. The oldest formations are found in the Greenhorn Mountains, where a wide variety of complexly folded and faulted sedimentary and volcanic rocks form the eastern boundary (Beaulieu 1972). In the Strawberry and Aldrich Mountains, which form the southern boundary, Triassic and Jurassic sedimentary shales, mudstones, sandstones, and siltstones are found from Canyon City west to Aldrich Mountain; to the east the peridotites, gabbros, and serpentines of the Canyon Mountain complex predominate.

North and west of the Strawberry-Aldrich and Greenhorn ranges, Tertiary volcanics of the Clarno, John Day, and Columbia groups underlie the remainder of the area. These include rhyolites, breccia, tuff, and water-laid ash along with basalt and andesite flows.

Structure in the area consists of a series of northwest-southeast-trending anticlines and synclines along with three major fault systems.

Soils

Soils are divided into three major physiographic areas: alluvial fans and flood plains, mainly along the main stem of the John Day River and the lower reaches of the North Fork; medium elevation uplands (2,000-5,000 feet); and high elevation uplands (5,000-8,000 feet) and open basins or mountain valleys.

The alluvial fans and flood plains are generally arable and used for crops, hay, or improved pasture. They occur on nearly level to gently sloping fans and terraces with deep, well-drained loam and clay-loam soils and deep, somewhat poorly drained alkali silty clay loam or silty clay loam with weak pan soils. The flood-plain soils are deep, well-drained silt loam or sandy loam, and moderately deep gravelly soils that are well-drained loams, somewhat poorly drained silt loam-sandy loam, or poorly drained silty clay loam.

The medium elevation uplands are primarily areas of sediments and volcanics that support shrub-grass vegetation. They occupy the zone between the alluvial fans and flood plains and the high elevation uplands and mountain valleys. Where these soils occur over sediments, they are moderately deep clayey soils. Where they occur over loess or ash, they are silty, nonstony soils.

The high elevation uplands are forested areas of sediments or volcanics. National Forest lands occupy most of this physiographic area. Included are deep, nonstony soils comprised of clay over sediments; silty clay loam over clay, silty clay loam, and silt loam derived from loess; silt loam and loam from volcanic ash; and moderately deep, nonstony soils, mostly in mounds.

Figure 1-4—Little Boulder Creek during peak streamflow.

The soils over volcanic rock are moderately deep, stony soils including reddish, silty clay loam; brownish, loam-clay loam; and brownish, gravelly clay loam. Other areas within the high elevation uplands are shallow, stony soils lacking forest cover. The major mountain valley or open basin is Fox Valley. This subdivision supports grass-shrub and wet meadow vegetation. Included are dark, silty, well-drained soils that are shallow over tuff, moderately deep over tuff, or deep over old sediments; black, poorly drained soils developed from alluvium that are silty clay, silty clay loam, or alkali-affected, silty clay loam.

Climate

The EVAL area ranges from semiarid to cold, subhumid. Annual precipitation is about 10 inches at low elevations and increases to about 40 inches in the mountains. About 80 percent of the precipitation occurs between October 1 and May 31 (Fowler and others 1979). Precipitation in the low elevations is principally rain; high elevations have snow between October and May.

The growing season ranges from 80 to 120 days, depending on elevation. At the high elevations, no months are considered frost free. Temperature extremes range from -50 to +110 degrees F. Summers are hot and dry, with the exception of low night temperatures in the high mountains. Winters are cold and moist.

Hydrology

The John Day River System drains the entire area; about 75 percent of the runoff is from National Forest lands. The river system has three major drainages within the project area: North Fork, Middle Fork, and the main stem. The Middle Fork drains most of the area. Peak streamflow is in a 6-week period centering about mid-April and results from snowmelt and occasional heavy rain (fig. 1-4). Minimum streamflow occurs between July and October. Yearly extremes are related to differences in winter snowpack. Water quality standards for the project area are governed by the Oregon Department of Environmental Quality. Maximum water temperatures occur during periods of low flow and occasionally exceed the tolerance of cold water fish in small tributaries. In areas where livestock are concentrated, coliform bacteria standards for primary contact recreation may be exceeded for short periods.

Flora

The Forest-Range Environmental Study identified 34 ecosystems in the 48 contiguous States (Garrison and others 1977). Ten of these ecosystems occur in the Project Area: Douglas-fir, ponderosa pine, lodgepole pine, larch, fir-spruce, sagebrush, juniper, mountain grasslands, mountain meadows, and alpine. Forest ecosystems dominate the mountainous terrain, which is largely National Forest land. The mountain grasslands, sagebrush, and juniper ecosystems dominate the hilly terrain, which is mostly private and Bureau of Land Management land.

Fauna

A wide variety of animal life is found in the Evaluation Area. Huntable big game include mule deer, Rocky Mountain elk, black bear, pronghorn antelope, cougar, and bighorn sheep. Upland game birds are ruffed grouse, blue grouse, mourning doves, California and mountain quail, chukars, Hungarian partridge, turkey, and pheasant. Waterfowl includes ducks and geese.

Furbearers include beaver, mink, muskrat, raccoon, skunk, badger, bobcat, and coyote.

The peregrine falcon is the only nationally recognized endangered species that may occur in the area. Species considered threatened by the Oregon Department of Fish and Wildlife include the bald eagle and snowy plover.

The Middle Fork, North Fork, and main stem of the John Day River are spawning and rearing habitat for steelhead and chinook salmon. The streams, lakes, and reservoirs also serve as habitat for several species of trout.

In addition to these species there is a wide variety of nongame birds, mammals, and fish.

Economic Conditions

Grant County, Oregon, has limited economic opportunities compared to more heavily populated regions. The county lacks a broad industrial base, and it has little potential for growth in new or existing industry. The County population is about 8,000 in an area of 4,533 square miles—one of the least populated counties in Oregon. Major population centers and markets for agricultural and forest products are far removed, and transportation links are primarily paved, two-lane roads. Residents rely on income generated from the sale of basic resource-industry. The future holds little promise for diversification and industrialization. If the people of Grant County are to maintain their economic base, the conservation and development of renewable resources and improved management of the basic resources industries—forestry, agriculture, and recreation—will be required. Sales of agricultural and forest products account for over 50 percent of the income. Over 60 percent of all lands within Grant County are controlled by Federal and State agencies, primarily the Forest Service and the Bureau of Land Management. Consequently, County economic conditions are strongly dependent on public land management decisions and policies.

Organization and Cooperating Agencies

The Oregon Range Evaluation Project lead agency was the Forest Service, including the National Forest System, State and Private Forestry, and Forest Service Research. Primary cooperating agencies included the Soil Conservation Service and Agricultural Stabilization and Conservation Service in the U.S. Department of Agriculture; the Bureau of Land Management in the U.S. Department of the Interior; Oregon Department of Forestry, Oregon Department of Fish and Wildlife, and Oregon State University Extension Service. Memoranda of Understanding were developed between the Forest Service and cooperating Federal and State agencies that detailed the responsibilities of each agency and designated funds to be used to accomplish the work.

Other cooperating organizations and institutions were the Farmers Home Administration; the Grant County Resource Council; the National Park Service and the United States Fish and Wildlife Service, Department of the Interior; the Soil and Water Conservation Districts; Oregon State University; Washington State University; Southwestern Oregon State College; and Eastern Oregon State College.

EVAL was directed by a nine-member team. The National Forest System provided the project coordinator, who served both as team leader and representative for the National Forest System and the State and Private Forestry. Each primary cooperating agency, including Forest Service Research and private landowners, was represented by a team member. Each member of the team had an equal voice. The EVAL Project was approached as a continuous team effort with a clear understanding that the project required the cooperation, consultation, and understanding of all participants (fig. 1-5).

Each agency represented on the EVAL team continued their traditional role and responsibility.

Forest Service

The Forest Service role was carried out by an interactive group of people from the National Forest System, State and Private Forestry, and Research. Fiscal accountability for all appropriated project funds was a primary Forest Service responsibility.

The National Forest System planned and implemented the Accelerated Range Program on National Forest lands within the Evaluation Area. Areas where strategies were applied were large enough to reflect practical management for realistic livestock distribution and forage use.

Responsibilities included mapping vegetation and determining management strategies, assisting in coordinated resource planning, applying range practices to achieve prescribed management strategies, and maintaining strategies and practices throughout the project. District Rangers remained responsible for administering grazing permits and other uses of the National Forest.

The primary role of State and Private Forestry was to work through Federal and State agencies to implement the Evaluation Project on private forest-rangelands. They were responsible for securing cooperative agreements between agencies and private landowners, and facilitating the transfer of funds from Forest Service accounts to cooperating agencies and private landowners as work was accomplished.

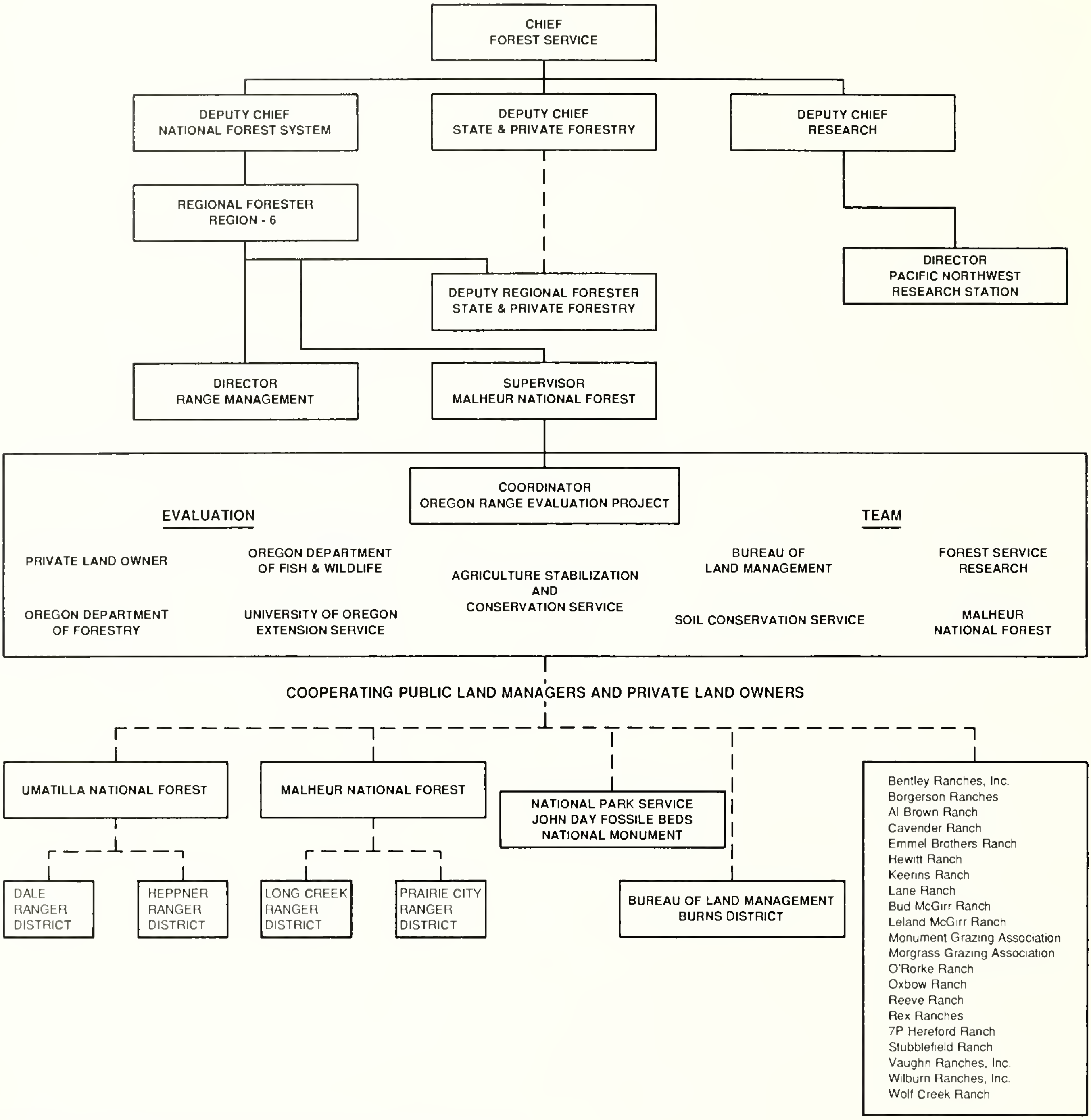

Figure 1-5—Oregon Range Evaluation Project organizational chart.

The role of Forest Service Research was to assess social, economic, and environmental effects of implementing the range management strategies. Research helped design the range practice experiments to isolate variables effectively and exclude external variables so that the results could be clearly and easily interpreted. Research was also responsible for reporting the results derived from the EVAL Project to appropriate users.

Soil Conservation Service

The Soil Conservation Service provided technical assistance to cooperating private landowners. The primary role of the Service was to inventory the range resources and assist in preparing the Coordinated Resource Management Plans (CRMP's) and Long-Term Agreements (LTA's). The Service also provided the technical expertise, standards, and guidelines for installing range practices on private lands and reviewed and certified their completion.

Agricultural Stabilization and Conservation Service

The role of the Agricultural Stabilization and Conservation Service was to facilitate LTA's and document cost-share payments due participating private landowners after technical certification by the responsible agency. The County Committee reviewed each request for payment to ensure it was in line with the cost of the work accomplished. The County Committee provided assistance to the EVAL team by determining local rates for landowners who chose to use their own labor or machinery to install range practices.

Bureau of Land Management

The role of the Bureau of Land Management was limited during the EVAL project because of prior litigation (U.S. District Court for the District of Columbia 1975). No tests of range practices were implemented on Bureau of Land Management lands through the EVAL project, but the bureau did participate in developing CRMP's, especially on their lands.

Oregon Department of Forestry

The Oregon Department of Forestry provided technical assistance to participating private landowners for forestry management and practices. State Forestry was also responsible for approving prescribed burns, issuing burning permits, and providing technical assistance for prescribed burns on private lands. State Foresters inventoried and developed CRMP's for forest resources on private lands. They provided the technical expertise, standards, and guidelines for installing certain land management practices on private lands and for reviewing and certifying their completion.

Oregon State University Extension Service

The Extension Service was the primary information and education organization: they prepared brochures, pamphlets, and slide programs. Extension was responsible for making landowners aware of the goals, opportunities, and requirements for participating in the EVAL project. Extension served as a technical consultant and participant in developing CRMP's. The Service provided technical expertise, standards, and guidelines for installing certain of range practices on private lands and reviewing and certifying their completion. The Extension Service facilitated communication between cooperators and the EVAL team and scheduled the use of such equipment as rangeland drills, plows, and seeders.

Oregon Department of Fish and Wildlife

The Oregon Department of Fish and Wildlife provided technical assistance on fisheries and wildlife habitat needs for preparing CRMP's. Wildlife biologists also provided expertise to private landowners interested in enhancing wildlife habitat on their lands.

Private Landowner Representative

The private landowner representative provided practical assistance to the EVAL team and participating landowners by providing the ranchers' point of view at team meetings and adding more practicality in the development of CRMP's and LTA's. The private landowner added stability and coordination between ranchers and team members and helped solve disagreements. The representative provided the EVAL project with a source of credibility and communication, which are sometimes perceived as poor in the government sector.

The Evaluation Project

EVAL was conceived as a 10-year project, with funding through the three branches of the Forest Service (fig. 1-6) (appendix A, table 2). State and Private Forestry provided funding for primary cooperating agencies except the Bureau of Land Management, which did not request reimbursement (fig. 1-7) (appendix A, table 3). The project supported 189 full-time permanent employee-years from fiscal year 1976 through 1986 (appendix A, table 4). By 1982, several personnel changes and a significant decrease in project funding had occurred. As a result, project objectives were reviewed and the outputs to be evaluated were decreased from 18 to 6 (appendix A, table 5); the time for collecting data decreased 1 year; and the project was extended by 1 year to provide additional time for data summaries, analyses, and preparation of publications.

The objective of EVAL was reduced to determining the most cost-effective means of providing increased herbage and browse for livestock and determining the effects on water quantity and quality and consequences for the local economy.

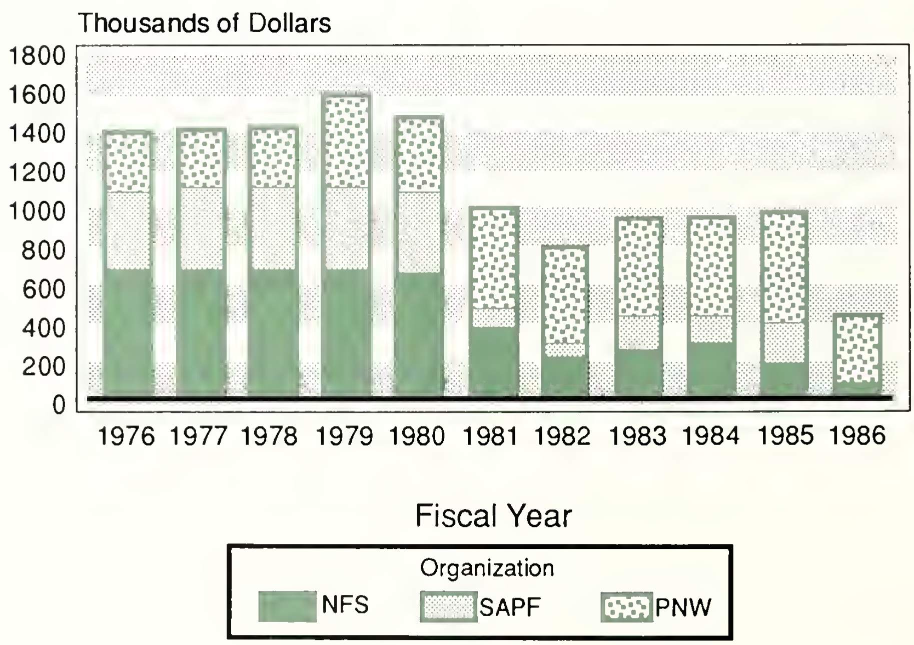

Figure 1-6—Appropriated funds for the Oregon Range Evaluation Project, 1976-1986.

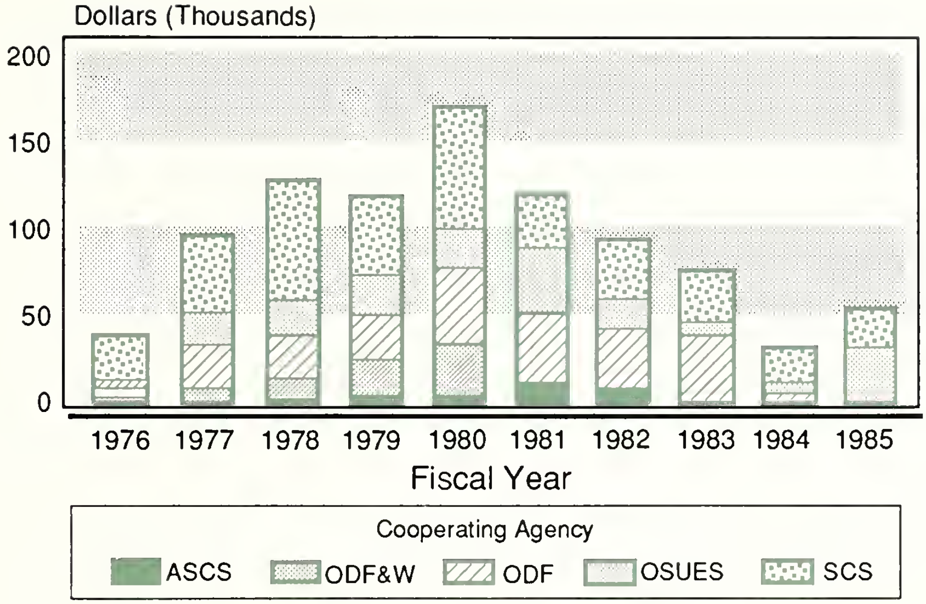

Figure 1-7—Forest Service reimbursement to agencies cooperating in the Oregon Range Evaluation Project.

Revised Goals and Objectives

The goal of EVAL was to acquire, develop, assemble, and relate information needed to manage the range resource with related resources such as, water, forest, wildlife, and recreation, in an economical and harmonious manner.

Specific objectives included were to

- Identify and apply the appropriate range management practices that can be expected to enhance herbage production.
- Evaluate the costs associated with each practice individually and in combination, to achieve the range management strategies for each vegetative type and each pasture.
- Evaluate the direct effects on herbage and browse production.
- Evaluate the effects on water quality and quantity.
- Evaluate the effect of management strategies on carrying capacity and the allocation of animal unit months (AUM's) within pastures.
- Determine economically optimal management strategies for public and private lands.

Accomplishing these objectives was a mutual undertaking by the primary cooperating agencies. The project was divided into four major elements: implementing, maintaining, monitoring, and reporting. These elements were used to stratify project activities, including funding responsibility and work planning.

Figure 1-8—Over 600 sites were monitored to determine the effect of grazing strategies on herbage and browse production.

Implementing

"Implementing" included selecting private landowners to cooperate with the project, developing CRMP's and LTA's, and establishing selected range management practices on public and private land. Practice implementation was scheduled for the first 5 years of the project, 1976 through 1980, but funding interruptions, landowners' financial constraints, and scheduling problems extended implementation through 1983. Once the strategies were implemented, the range practices had to be maintained at acceptable standards for the duration of the project to obtain quality data. Forest Service Research was responsible for collecting baseline data and evaluating the effects of grazing management strategies on environmental, economic, and social resources. The reporting included data management, data summaries and analyses, and dissemination of results to public and private land managers, resource planners, private landowners, educators, and other interested persons.

Monitoring

The Forest Service, Pacific Northwest Research Station, was assigned monitoring responsibilities for EVAL. The monitoring project was headquartered at the Forestry and Range Sciences Laboratory, La Grande, Oregon. Their initial assignment broadly consisted of assessing environmental effects, economic returns, and social benefits (fig. 1-8).

Analysis of range practices that were needed to achieve a prescribed management strategy emphasized economic input so that production goals could be accomplished with least cost. Ongoing practices were carefully monitored throughout the EVAL project to determine which practices might be environmentally or socially unacceptable, or uneconomical.

Figure 1-9—Construction costs were recorded for each range practice installed on the Oregon Range Evaluation Project.

Analyzing timber harvesting activities, which have a much greater impact on a site than range management activities, was not within the scope of the EVAL project. Therefore, sites that had been subjected to timber harvesting within 5 years preceding EVAL were avoided when monitoring sites were selected. Range practices were established, however, in pastures with recent timber harvests to take advantage of the additional herbage produced by tree removal. Precommercial thinning and debris disposal designated as range practices were monitored.

Monitored Outputs

The 6 outputs remaining from the original 18 were divided into 3 primary groups: (1) animal unit months, herbage and browse production, herbage and browse utilization, and stocking; (2) water yield, storm runoff, water quality (including sediment); and, (3) economic assessment, which includes employment and animal value, and practice cost accounting (fig. 1-9).

To accomplish the economic assessment and evaluate the investments in precommercial thinning, the value of wood yield had to be included. Some of the discontinued outputs were completed under the terms of cooperative agreements made before 1982, including birds, dispersed recreation, scenic beauty, and cultural heritage, and have been prepared for publication. The remaining six outputs and their related components were analyzed and published in various scientific outlets.

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2 Development of Management Plans and Management Strategies

H. Reed Sanderson

The Coordinated Resource Management Plan (CRMP) process was chosen for EVAL for three reasons: environmental assessments were needed to apply management practices on private and public lands, environmental organizations agreed that CRMP was an acceptable environmental assessment, and the process was already established with most of the agencies in EVAL (Hansen and Mann 1979). Thus, planning could begin immediately. The total ranch operation was included in each CRMP, including associated Forest Service or Bureau of Land Management grazing allotments. Private leased land was also included with the concurrence of the owner, and the lease had to be effective for the duration of the program.

The Soil Conservation Service was responsible for the livestock grazing part of the CRMP on private and non-Federal public lands, and the Oregon Department of Forestry was responsible for forest management on private lands. The Forest Service was responsible for National Forest grazing allotments. On Bureau of Land Management grazing allotments, the Soil Conservation Service prepared the CRMP with the concurrence of the Bureau.

The CRMP process began with a meeting of the evaluation team and planning personnel with a rancher, reviewing the ranch property, and discussing the rancher's management objectives, potential practices, and the objectives of EVAL (fig. 2-1). After this meeting, the vegetation was mapped, the grazing and timber resources were inventoried, and the CRMP was prepared.

Figure 2-1—Coordinated resource management planning began by viewing the ranch property and discussing management objectives with the landowner.

Although the recommended guidelines were followed (Oregon Interagency Task Group for Coordinated Resource Management 1978), the initial CRMP's were not satisfactory. The plan was too general and poorly organized. The ranch and public land resources and problems were inadequately identified and the environmental impact was not satisfactorily addressed. Neither the rancher nor the evaluation team were satisfied.

A more complete process was developed that listed all of the recommended management practices for each pasture with associated costs, benefits, and environmental impacts on the range, timber, wildlife, water, and soil resources. On private lands, the primary objective was to solve management problems and to maximize the economic return by improving forage and timber production. Some landowners were also interested in leasing hunting rights for elk and mule deer. Range alternatives were developed for the entire ranch, including converting croplands and haylands to permanent pasture when feasible, and forestry alternatives were developed for each timber stand. Converting timber sites to range sites was not an option because it was prohibited by the Oregon Forestry Practices Act.

On public lands, the primary objective was to solve management problems and to optimize and integrate grazing management with other uses. Active timber sale areas, however, were not included in the CRMP because the timber harvest activities prevented installing range practices that could be evaluated during EVAL.

The second plan was a well-organized document that was reviewed and updated annually by the EVAL team and each private landowner; completed and planned accomplishments were clearly identified; and the plan was easily adjusted to meet new management objectives. Two maps were attached: one map illustrated the vegetative resources; the other, the present and potential management practices (fig. 2-2).

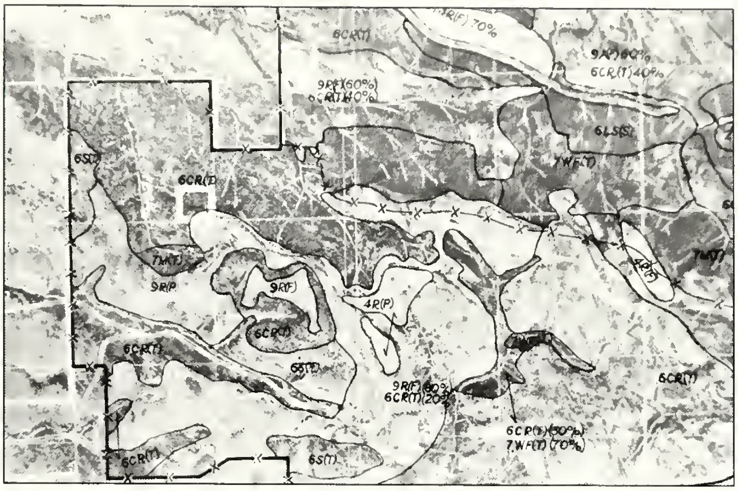

Figure 2-2—Each Coordinated Resource Management Plan included a practice map that showed the locations of existing and potential range management practices.

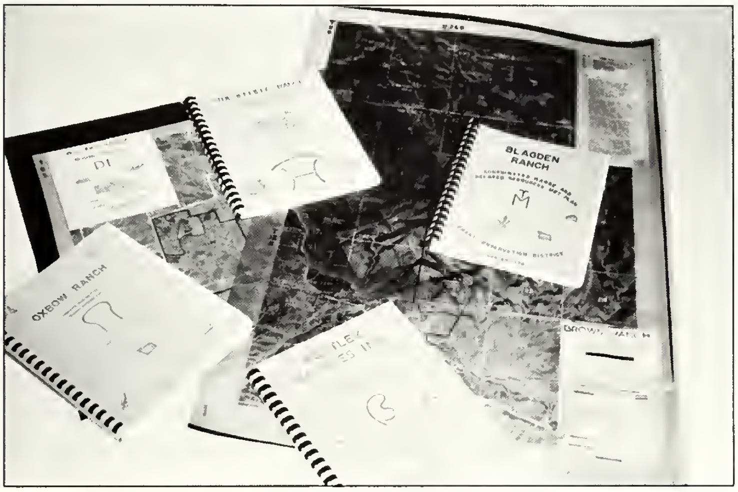

Figure 2-3—The new format for the Coordinated Resource Management Plans provided an excellent planning document and was well received by the land owners.

The ranchers were very satisfied with the new CRMP's. They had a document that a loan agency could clearly review for costs and benefits if a rancher needed a loan to install the recommended management practices (fig. 2-3). The CRMP was also an excellent prospectus that a landowner could show a prospective purchaser.

The private landowner and the responsible land management agencies approved all plans for their respective lands, with final approval by the project coordinator. All parties had signatory approval.

Management Strategies

Present management strategies were determined for each pasture while the CRMP was being developed. Planned strategies were selected to meet objectives of the landowner and EVAL, and they reflected the management intensity that could be achieved. For example, expecting rocky, shallow soils to respond economically to cultural practices, such as seeding and fertilizing was unreasonable; therefore, such pastures were not intensively managed.

The management strategies (Forest-Range Task Force 1972) used in EVAL were developed for the Forest-Range Environment Study (FRES) and modified to reflect their practical application (Sanderson and others 1988). Five strategies, A through E, represented the intensity of management. The least intensive, strategy A, did not include livestock. Strategy B included livestock, but no investments were made to use the available forage efficiently; the livestock were driven into the pasture and the gate closed behind them. Only practices that improved livestock distribution—such as water developments, fences, and trails—were applied in strategy C pastures. Cultural practices—such as seeding, fertilizing, and controlling undesirable brush—were applied in strategies D and E, in addition to the practices needed to improve distribution. Strategy D optimized grazing management with the other resources; strategy E was changed to reflect the realistic management goal of maximizing commodity production. Strategy E was applied only on private lands; it originally required livestock production to be maximized, which included converting forest sites to range production. The problem was that converting forest sites to range sites is illegal, and not an option of interest to private land owners. They were interested in optimizing their income by developing all of their economic opportunities; not just the range opportunities. Although livestock production was their primary source of income, some ranchers obtained additional income from timber and hunting rights (fig. 2-4), and some wanted to manage the timber for future income.

Strategies A through D required that any damaged resource be corrected and maintained through responsible land stewardship. Strategies B through D had multiple-use objectives; strategy E did not, but required stewardship of the land and water resources. Pastures where environmental degradation had occurred from past management practices were indicated as strategy X to indicate the need for corrective action (table 2-1).

Figure 2-4—Fee hunting provided additional income for some ranches and wildlife habitat was included as a management objective.

Table 2-1—Range management strategies applied during the Oregon Range Evaluation Project

Strategy	Definition
A	Environmental management without livestock. Livestock are excluded by fencing, riding, public education, and by incentive payments.
B	Environmental management with livestock. The goal is to achieve livestock control. No attempt is made to achieve livestock distribution.
C	Extensive management of environment and livestock. Management seeks full use of available forage through efficient livestock distribution.
D	Intensive management of livestock and environment. Management seeks to optimize livestock forage production consistent with maintaining the environment and providing for multiple use.
E	Environmental management with commodity production maximized. Management seeks to maximize ranch income through all available marketable commodities. Stewardship of soil and water are required and multiple use is not a consideration.
X	Exploitative management. Resource degradation is occurring. This strategy is not a management goal.

Range Management Practices

Twenty-four range management practices were applied to attain the management strategies (table 2-2). Specifications were developed for each practice, technical responsibility was assigned, and the Federal cost-share determined, generally 75 percent. Necessary State or Federal permits were obtained, and a cultural resource survey was conducted on both Federal and private lands where practices would disturb the ground. The same practice specifications were applied for private and public lands.

Table 2-2—Range practices installed on public and private lands

Range practice	Unit	Ownership		Total
		Private	Public	
Fertilization	Acre	533.0	325.0	858.0
Irrigation dam	Each	1.0		1.0
Irrigation ditch	Mile	.5		.5
Drainage structure	Feet	420.0	5.3	420.0
Check dam	Each	3.0	8.0	11.0
Brush control	Acre	3,181.0	70.0	3,251.0
Weed control	Acre	726.0	145.0	871.0
Rodent control	Acre	1,363.0	547.0	1,910.0
Timber thinning	Acre	2,753.0	36.0	2,789.0
Debris disposal	Acre	3,053.0	1,698.0	4,751.0
Seed, grassland	Acre	1,858.0		1,858.0
Seed, brush and timber	Acre	3,195.0	1,698.0	4,893.0
Water developments	Each	126.0	187.0	313.0
Fence construction	Miles	41.0	193.0	234.0
Fence removal	Miles	2.0	85.0	87.0
Cattle guards	Each	3.0	80.0	83.0
Livestock trails	Miles		15.0	15.0
Planned grazing	Acre	196,000.0	370,000.0	566,000.0

Long-Term Agreements

The Long-Term Agreements (LTA's) were the action plans for the CRMP's and the contract between the Forest Service and the private landowner. The LTA specified the number, acres, or miles for each practice scheduled to be implemented in each pasture; Federal cost-share in percentage and dollars; and year to be implemented. After each practice was certified and approved for payment, the amount completed, actual Federal cost-share, and month paid was added. The total cost-share for an individual landowner was limited to $50,000; for Cooperative Grazing Associations the limit was $80,000. These limits were subject to review and adjustment on an individual basis by the evaluation team.

Landowners could install practices with their own equipment and labor, or they could contract part or all of the job. The county Agriculture Conservation Program Committee determined dollar value for the landowner's equipment and labor, based on the type of equipment or labor on an hourly basis. Materials were cost-shared according to the verified (sales receipt) value. Contracted work was cost-shared based on the verified contract payment. Completed practices were inspected and approved by the responsible agency; costs were reviewed by the county Agriculture Conservation Program Committee and forwarded to the evaluation team for final approval. The county Agriculture Conservation Program Committee review provided consistency in payment for practices and alerted the EVAL coordinator to excessive costs. Such cases were reviewed by the evaluation team to determine appropriate payment.

The LTA also obligated the private landowner to provide cost data for the installation of the range practices and actual use records for each pasture included in the Agreement and provided access for research personnel to private lands.

The landowner was responsible for maintaining the practices throughout the Project. If a ranch was sold, the new owner could elect to continue with the project. Then, the new owner signed the existing CRMP and LTA, after mutual agreement on any modifications. If the new landowner elected not to continue the agreement, the seller was liable for reimbursing the Federal Government for all cost-shared dollars received under the agreement. New owners always elected to continue with the project when practices were installed prior to the time of the sale. In a few cases where practices had not been installed and the sale involved only part of the ranch property, the allotted dollars were shifted to pastures that were not included in the sale.

Strategy Attainment

The FRES strategy definitions were satisfactory during the planning phase of EVAL but not for evaluating accomplishments. First, they did not allow for less than total accomplishment of the planned strategy. Second, they included no means of accounting for forage production as a result of silviculture activities; consequently, total forage production was underestimated. The first problem was solved by expanding strategy definitions and providing provisions for accomplishing less than the total strategy goal (table 2-3). To account for forage produced by silviculture activities, the percentage of the forest area that had the overstory trees removed or thinned and an understory that was producing additional forage—which was available for livestock—was rated on a scale of 1 to 4 (0-25 percent, 26-50 percent, 51-75 percent, and 76-100 percent). This rating system provided a means of adjusting the stocking rates to use forage that had not been accounted for.

Table 2-3—**Range management strategies and substrategies used to determine strategy attainment, Oregon Range Evaluation Project**

Strategy and substrategy	Definition
A	Environmental management without livestock.
B:	Environmental management with livestock.
B1	Preferred areas receive light use.
B2	Preferred areas receive moderate or greater use.
B3	Preferred areas receive moderate or greater use and have received increases in forage base resulting from timber activities not specifically designed for range outputs.
C:	Extensive management of environment and livestock.
C1	Less than 25% of the usable areas have adequate livestock distribution.
C2	At least 25% but less than 75% of the usable areas have adequate livestock distribution.
C3	At least 75% of the usable areas have adequate livestock distribution.
D:	Intensive management of livestock and environment.
D1	Less than 25% of the available forage base is managed to maximize joint resources through appropriate cultural practices.
D2	At least 25% but less than 75% of the available forage base is managed to maximize joint resources through appropriate cultural practices.
D3	At least 75% of the available forage base is managed to maximize joint resources through appropriate cultural practices.
E:	Environmental management with commodity production maximized.
E1	At least 25% of the available forage base is managed to maximize net economic benefits.
E2	At least 25% but less than 75% of the available forage base is managed to maximize net economic benefits.
E3	At least 75% of the available forage base is managed to maximize net economic benefits.
X:	Exploitative management.
X1	Less than 25% of the area has resource degradation occurring.
X2	At least 25% but less than 75% of the area has resource degradation occurring.
X3	At least 75% of the area has resource degradation occurring.

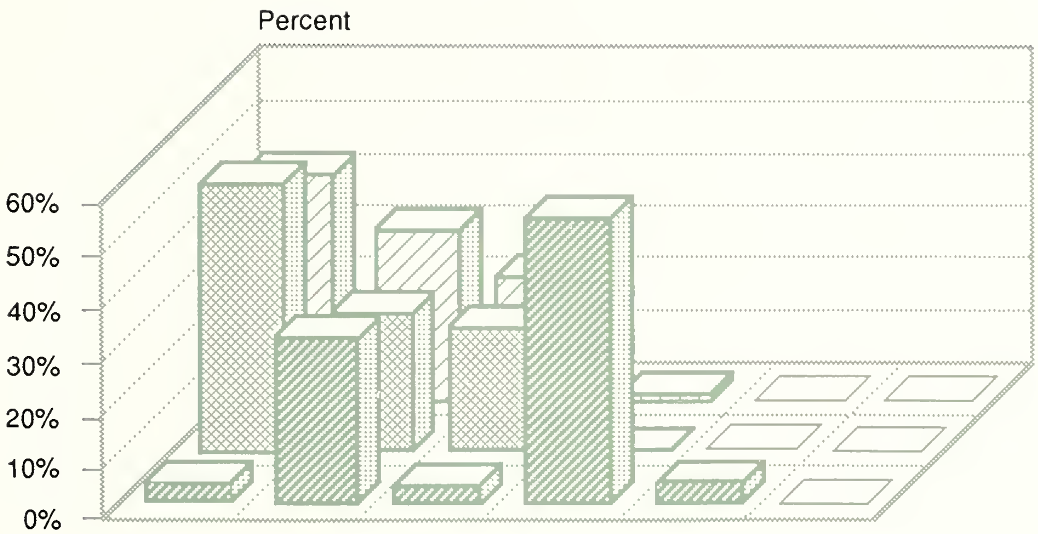

Figure 2-5—Primary range management strategies before EVAL compared with EVAL planned and achieved management strategies on private, Federal, and combined private and Federal lands EVAL.

Figure 2-5A—Existing, planned, and achieved strategies on private lands.

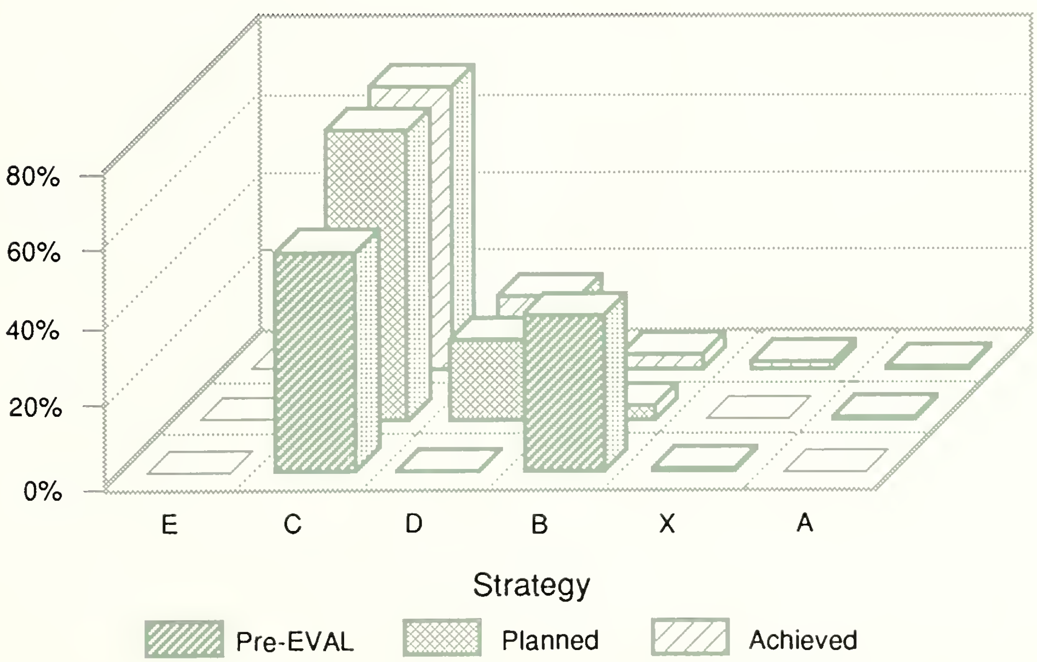

Figure 2-5B—Existing, planned, and achieved strategies on Federal lands.

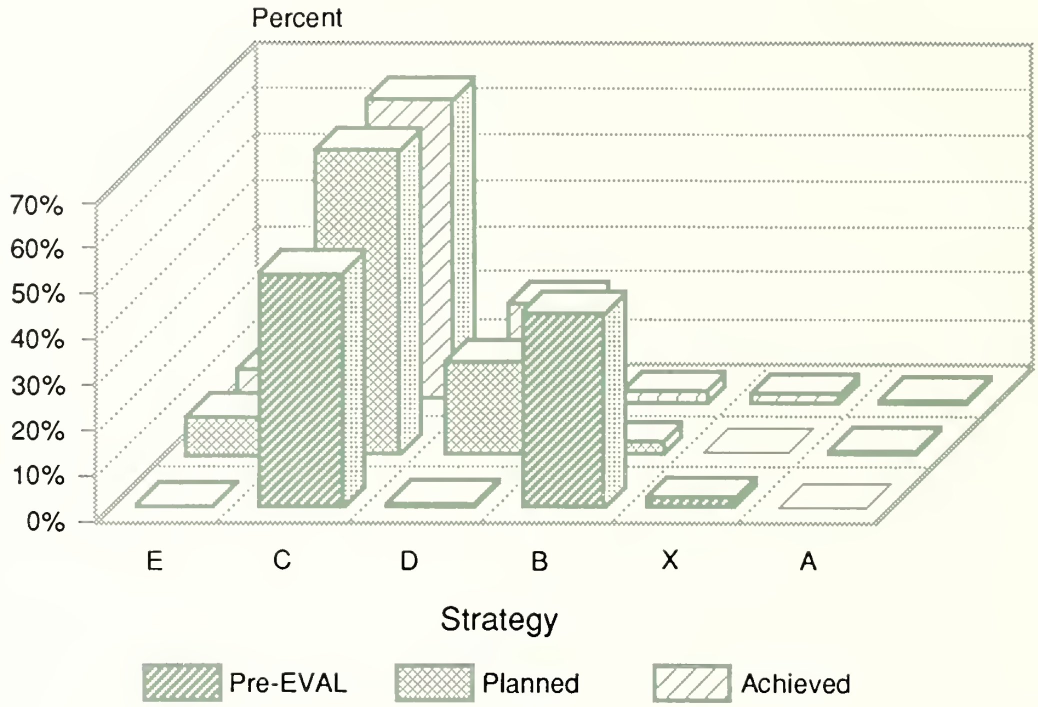

Figure 2-5C—Existing, planned, and achieved strategies on private and Federal lands.

Accomplishments

The Coordinated Resource Management Plans were prepared for 22 private ranches. One CRMP was not followed by an LTA because the needs and solutions outlined in that CRMP pertained primarily to crop and haylands, which were not included in the EVAL project. About 196,000 acres of private land and about 389,000 acres of public land were covered in the remaining CRMP's.

The total Federal cost-share for the 21 LTA's was $636,200 to install management strategies on about 58,000 acres of private land, which was matched by $205,300 by the private landowners. About $1,183,000 was invested on 283,000 acres on 16 National Forest grazing allotments. The total effect was to increase the management intensity on both public and private lands (fig. 2-5) and management strategies were achieved on 96.5 percent planned areas (Sanderson and others 1988).

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3 Range Improvement Specification and Costs

Thomas M. Quigley

One immediate task facing the EVAL management team was to assemble specifications on state-of-the-art range management practices. Beginning with existing guides for improvements and handbooks, the interagency team extracted the most applicable practices under the conditions of the EVAL program. The specifications resulting from this interagency effort included modifications suggested by ranchers and contractors, who implemented and maintained these improvements. Although the earliest list of specifications dated to the beginning of the EVAL program, the final version resulted from changes recommended after applying and maintaining improvements.

The specifications were used to guide the application of practices on private and Federal land. The handbook documenting the specifications is available for reference and is intended for use by ranchers, contractors, resource managers, and anyone who plans, installs, and maintains structural improvements (Sanderson and others, in press). It can be used as a guide during construction, a decision tool during planning, and a source of specifications for drafting contracts. It has been specifically designed to be copied to include in contract specifications or project designs and guides. Specifications are included for six types of structural range improvements, including seven kinds of fences and five kinds of water developments (table 3-1). Two range improvements applied extensively during the EVAL project were fences and water developments.

No attempt will be made here to provide a detailed description of all structural and nonstructural practices applied during the EVAL project. A brief description of those practices where cost data was collected is provided, however. Specifications actually used at a given site were guided by the EVAL specifications but were individually modified through interaction of the EVAL team with a multidisciplinary planning team. Such factors as hiding and escape cover for wildlife were prominent features of the improvements that altered forest canopy, such as precommercial thinning and juniper removal.

Table 3-1—Listing of structural improvement specifications provided in the specifications handbook

Improvement Category
Fences:
Barbed wire
Woven wire
Electric
Buck and pole
Log worm
Block and pole
Log crib
Gates
Cattleguards
Stiles
Water developments:
Spring developments
Storage tanks
Water troughs
Stock ponds
Trick tanks and guzzlers
Livestock access trails

Practice Descriptions

Permanent Wire Fence

Permanent wire fences were constructed to control livestock movement and access (fig. 3-1). The fences were either 3 or 4 barbed wire strands using rock-jack, figure-four fencing techniques. Fence right-of-ways were cleared.

Let-Down Wire Fence

Let-down fences were constructed in areas where snowfall was likely to damage wire fences. These fences were typically made with 3 strands of barbed wire.

Fence Reconstruction

Fences that were in poor condition and required extensive work before they could be used were reconstructed.

Spring Development

Developing springs for watering livestock typically consisted of fencing the spring to exclude livestock, installing a spring box, and piping the water to a watering trough (fig. 3-2).

Spring Redevelopment

Existing spring developments in poor repair were brought into compliance with the standards and specifications for new developments. This process sometimes included replacing the spring box, piping, or water trough.

Stock Pond Construction

Stock ponds were constructed in intermittent water drainage areas. A backhoe was usually used to construct the ponds, a spillway was provided, and the water was sometimes piped to a watering trough.

Figure 3-1—Permanent wire fence in a ponderosa pine ecosystem.

Figure 3-2—Spring development with water piped to a watering trough.

Stock Pond Reconstruction

The reconstruction of stock ponds was necessary where the existing structure failed to adequately hold or distribute water. Bentonite was commonly applied as a sealant for the pond.

Large Water Developments

Water developments with multiple watering sites were called large water developments. Extensive use of piping and development of an adequate water supply were the primary costs. The water source could be a stock pond or a well, with either a windmill or electric pump.

Livestock Access Trails

Trails were constructed to provide livestock access to isolated or otherwise inaccessible areas. Trails were constructed with hand tools or by bulldozers and backhoes.

Rangeland Drill Seeding

A rangeland drill was used to seed rough and rocky terrain where a conventional drill would not work.

Figure 3-3—Burning as a sagebrush control treatment.

Sagebrush Seeding Treatments

Seeding in the sagebrush ecosystem generally required removing or reducing sagebrush before seeding. On sites where sagebrush was sparse, the rangeland drill was used without sagebrush removal. Sagebrush was removed, and the area seeded by plowing, disking, and drilling; beating the brush with a mechanical beater and then drilling; spraying with herbicide, plowing, and drilling; or burning before seeding.

Sagebrush Control Treatments

In areas where sufficient forage species were present, the sagebrush control treatments did not require seedings. The control methods used in EVAL included plowing, beating, burning, and spraying the sagebrush (fig 3-3).

Juniper Seeding Treatments

Chainsawing juniper and pushing juniper over with a bulldozer were both used before seeding on some juniper sites. These techniques of removing juniper were followed by disking, drilling, or both. On some low-density juniper sites, removing juniper was not recommended, but seeding was. On these sites, the area between trees was plowed, disked and drilled.

Juniper Control Treatments

To release the forage species, junipers were removed either by bulldozer or with a chainsaw. Trees were either left where they fell or piled by bulldozer or by hand.

Figure 3-4—Application of fertilizer to a mountain meadow.

Mountain Grassland Seedings

Seedbed preparation followed by drilling was the most common seeding method in mountain grasslands. Other techniques included disking followed by broadcast seeding or plowing, disking, and drilling.

Mountain Meadow Seedings

Five different approaches were used in seedings in the mountain meadow ecosystem: chemical preparation followed by drilling; rototilling followed by drilling; disking, plowing, and drilling; drilling with the rangeland drill; plowing, disking, harrowing, and broadcasting seed.

Fertilizing

Soil nutrients were applied to increase forage production or to provide nutrients for new seedings (fig. 3-4).

Check Dams

Check dams were placed in intermittent stream channels to halt erosion, raise the water table, or both. Dams were typically constructed with the use of a bulldozer or backhoe.

Water Spreading Systems

Water spreading systems were used to increase available forage and to improve livestock distribution. An instream structure with a network of ditches spread the water.

Drainage Systems

Drainage systems were installed on areas too moist to support healthy stands of forage.

Rodent Control

Rodent control was most commonly done in seeded areas. When rodent control was part of a seeding project, individual costs of rodent control were included as a part of the seeding cost.

Figure 3-5—Thinning followed by debris disposal was a common range treatment in forested ecosystems.

Precommercial Timber Thinning

Thinning of timber stands followed specifications that emphasized the use and enhancement of forage. Spacing was typically wider than recommended for silvicutural objectives only. Disposing of debris from thinning was to provide access by livestock as well as reduce fire hazard (fig. 3-5). Thus, debris was piled somewhat more than with standard timber treatments. Broadcast, drilling, and dribble seeding were approaches used to seed after thinning. Dribble seeding is continuous slow release of seed from tanks mounted on the side of the bulldozer as it works to pile and remove debris.

Debris Disposal

Debris disposal was the piling of logging and thinning slash that had not been piled in prior timber treatment. The goal was to enhance forage production and provide livestock access as well as reduce fire hazard.

Improvement Costs

One of the major objectives of EVAL was to determine the representative costs of range improvements for the ecosystems in the study area. Through the CRMP and LTA processes more than 1,000 improvements were monitored during the project. Methods were established to track actual labor, equipment, and material used in constructing fences, developing water, seeding, and installing other range improvements. The objective was to determine the costs for skilled and unskilled labor, equipment, material, and maintenance for each type of practice and to determine if the size of project effected the average unit cost.

Other studies of costs for range improvement have focused on the amount of money required to finance construction (Heady and Bartolome 1977, Horvath and others 1978). The EVAL data measured the physical inputs and converted them to monetary terms. Assuming a constant state of technology, averages across years, ranches, allotments, and pastures represent the inputs needed to implement a given practice. All structural improvements, private and public, were constructed to the same specifications developed through the EVAL program (Sanderson and others, in press).

A record-keeping system was established to collect information on the costs of constructing each improvement on private and Federal land. Cooperators, contractors, and agency personnel implementing range improvements were required to record the amounts and kinds of labor, equipment, and material used for each improvement. Labor was recorded by type of work and was separated into skilled and unskilled. Equipment was recorded by type and total time used, miles driven, and work accomplished. Cost information, therefore, was for the amount and kind of labor, type and amount of material used, and the kind and horsepower of the equipment used, rather than just listing the costs incurred. Tracking actual costs would have shown the effect the EVAL project had on local contracting. The demand for range improvement work exceeded the amount that could be supplied by the local economy. Because actual times and types of labor, equipment, and materials were used, the contracting costs were not biased. A list of rates and charges was established for labor, equipment, and material (F.O.B. John Day, OR) and was based on 1978 dollars. These rates were applied to each type of construction project to determine 1978 dollars for each cost category.

Contractors did most of the construction work on Federal lands; minor amounts were done by Federal employees. On private lands, the work was split between contractors and private landowners. Each cooperating landowner provided cost data before receiving cost-share funds through the LTA process. On Federal lands, the contracting officer's representative was responsible for collecting cost information from contractors and employees.

Definitions for labor followed closely those in Duran and Kaiser (1972). Skilled labor included all that required special training or knowledge, such as chain-saw operators, truck drivers, and heavy equipment operators. Unskilled labor included post-hole diggers, fence builders, and other hand laborers. Some work required two people, one to operate equipment and the other to act as a guide or to move materials and drive another vehicle with materials to the site. Labor was separated by type of labor accomplished by the hour. Thus, time reported as "driving" was considered skilled labor, whereas time used assisting another operator was considered unskilled, even though the same person was doing the work.

Although costs were initially determined in 1978 dollars, they have been converted to 1986 dollars by using indices reported annually by the USDA Statistical Reporting Service. The index used was the "Agricultural Prices Paid Index for Production Items With Non-farm Origin," which includes such items as fertilizer, fuels, building and fence supplies, farm services, and wages (USDA Statistical Reporting Service 1987). To convert from 1978 to 1986 dollars, the 1978 cost was multiplied by 1.51, the ratio of 1986 index to the 1978 index.

Fence Costs

No significant differences were found between fencing costs on private and Federal land; thus, all fencing data were combined. The size of a fence project was also analyzed to determine its relation to the cost per mile of fence. Thus, costs were estimated for each ecosystem and size of fence project by cost category (skilled and unskilled labor, material, and equipment) and type of fence. A negative factor for the size of fence project indicates that as size increased, cost per mile decreased.

From 1976 through 1984, the EVAL project monitored the construction of 127 fences on more than 210 miles of forest and rangeland. Costs for permanent wire-fence construction and reconstruction, fence removal, and let-down wire-fence construction by ecosystem and cost category were determined (figs. 3-6 and 3-7). Only coefficients significantly different from zero are shown (appendix B, table 1).

The average total cost for 154 miles of permanent wire-fence construction ranged from $2,839 per mile (juniper ecosystem) to $5,462 per mile (larch ecosystem). The average cost for forested (Douglas-fir, ponderosa pine, larch, and lodgepole pine) ecosystems was 60 percent greater than for nonforested ecosystems. In forested ecosystems, the costs were about evenly divided among cost categories; in nonforested ecosystems, costs were mainly for material and unskilled labor. Thus, forested ecosystems required additional investments in skilled labor and equipment. Size of fence projects was a significant factor for unskilled labor and materials. Large fences required less unskilled labor per mile ($148) than small fences because moving materials and equipment at the beginning and end of each project takes longer for large fences. Dividing this time among more miles of fence results in reduced per-mile labor expense. The cost of materials was $189 per mile more for large projects than for small ones; more on-site materials were used for short fences. These two offsetting factors, unskilled labor and material costs, resulted in no significant size-of-fence factor in total average costs.

Costs for construction of 45 miles of let-down wire fence ranged from $3,615 per mile in the alpine ecosystem to $5,733 per mile in the Douglas-fir ecosystem. Expenses were significant in all cost categories for the Douglas-fir and larch ecosystems, whereas only expenses for unskilled labor and material were significant in the lodgepole pine and sagebrush ecosystems. Skilled labor required to construct let-down fences in the alpine ecosystem was not significant. The size of the project did not significantly reduce per-mile costs. Labor was more than 50 percent of the total cost for the forested sites, whereas most of the expense for nonforested ecosystems was for material and equipment.

Wire-fence reconstruction was monitored on 14 fences and totaled 11.6 miles. Total average costs ranged from $1,919 per mile in mountain grassland to $4,673 per mile in ponderosa pine. Size of the project did not significantly influence per-mile costs. Costs for materials were generally small because old fence materials were reused and new wooden posts and stays were made from materials on the site. As with fence construction, reconstruction on forested sites was more expensive than on nonforested sites. Most costs were for labor on forested sites, whereas most costs on nonforested sites were for materials. One fence cost substantially more because little of the old fence material could be used in reconstruction, which made total costs for the ponderosa pine ecosystem high.

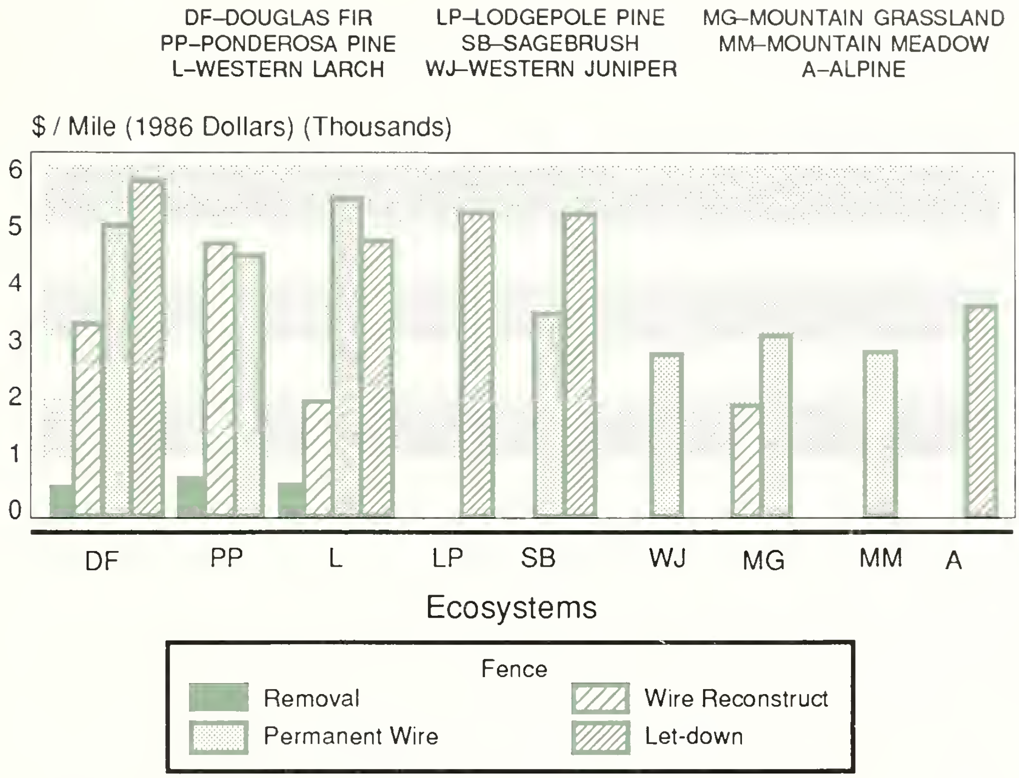

Figure 3-6—Fencing costs by fence type and ecosystem.

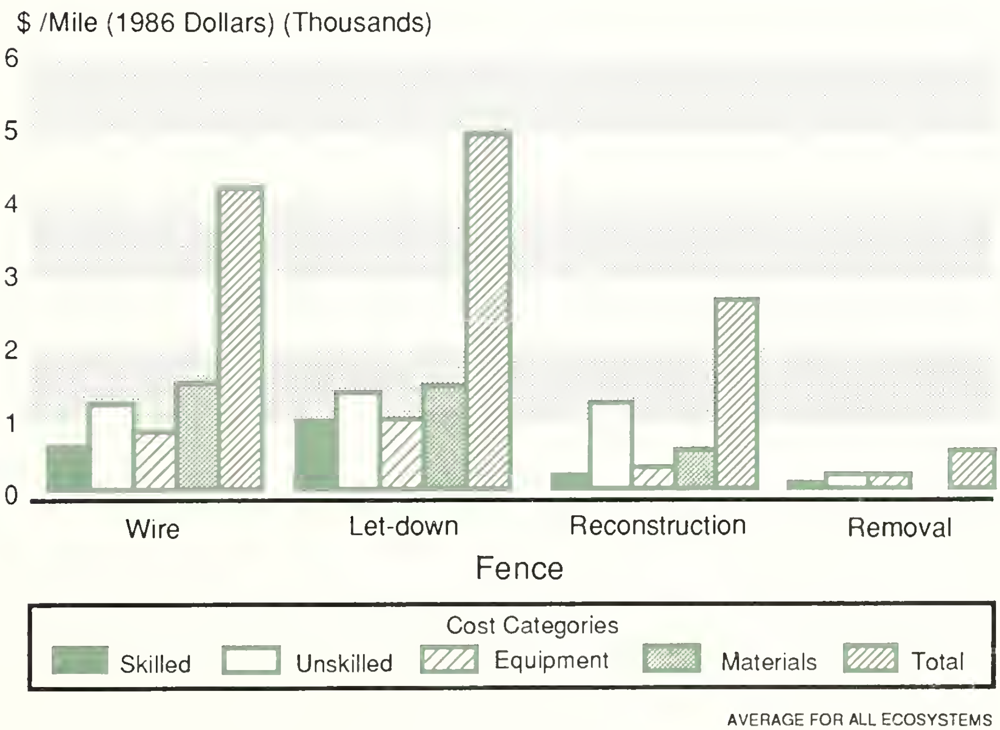

Figure 3-7—Fencing costs by fence type and cost category.

A total of 65 miles of fence were removed from 46 sites. Costs ranged from $550 per mile in a Douglas-fir ecosystem to $704 in ponderosa pine. Costs were split between labor and equipment. Average total costs per mile were reduced by $88 per additional mile of fence removed, and unskilled and skilled labor costs were reduced by $38 and $23, respectively. Combined labor costs show small differences among ecosystems, whereas equipment differences are substantial. The ponderosa pine ecosystem had the highest cost for equipment and the highest total cost.

The use of equipment requires skilled operators; thus, two costs are incurred—equipment and skilled labor. When either of these costs were significantly greater than zero, the other was also significantly greater than zero. The only exception was significant equipment costs for alpine ecosystem with no significant costs for skilled labor. We believe this was due to the distance from material sources (town) and the location of the fence. Equipment expenses included costs for transporting crews and material to the work sites. Fence removal required little, if any, chainsaw or heavy equipment work to clear rights-of-way. Significantly greater amounts of skilled labor were required for constructing let-down wire fences than for other fences. Fence removal and reconstruction required the least amount of skilled labor.

Differences in the amount of unskilled labor required were not significant for fence construction or reconstruction. Fence removal required the least amount of unskilled labor. Larger wire-fence construction and removal projects had a lower cost per mile for unskilled labor.

Fence removal was the only fencing project where average total cost per mile decreased as fence length increased. Based on this finding, average costs might be reduced if fence removal is done as one project. If the use of labor is a concern, planning projects for constructing and removing permanent wire fences may reduce the per-mile expense for unskilled labor.

Costs for reconstructing fences were significantly less than for either permanent or let-down wire-fences, primarily because of the low requirements for equipment and material. Costs for let-down fences are usually higher than costs for permanent wire fences (but not significantly different). Let-down fences, however, require significantly more skilled labor for construction than any other wire fence. No significant per-mile cost savings were found in total average fence construction cost when fences were longer, and the only significant difference in construction costs was in skilled labor.

Other types of fence improvements were used in the EVAL project, but data were not sufficient to allow analysis.

Small Water Development Costs

No significant difference was found between water development costs on private and Federal land; thus, all water development data were combined. Each development was mapped by ecosystem. Costs were determined for skilled and unskilled labor, material, and equipment for each of four types of small water developments: spring development, spring redevelopment, stock pond development, and stock pond redevelopment. Costs were summarized according to development type and ecosystem (figs. 3-8, 3-9, and 3-10). A total of 437 small water development projects were monitored on the Evaluation area.

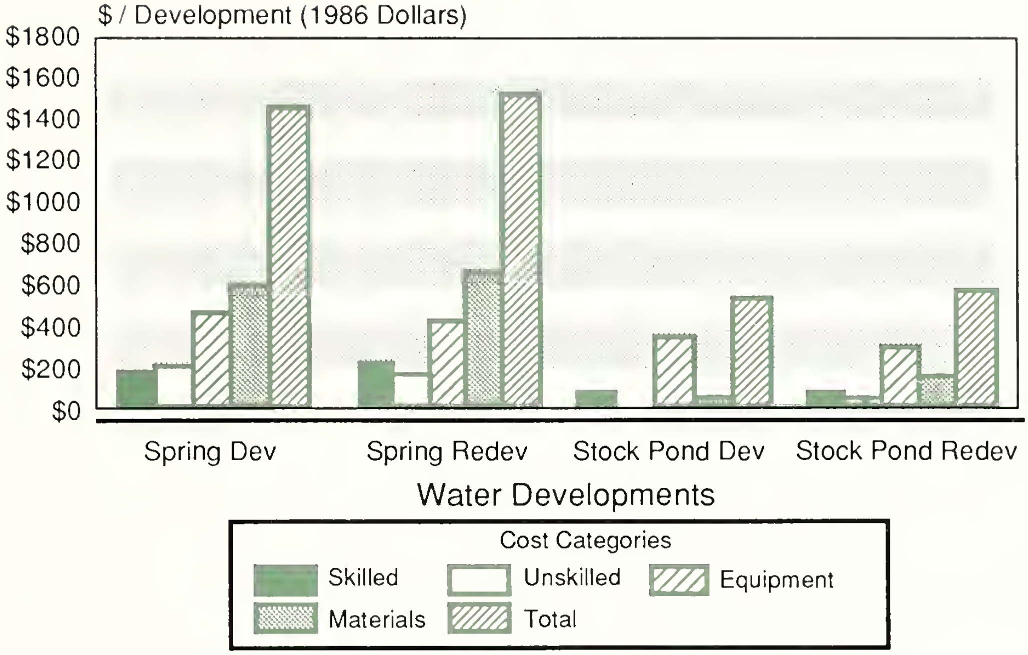

Figure 3-8—Small water development costs by development type and cost category.

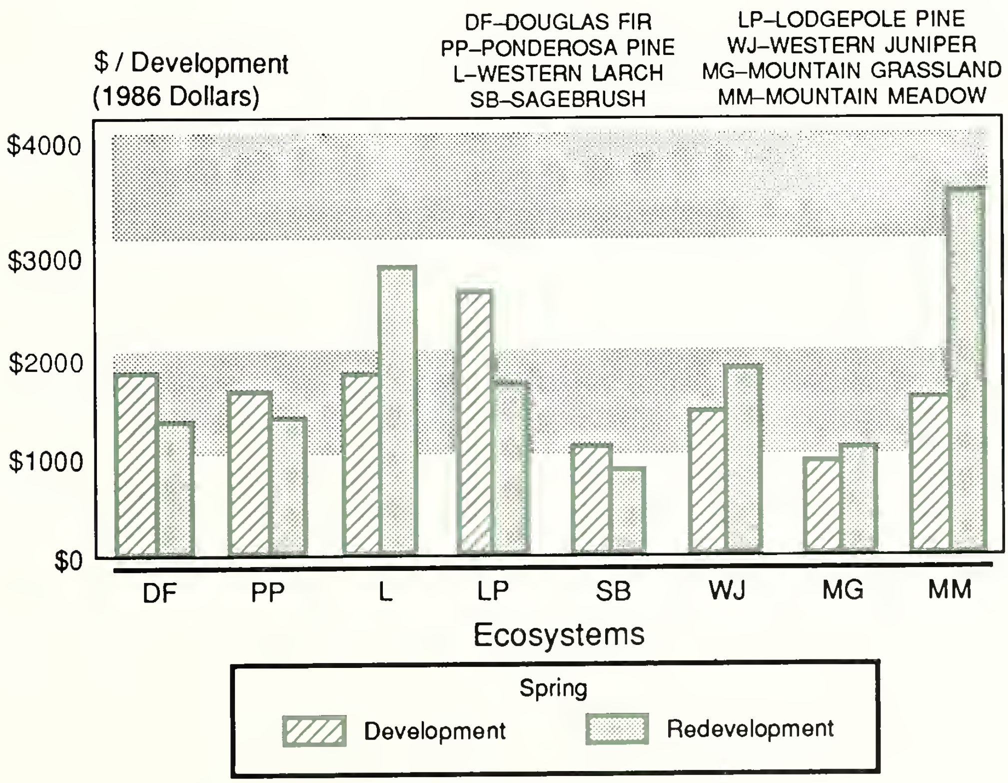

Figure 3-9—Spring development and redevelopment costs by ecosystem.

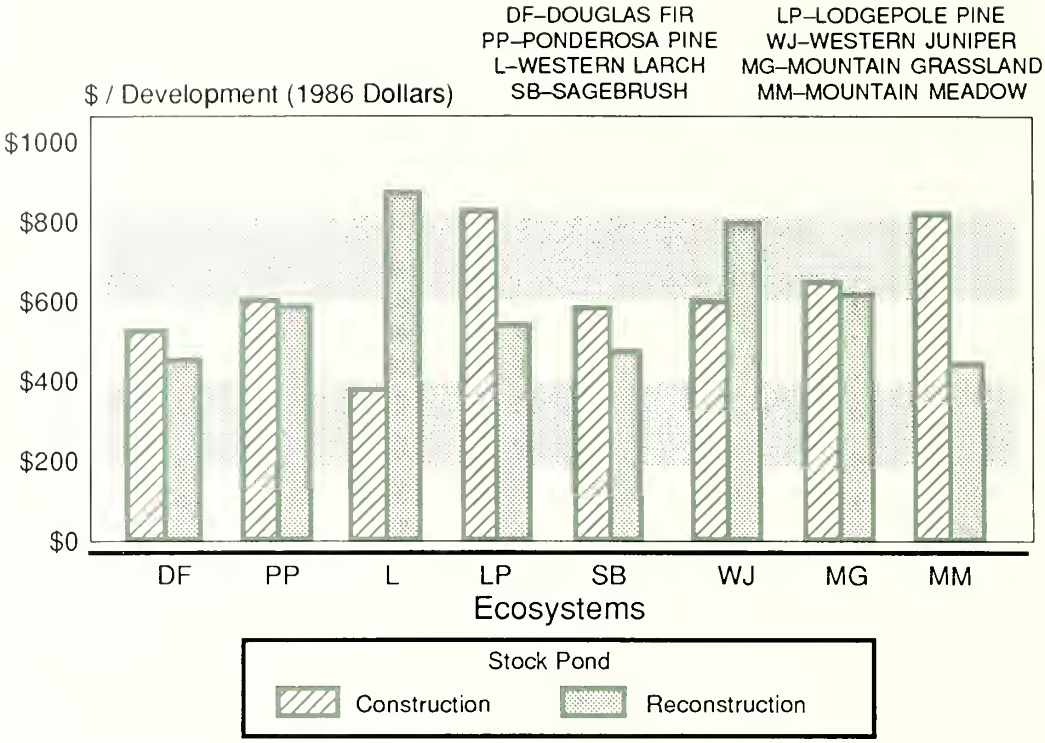

Figure 3-10—Stock pond construction and reconstruction costs by ecosystem.

Spring developments—The average total cost for installing 102 spring developments was $1,482 (appendix B, table 2). Developments in the forested ecosystems were, as a group, 57 percent more expensive than developments in the nonforested ecosystems. Expenses were about evenly divided between the combined equipment and skilled labor costs and the combined material and unskilled labor costs. Materials generally consisted of fencing supplies, water troughs, and plastic and galvanized pipe and fittings; skilled labor and equipment costs were mainly for backhoe use.

The average total cost for redeveloping 39 spring developments was $1,559 (appendix B, table 4). Skilled labor and equipment costs combined to about 50 percent of the expense for redevelopment. No significant difference was found to exist between the average costs of spring developments and spring redevelopments. Significantly more material and skilled labor was used to redevelop springs than to develop them initially. This difference reflects the need to remove old material and replace it with new. The time requirements and efforts to save existing materials proved more costly than moving into an undeveloped site. Not all circumstances permit development of a new site because water must be developed where it occurs in arid ecosystems. The higher cost was usually contributed by the need to bring the old development up to current specifications.

Stock pond developments—Constructing new stock ponds was the most frequently applied small water development practice (211 ponds)(appendix B, table 4). The average cost was $559 per development. Skilled labor and equipment expenses combined to 86 percent of the total cost. No trend in cost differences was found between forested and nonforested ecosystems. In instances where installations were most expensive, the additional costs were typically accounted for through distance from towns and highway access. Moving equipment to and from sites was often a substantial cost.

No substantial difference was found between reconstructing stock ponds and constructing stock ponds (appendix B, table 5). Significantly less equipment and more material was used in reconstruction than in initial construction. This difference relates to the selection of ponds for reconstruction: stock ponds were selected for reconstruction because they failed to hold water for long periods. The remedy was to use bentonite sealant rather than using a backhoe to dig further. Thus, material was substituted for equipment. The result was that the cost of reconstructing was statistically similar to the cost of initial construction.

Constructing or reconstructing stock ponds was less than one half as expensive as developing or redeveloping springs. The expense of purchasing and installing stock tanks represents one of the major differences.

Large Water Developments

Three large water developments with multiple watering sites were installed on private land (appendix B, table 6). Two sites used dams at the water source and pipelines to distribute water, at an average cost of $6,918. Equipment costs accounted for 45 percent of the total cost. The third site used a well for the water source and used a pipeline to distribute water, for a total cost of $5,816; material accounted for 73 percent of the cost.

Brush Control and Seeding—Nonforested Ecosystems

Seeding in the sagebrush, juniper, mountain grassland, and mountain meadow ecosystems were monitored on 87 sites covering 5,093 acres. Seedings in the sagebrush and juniper ecosystems typically were associated with treatments of the sage and juniper. Some sites in these two ecosystems had densities of brush low enough that removing it before seeding with a rangeland drill was not required.

Sagebrush ecosystem—Four of the five sagebrush seeding treatments included removal of sagebrush (appendix B, table 7). The use of a rangeland drill without removal of sagebrush was accomplished on four sites (246 acres). On these sites, the density of sagebrush was relatively low. The most expensive treatment was to spray sagebrush, plow, and then drill ($196/acre), with 73 percent of the cost being materials (fig. 3-11). The least expensive treatment technique was using the rangeland drill without treating the sagebrush ($57/acre). On average, the equipment and material costs accounted for 81 percent of the total cost.

Ten sites (1,086 acres) had sagebrush removed to allow release of existing vegetation (appendix B, table 7). On average, the equipment and skilled labor costs accounted for 89 percent of the total cost (fig. 3-11). The average cost of treatment was $26 per acre. Cost of burning and aerial spraying of the sage were nearly similar

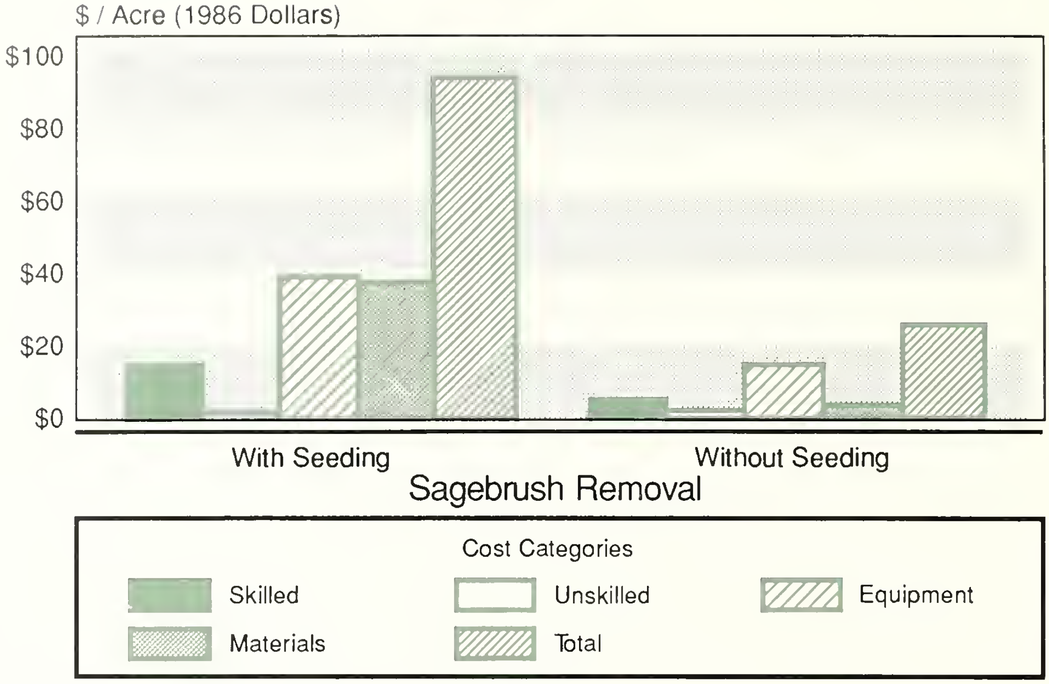

Figure 3-11—Sagebrush treatment costs by cost category.

($12 and $15 per acre) and were the least expensive techniques. The most expensive technique was used on one site; sagebrush was sprayed from ground vehicles. Seeding of treated sagebrush appears to be $57 per acre more than treating the sagebrush with no seeding to follow.

Juniper ecosystem—Treatments in the juniper ecosystem consisted of removing trees or removing trees plus seeding. On sites with sufficient understory vegetation that removing trees was the only treatment, the expense on average was $68 per acre (fig. 3-12). Treatments included bulldozing the juniper and machine piling, chainsawing the juniper and machine piling, chainsawing the juniper, and chainsawing the juniper and hand piling (appendix B, table 8). A total of 1,286 acres were treated on 23 sites. Over 92 percent of the cost of treatment was for skilled labor and equipment.

On sites that were seeded after removal of juniper (227 acres), the average cost was $96 per acre. Treatments included falling juniper trees with a chainsaw and drilling around the felled trees, bulldozing the trees, disking and drilling around the felled trees, and plowing, disking, and drilling around the standing juniper trees. Skilled labor and equipment accounted for 78 percent of the expense of these treatments.

Mountain grassland ecosystem—Seeding in the mountain grassland ecosystem involved the mechanical preparation of the seedbed and either broadcasting seed or drilling seed in the seedbed (appendix B, table 9). Skilled labor and equipment costs combined for 72 percent of the total cost of treatment (fig. 3-13). Mechanical seedbed preparation used equipment on the site at least four times. These typically were to disk, harrow, drill, and pack. Rodent control in conjunction with seeding was

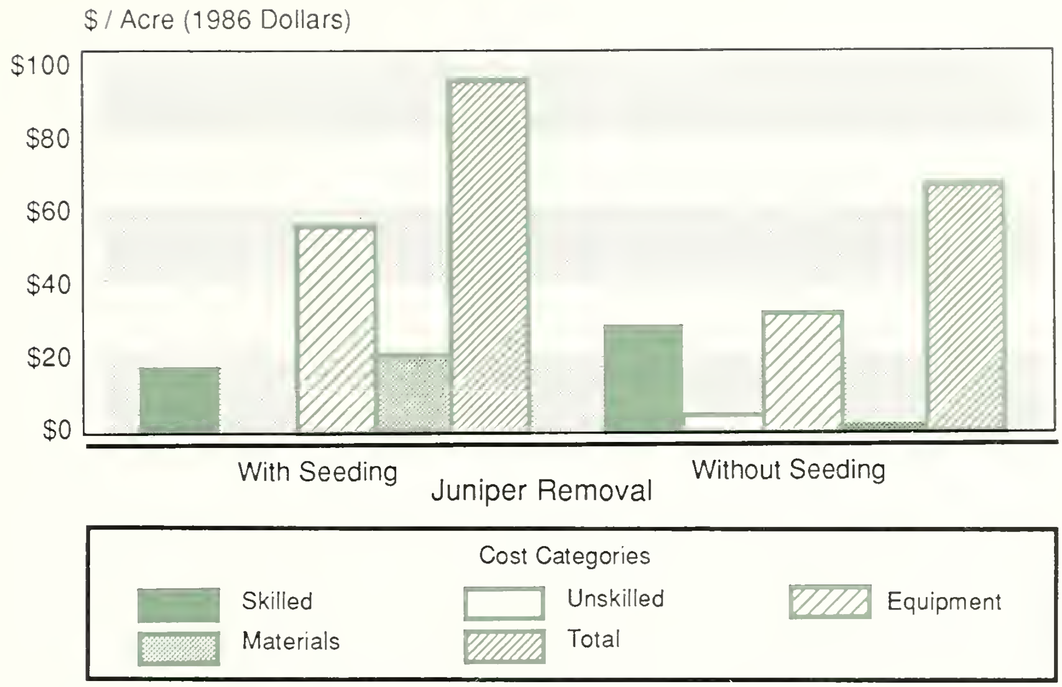

Figure 3-12—Western juniper treatment costs by cost category.

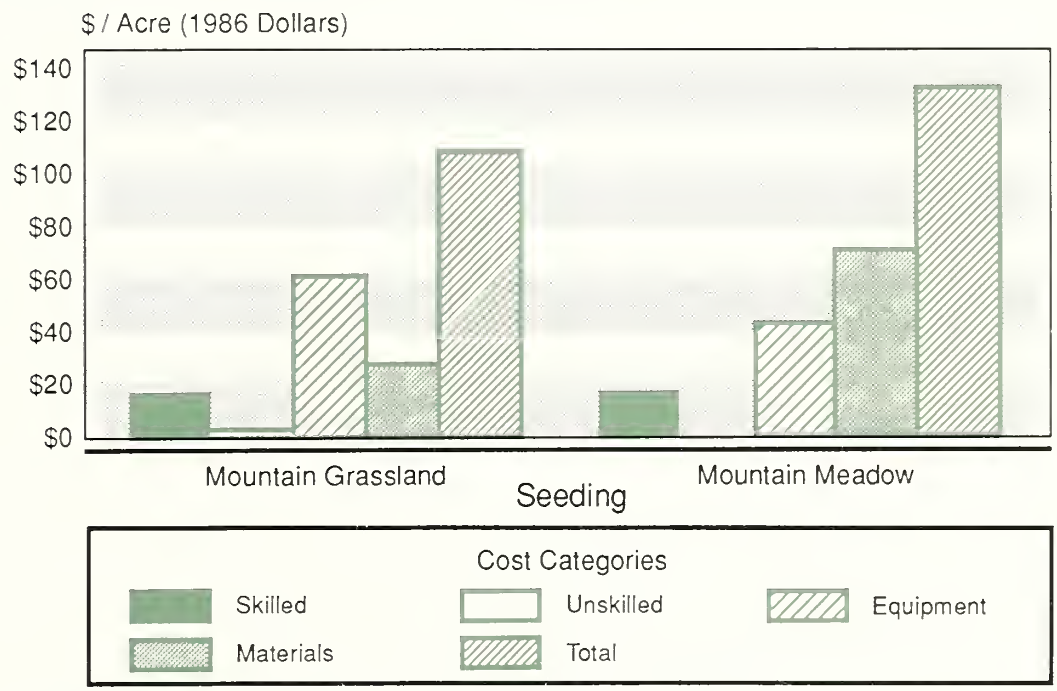

Figure 3-13—Mountain meadow and mountain grassland seeding costs by cost category.

common and was included as a seeding expense. Where seedings were applied to the mountain grassland ecosystem, the appropriate application technique was to prepare the seedbed with mechanical preparation in over 90 percent of the treated area (992 acres).

Mountain meadow ecosystem—Seeding in the mountain meadow ecosystem was accomplished with five different treatments (appendix B, table 10). Although average costs ranged from $52 to $148, no significant differences were observed (fig. 3-13). On average, the cost of seeding in the mountain meadow ecosystem was $132 per acre, nearly evenly split between the combined cost of skilled labor and equipment and the cost of material.

Debris Disposal

In the forested ecosystems, debris disposal was undertaken to reduce the chances of fire as well as provide opportunity to produce additional forage and make that forage available. No significant difference was found between average cost of three techniques of debris disposal treatments (fig. 3-14). The three methods of debris disposal used in this study all included mechanical piling of debris; the difference was associated with the means of seeding (Appendix B, table 11). On three sites (99 acres), the seeding was preceded by mechanical seedbed preparation; on seven sites (637 acres), the seed was broadcast after machine piling; and on three additional sites (91 acres), debris piles were burned and the burn spots seeded. The costs for the burning of piles and seeding of the burn spots does not reflect the expense of piling the debris. The majority of the expense of piling debris is for skilled labor and equipment.

Debris disposal with machine piling and no followup seeding was accomplished on 192 acres (appendix B, table 11). The cost of this treatment was nearly half that of the treatments that included seeding. The exclusion of materials for seeding and the unskilled labor associated with the seeding were the primary differences.

Precommercial Thinning and Piling

Data from the Douglas-fir and ponderosa pine ecosystems were used to determine the average costs of thinning and piling treatments with range objectives. The range objectives resulted in wider spacing than what is typically recommended for timber objectives and also required clearing the debris to a greater extent and seeding the disturbed areas with forage species. The most expensive treatment was to thin, pile, burn the piles, and broadcast seed the disturbed areas ($250/acre)(fig. 3-15). No significant difference was observed between the treatment of thinning, piling, and dribble seeding and the treatment of thinning, piling, and broadcast seeding after piling debris (appendix B, table 12). Most of the expense was always in skilled labor and equipment.

On eight sites that were thinned and piled but not seeded the average cost per acre was $150. On two sites that were thinned but had no piling or seeding, the cost was $66/acre. The main differences in cost were reflected in the lower cost of materials and equipment because the treatment excluded seeding and piling expenses.

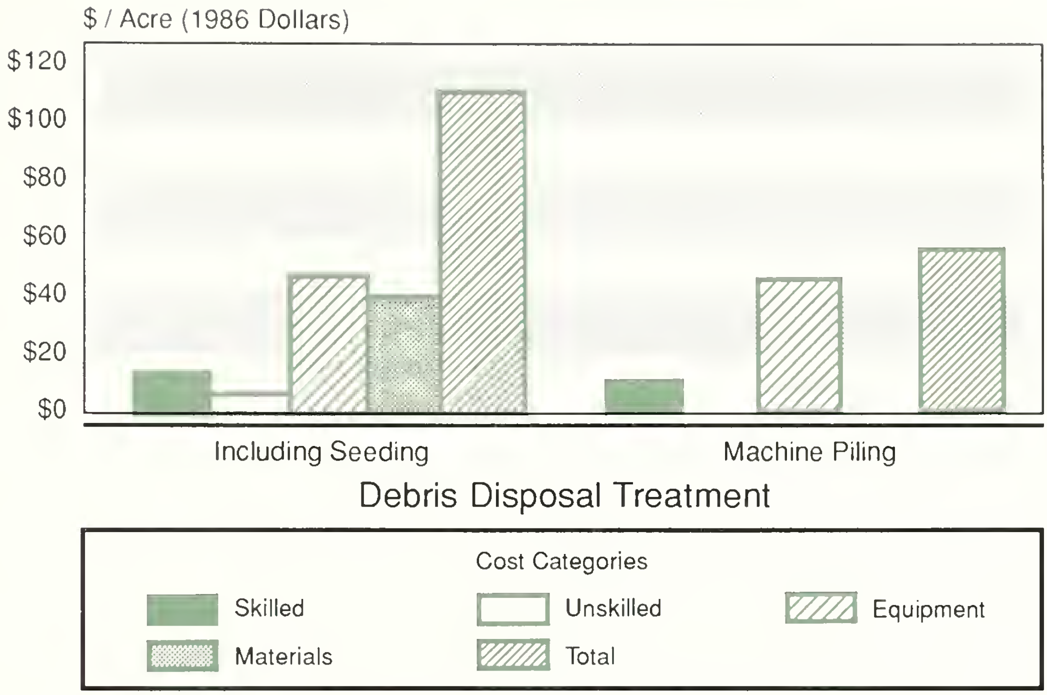

Figure 3-14—Debris disposal with seeding and debris disposal with machine piling and no seeding costs by cost category.

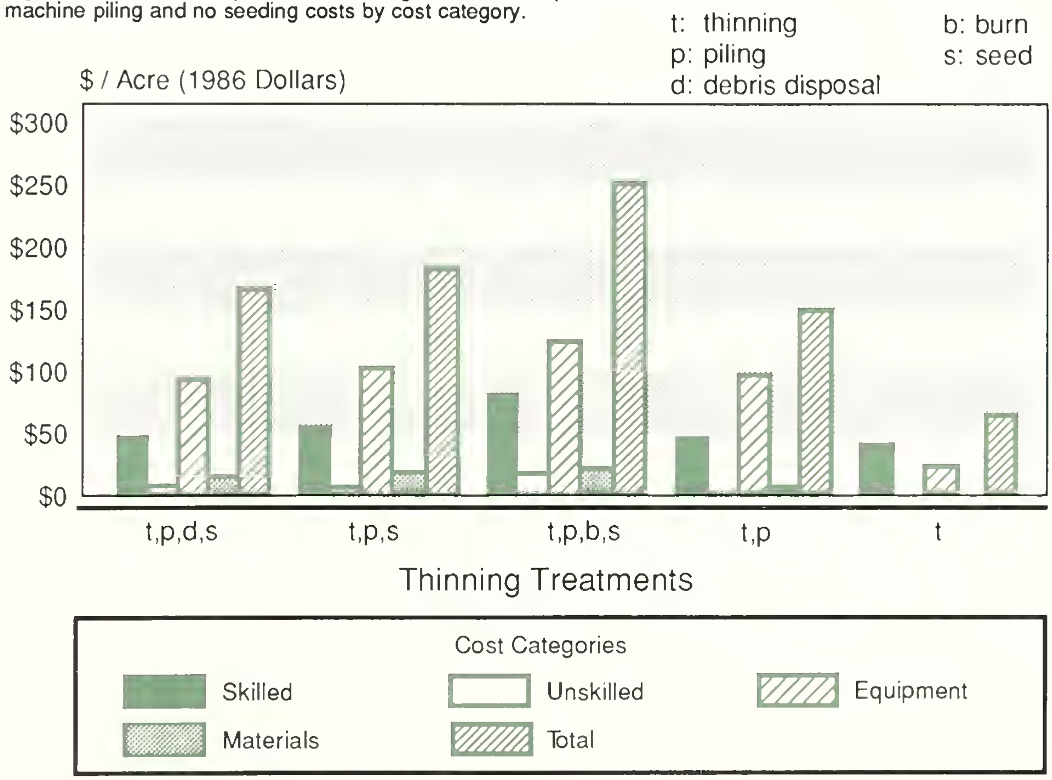

Figure 3-15—Thinning treatment costs by cost category.

AVERAGE FOR ALL ECOSYSTEMS

Fertilizing

Fertilizing was monitored on 472 acres at seven mountain meadow sites (appendix B, table 13). Significant differences were observed between the Federal land sites and the private land sites. Large areas fertilized on the Federal sites resulted in larger equipment being used, and transportation expenses to and from the sites were greater than on the private land sites. Access was less readily available on the Federal sites, and the terrain was more rugged than on private land sites. These factors combined to produce fertilizing costs nearly three times more expensive on Federal than on private lands.

Check Dams and Water Spreading Systems

Check dams were installed on four separate sites at an average cost of $485 per dam (appendix B, table 13). The objective of the dams was to halt erosion and raise the water table. Expenses were spread among all the cost categories.

Water spreading systems were used on two sites. The systems consisted of instream structures and ditches to spread water over 392 acres. The average cost was $739 per acre. Over 75 percent of the expense was for equipment.

One water drainage system was installed to treat 195 acres. The average cost for treatment was $4 per acre. Equipment expenses accounted for 74 percent of the cost.

Weed Control

Weed-control measures were accomplished on five Federal land sites using truck-mounted boom sprayers and herbicide (appendix B, table 14). Costs were nearly evenly split among skilled labor, equipment, and material for a total average cost of $36 per acre.

Controlled Burn Fireline Construction

Fire was used as a management practice to improve forage conditions or remove competing species. Constructing fireline to contain these controlled burn areas cost an average of $1,182 per mile with 65 percent of the expense occurring in the equipment category (appendix B, table 14).

Rodent Control

Rodent control was undertaken on four Federal sites totaling 341 acres (appendix B, table 14). The average cost was $12 per acre. Rodent control was also undertaken in conjunction with seeding on some of the private and Federal lands. When rodent control was used with other treatments, it was considered a part of the seeding treatment, and the costs were added to the seeding costs.

Livestock Access Trails

The average per mile cost of constructing livestock access trails with machines (bulldozers or backhoes) was $1,781 per mile (0.6 mile actual construction occurred) (appendix B, table 14). Over 80 percent of the expense was for equipment. Constructing trails by hand cost $575 per mile; expenses were evenly split among skilled labor, unskilled labor, and equipment. A total of 15 miles of access trails were built by hand.

Summary

Improvement expenses depend to some extent on the ecosystem, the specifications for construction, and the type of improvement selected. In planning fence construction, considering the ecosystem and type of fence needed can reduce the total cost of the project. Reconstructing fence costs substantially less than new construction, and the costs of fence removal can be lessened by selecting larger projects.

Modifying the fence layout to avoid an ecosystem with higher construction costs may be possible. Permanent wire fences constructed in Douglas-fir and larch ecosystems are the most expensive; those in mountain meadow and juniper are the least expensive. The size of the fence project does not appear to affect the per-mile costs for new fence construction; however, cost savings are $88 per mile for large fence-removal projects.

Constructing stock ponds was less expensive than developing springs. Reconstructing small water developments does not appear to be any less expensive than the initial construction. Although selecting the ecosystem is often not an option for the placing of water developments, differences in the cost of construction were related to the ecosystem.

Treating brush in the sagebrush and juniper ecosystems by removal and seeding appear to cost about the same. The cost increases depending on the number of entries required for the equipment. Treating sites by removing brush species as a release treatment for the existing forage species was similar in cost for the two ecosystems. Removing the additional entry of equipment and the expense of seeding results in a lower cost. The method of tree removal is also an important factor in describing the costs of treatment. Felling the juniper trees and not piling the debris was the least expensive treatment. Individual site characteristics will dictate whether this is appropriate for the site.

Costs for seeding in the forested ecosystems differed among treatment types. The most expensive treatment was to thin, pile, burn the piles, and broadcast seed. Costs increased with the number of times the stand was entered for treatment. Costs were least with debris disposal that included burning the piles and seeding the burn spots.

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4 Herbage and Browse Responses to Management Strategies

H. Reed Sanderson

Vegetation Site Types

EVAL began in 1976 with a period of exigency. Vegetation data was needed immediately for the project area, which included about 1.5 million acres. Available information had been classified and mapped in two different ways: National Forest lands had been classified and mapped according to "Plant Communities of the Blue Mountains in Eastern Oregon and Southeastern Washington" (Hall 1973), and private lands had been classified and mapped by the Soil Conservation Service according to "Range Site Handbook for the John Day Land Resource Area of Oregon" (Anderson n.d.). Both methods were satisfactory when used separately by each agency but presented problems when used together. Communication was often difficult among agencies and with private landowners because terminology was inconsistent and the same sites often were called by different names. Major problems occurred when plant communities and range sites were compared because classification and inventory methods were different, and because Soil Conservation Service range sites were biased toward the mountain grassland ecosystem and their vegetation analyses were based on the fire climax concept.

All of the problems confounded management decisions and monitoring activities. Ranchers were confused and frustrated. Some landowners expressed concern about bureaucratic policies that prevented agencies from using the same terminology (Gibbs and Matheson 1979). A common vegetation classification system was clearly needed.

The EVAL team approached the Executive Group for Coordinated Resource Management Planning because one of its goals was to develop a standardized vegetation classification and inventory system (Hansen and Mann 1979). A task group was assigned to assist with this problem; with insufficient time to collect data for a new classification system, the task group combined the Blue Mountain plant communities with the John Day range sites into 51 interagency site types.

Figure 4-1—Maps were prepared that used interagency site types to describe vegetation communities.

Vegetative data were then mapped and discussed as site types, and the same terminology was used to describe all of the communities (fig. 4-1). Presentations to the ranchers were straightforward, and agency personnel had a better understanding of the total forage resource. The common terminology solved the communication problem, and the agencies presented an improved and a more professional impression to the private landowners.

The task group also tried to solve the Soil Conservation Service bias for grassland vegetation by interpreting the ecosystem definition based on potential natural vegetation, as described by Driscoll and others (1984), with management implications: Ecosystems had to be self-perpetuating in the presence of proper livestock management. If brush control practices would be necessary to maintain a site classified as grassland, that site was **not** correctly classified. If sagebrush or juniper were removed from a site classified as grassland and the site could be maintained as grassland while being properly grazed by livestock without further brush control, it was correctly classified. But if further brush control was needed, it was not correctly classified. Where sagebrush or juniper continued to grow, the site should be classified according to the dominant vegetation—sagebrush or juniper—that is expected to exist in the absence of human influence. This interpretation has important management implications: if land managers decide to establish grassland vegetation on a site classified as either a sagebrush or juniper ecosystem, they must be prepared to continue cultural practices to maintain the grass. Obviously, such a decision has an attached economic cost.

The grassland bias, however, was not removed because it was deeply rooted in Soil Conservation Service philosophy. The vegetation descriptions for the disputed range sites did not include juniper or sagebrush as a component of the fire climax vegetation. Because time was inadequate for developing new site descriptions, each grassland range site on private land was visually evaluated. If juniper occurred at a density of more than two plants per acre, it was classified as a juniper ecosystem. If sagebrush was viewed as the dominant vegetative component, the site was classified as a sagebrush ecosystem. These decisions were based on the criteria that the potential natural vegetation would be juniper or sagebrush, and that fire is no longer a major component in the successional dynamics of these plant communities.

Such an interpretation may violate the concepts of an ecological classification system. Under present environmental conditions, however, these sagebrush or juniper sites are not seen as successional stages of a grassland climax. Therefore, managing vegetation according to obvious conditions rather than theoretical factors that may or may not occur seems logical.

EVAL described vegetation as "resource units" for data summaries and reports. Resource units described the vegetation in terms of ecosystem, productivity, and condition class (Garrison and others 1977). The forest ecosystems were based on USDA Forest Service (1967) forest survey types. Forest production was based on four rates of annual wood fiber growth (cubic feet per acre); condition was based on timber stand-size class (fig. 4-2).

The range ecosystems were based on potential natural vegetation (Küchler 1964). Range production was based on four rates of annual herbage and browse production (pounds per acre), and the quantity differed for each ecosystem; condition was based on vegetative cover, composition, and vigor, and soil factors (fig. 4-2).

A method was developed to convert Forest Service plant communities and Soil Conservation Service range sites to resource units and interagency site types, and to convert site types to resource units. The description of each plant community, range site, and site type was examined to determine the ecosystem and production rate. Condition was determined by examining the forest stand or vegetation during the field mapping.

ECOSYSTEM:

A. Forest

- Douglas-fir
- Ponderosa Pine
- Fir - Spruce
- Larch
- Lodgepole Pine

B. Range

- Sagebrush
- Juniper
- Mt. Grassland
- Mt. Meadow
- Alpine

PRODUCTIVITY:

Productivity Level	Wood	Forage				
		Juniper	Alpine	Sage	Mt. Grass	Mt. Meadow
	cu/ft/ac/yr	-lb/ac/yr-				
High	120+	(600-800)	(900-1200)	(1500-3000)	(2250-3000)	(3000-4000)
Mod. High	85-119	(400-599)	(600-899)	(1000-1499)	(1500-2249)	(2000-2999)
Mod. Low	50-84	(200-399)	(300-599)	(500-999)	(750-1499)	(1000-1999)
Low	0-49	(0-199)	(0-299)	(0-499)	(0-749)	(0-999)

CONDITION CLASS:

Forest Ecosystems:
- R = Non-stocked
- S = <28 cm dbh (11 in)
- T = >28 cm dbh (11 in)

Range Ecosystems:
- G = Good
- F = Fair
- P = Poor

Figure 4-2—Description of forest and range resource units used in the Oregon Range Evaluation Project.

Herbage and Browse Production

Herbage and browse production was sampled from 1977 through 1986 on 619 sites representing 10 ecosystems and 51 resource units. These data were collected under a variety of environmental conditions that could not be controlled; therefore, each year's data were standardized to an average production-year based on long-term average precipitation (Hanson and others 1982, 1983; Sneva and Britton 1983).

Five NOAA cooperative weather stations bounded the EVAL study area and one station was somewhat centrally located. All stations had precipitation records in excess of 20 years, except one, which was discontinuous for 3 years. The weather information was supplemented by 14 sites established during the EVAL project to collect additional precipitation data in the study area. Precipitation data from these sites were adjusted to provide records that reflected deviation from the long-term average precipitation. The entire EVAL study area was apportioned with polygons constructed around each station. Production data were then adjusted according to the crop-year precipitation deviation from the long-term mean crop-year precipitation of the assigned polygon.

Total production on the forest ecosystems averaged 129 pounds per acre and ranged from 47 (fir-spruce) to 173 pounds per acre (ponderosa pine). Production for strategies among all forest ecosystems ranged from 53 to 242 pounds per acre (fig. 4-3) (appendix C, table 1).

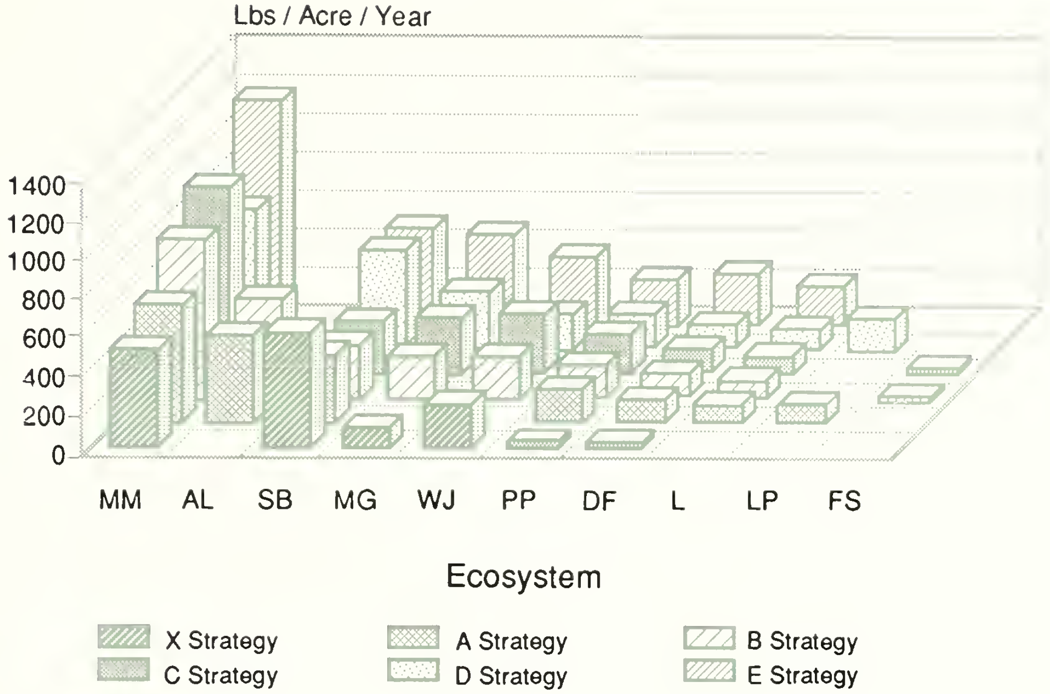

Figure 4-3—Herbage and browse production on forest and range ecosystems and management strategy. MM = Mountain Meadow; AL = Alpine; SB = Sagebrush; MG = Mountain Grassland; WJ = Western Juniper; PP = Ponderosa Pine; DF = Douglas-fir; L = Larch; LP = Lodgepole Pine; and FS = Fir-Spruce.

Total production on the range ecosystems averaged 372 pounds per acre and ranged from 200 (juniper) to 923 pounds per acre (mountain meadow). Range ecosystem strategies ranged from 300 to 553 pounds per acre (fig. 4-3) (appendix C, table 2).

Cultural treatments increased the herbaceous production on all sites except one fertilized, mountain meadow site (fig. 4-4) (appendix C, table 3). Seedings and treatments that release the understory vegetation, such as brush control and precommercial thinning, generally respond slower than fertilizer treatments and over a longer period of time (fig. 4-5). Consequently, except for the fertilized sites, these data report initial treatment responses.

Sampled production data did not consistently conform with published production data (table 4-1). Several explanations are possible, including errors in the base data used to classify production, inadequate sampling of current vegetation, improper ecosystem description, and condition classes not accounting for increased production from seeding. Further, forest ecosystem production is based only on wood production, which is a poor predictor of understory production (Basile 1971, Mitchell and Pickens 1985).

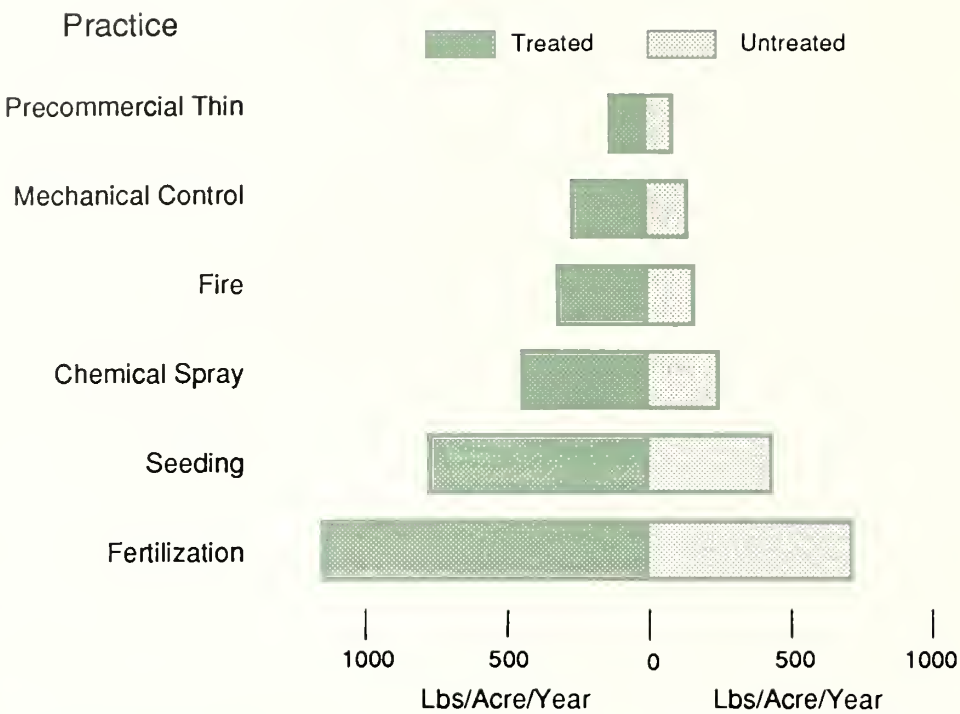

Figure 4-4—Average herbage and browse production as a result of range management practices.

Figure 4-5—A successful seeding practice (foreground) and juniper control on the lower slopes. Juniper was generally left standing in drainages for wildlife habitat.

Table 4-1—Comparison of actual annual herbage and browse production with published production levels for range resource units

Ecosystem and production level	Actual production	Garrison and others 1977
	pounds per acre	
Juniper:		
High	248	600-800
Moderately high	169	400-599
Moderately low	173	200-399
Low	182	0-199
Alpine:		
Moderately low	541	300-599
Sagebrush:		
High	1194	1500-3000
Moderately high	372	1000-1499
Moderately low	492	500-999
Low	254	0-499
Mountain grassland:		
Moderately high	338	1500-2249
Moderately low	668	750-1499
Low	191	0-749
Mountain meadow:		
High	1114	3000-4000
Moderately high	1771	2000-2999
Moderately low	786	1000-1999
Low	683	0-999

Forage Quality

Seasonal trends in forage quality and production were determined to convert herbage and browse data into beef production. Beef production on unimproved grassland sites was limited by low digestibility in June, whereas the improved sites maintained adequate protein and digestibility 1 or 2 months longer. Unimproved moist meadow sites were dominated by forbs that became senescent as soil moisture declined. Although the forbs were comparable to improved grasses in quality, they were generally not available because early grazing is not attempted until the soil dries in midsummer and the forage quality quickly declines.

Forage production on forested sites was primarily limited by the overstory. Improved larch sites, which were seeded after logging, produced 6.4 times more herbage than unimproved sites, but nutrient deficiencies would probably limit beef production by mid-July. Improved lodgepole pine sites, which were precommercially thinned and not seeded, produced about 90 percent more pinegrass than unimproved lodgepole pine sites. Both the larch and lodgepole pine unimproved sites maintained higher forage quality later into the grazing season than did the improved sites, probably because of the more rapid advance in phenology on the improved sites (Svejcar and Vavra 1985).

These data were used to determine carrying capacity, which was one of the primary elements used to develop the economic and beef production models.

Recommendations

The resource unit concept appears to be adequate for aggregating production data from a broad variety of plant communities for regional or national planning. Locally, however, the concept is not satisfactory for planning or applying range management principles and practices.

A unified classification system (Driscoll 1984) needs to be developed to include interpretive information for land managers and planners (Mueggler 1984). Such a system should be developed and accepted by all resource agencies.

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5

Effects of Management Strategies on Water Resources

Arthur R. Tiedemann and Dale A. Higgins

Water is one important resource commodity that originates from Federal wildlands. It is an essential element of and a driving force for industrial, agricultural, and municipal development. It is vital for onsite use by aquatic organisms, wildlife, recreationists, and livestock operators. Resource managers are charged with the task of maintaining adequate supplies of high-quality water from National Forest lands by meeting nonpoint-source pollution requirements of PL 92-500 (U.S. Laws and Statutes, etc. 1972). The National Forest Management Act (U.S. Laws and Statutes, etc. 1976) also specifies that forest management activities will be carried out without imparing soil productivity or degrading water quality.

Water is one of the most useful indicators of disturbances to the landscape that result from forest management activities and grazing. Responses may be manifested in changes in timing, quantity, and quality of flow. Water responses also provide an integrated view of the effects of the multiple management activities that occur on the landscape.

Because of the close relationship of water to management activities, water yield, storm runoff, and water quality were selected as three of the six resource outputs to be studied as part of EVAL. Specific objectives of the streamwater studies were to characterize background or baseline streamflow characteristics for five dominant forest and range ecosystems and evaluate the effects of four grazing strategies on those characteristics; to determine storm runoff characteristics of the five dominant forest ecosystems and assess effects of four grazing strategies; and to measure background characteristics and effects of four grazing strategies on streamwater temperature, sediment and turbidity, chemistry, and pollution indicator bacteria.

Procedures

To accomplish these objectives, 13 watersheds, comprising 5 dominant ecosystems, were established in pastures of Forest Service allotments, each managed under one of the first four grazing strategies described in chapter 1 (table 5-1). Streamflow was measured continuously at the outlet of each watershed 1978-84 by using a streamflow control structure (fig. 5-1) and strip-chart water-level recorder. Temperature was measured with instream recorders. Sediment was measured on grab samples and samples collected with automatic samplers. Chemistry and bacteria were measured on grab samples collected at intervals of about 1 month, except for 1984 when bacterial concentration was measured on samples collected weekly during the summer. Precipitation was measured year-round with standard or weighing bucket gauges equipped with alter shields. During summer, tipping-bucket gauges were used to measure rainfall intensity.

Table 5-1—Range management strategy, grazing system, and characteristics of the 13 study watersheds

Watershed name	Range management strategy, EVAL	Grazing system[a]	Eco-system[b]	Drainage area	Elevation above msl		
					Min	Mean	Max
				km^2	- - - - - meters- - - -		
Big Creek	A	none	FS	5.2	1817	1992	2225
Blackeye Creek	A	none	L	2.3	1599	1932	2344
Caribou Creek	C	DR	PP	6.3	1238	1493	1905
East Donaldson Creek	C	DR	L	4.1	1235	1478	1732
East Little Butte Creek	C	DR	L	3.0	1199	1487	2204
Flood Meadow	D	RR	LP/MM	18.1	1553	1678	1892
Keeney Meadow	D	DR	MM/PP	12.7	1638	1690	1862
Lake Creek	A	none	L	1.2	1532	1611	1732
Little Boulder Creek	C	DR	L	6.0	1453	1786	2301
Ragged Creek	A	none	L	8.8	1193	1559	1908
Tinker Creek	D[c]	DR	L	4.4	1472	1611	1886
West Donaldson Creek	C	DR	L	3.9	1235	1450	1659
West Little Butte Creek	B	SL	L	4.6	1199	1532	2277

[a] DR = deferred rotation, SL = season long, and RR = rest rotation.

[b] FS = fir-spruce, L = larch, MM = mountain meadow, PP = ponderosa pine, and LP = lodgepole pine.

[c] Strategy D at Tinker Creek was attained in water year 1981; all other strategies were attained in water year 1979.

Figure 5-1—A typical stream control structure and gauging station.

Streamflow Characteristics

Water yield[1]

Hydrology of the Blue Mountains is dominated by snow. About 80 percent of the annual rainfall occurs as snow during November through March. On average, 79 percent of the annual water yield occurs from March through June as a result of melting snow (fig. 5-2). On the EVAL watersheds, average monthly runoff peaked in May but the peak varied from March to June among watersheds, depending on elevation and aspect (fig. 5-3). Annual water yields (AWY) averaged 12.3 inches, with a range from 2.5 to 37.4 inches (appendix D, table 1). Ranges of AWY for individual watersheds were 2.5 to 8.7 inches for West Donaldson, 4.5 to 17.3 for Caribou, and 11.0 to 35.6 for Blackeye. The amount of rainfall yielded as runoff averaged 31 percent for all watersheds combined; it ranged from 9 percent (West Donaldson, in water year [WY]80) to 64 percent (Big, WY84; Blackeye, WY84). Annual water yield was statistically correlated with December through May rainfall, annual rainfall, and mean annual temperature. The regression relation,

$$AWY = 14.18 + 1.107 \text{ (Dec.-May rainfall)} - 0.692 \text{ (mean annual temperature)},$$

provided the best predictive relationship ($r^2 = 0.83$). A simpler relation

$$AWY = 0.762 \text{ (annual rainfall)} - 16.33,$$

provided an acceptable estimate of water yield ($r^2 = 0.71$), and the information is more readily available than for the first relationship (fig. 5-4).

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[1] This section is based on a manuscript in preparation by Higgins and others; report on file at Forestry and Range Sciences Laboratory, La Grande, Oregon.

Figure 5-2—Snowmelt discharge on a typical EVAL watershed.

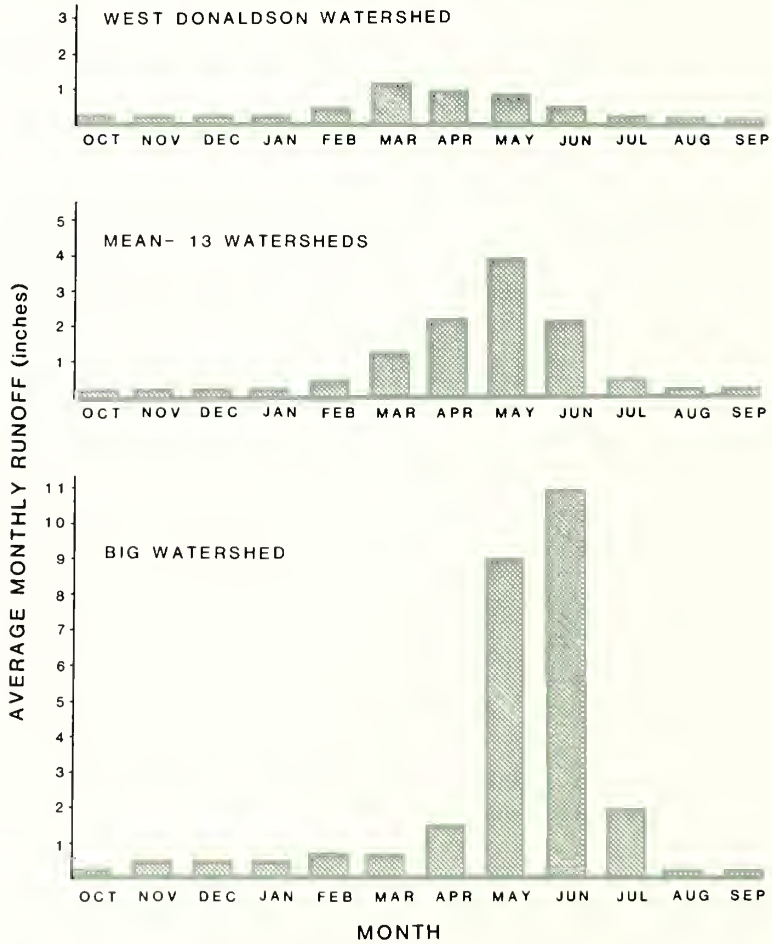

Figure 5-3—Average monthly discharge for watersheds with highest (Big) and lowest (West Donaldson) yields and mean of 13 watersheds.

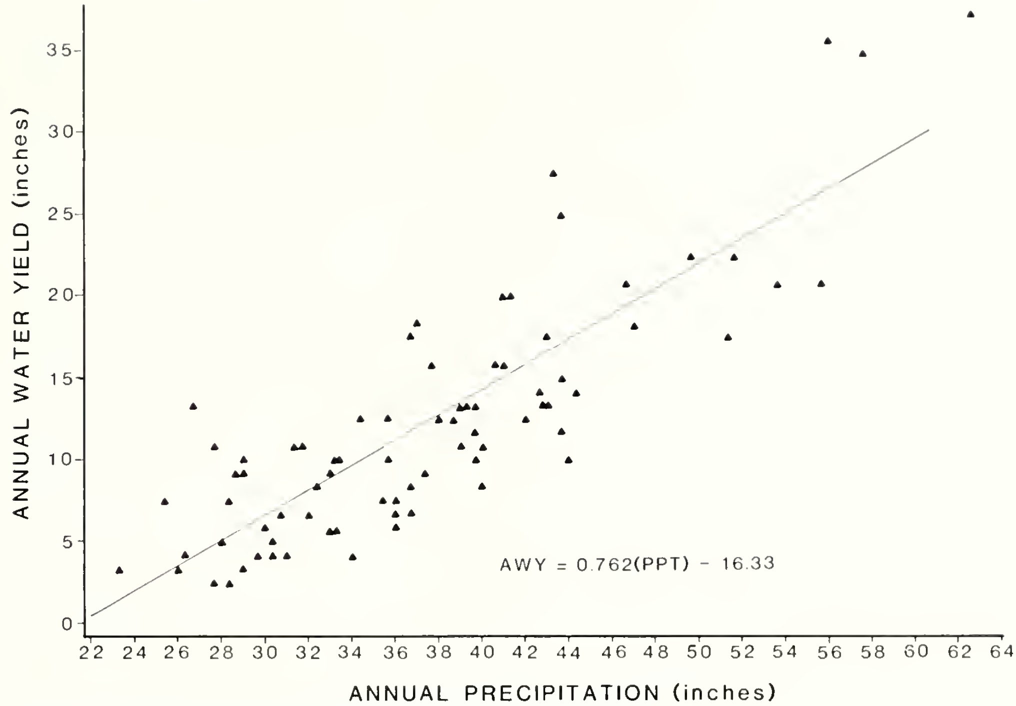

Figure 5-4—Annual water yield versus annual precipitation for 13 small watersheds in the Blue Mountains of eastern Oregon; water mean 1978-84.

Peak Flows

Determining peak flow rates is important for planning culvert sizes. Peak flow volume information is needed for planning flood and erosion control structures. Annual peak flows were produced by snowmelt, or, rarely, rain on snow events. Peaks occurred from February to June, but were concentrated in April (34 percent) and May (46 percent). Peak flows differed widely among watersheds and water years as indicated by the range of 0.5-55.3 $ft^3 \cdot sec^{-1} \cdot mi^{-2}$ (cfsm) (fig. 5-5; appendix D, table 2). For eight of the watersheds, strong correlation was found between the mean annual flood with a recurrence interval of 2.33 yr ($PQ_{2.33}$) and mean annual rainfall (MAP) defined by the equation $PQ_{2.33} = 10^{(-1.3107 + 0.0544 (MAP))}$ with $r^2 = 0.98$ (fig. 5-6).

Four of the watersheds—Caribou, Keeney, Flood, and Tinker—were above the regression line. Keeney, Flood, and Tinker may be more responsive to runoff because they tend to have heavier subsoils than the other watersheds. They also had the highest cattle stocking density and may have experienced greater soil compaction. Keeney and Flood, which plotted farthest above the regression line, also have the least topographic relief. Watersheds with low relief typically have a shorter, more synchronized snowmelt season than watersheds with high relief, which may also account for some of the higher response observed with these watersheds.

The median flood frequency for all watersheds is presented in figure 5-7. Curves for west Donaldson (steepest) and Keeney (flattest) illustrate the range of observed slopes.

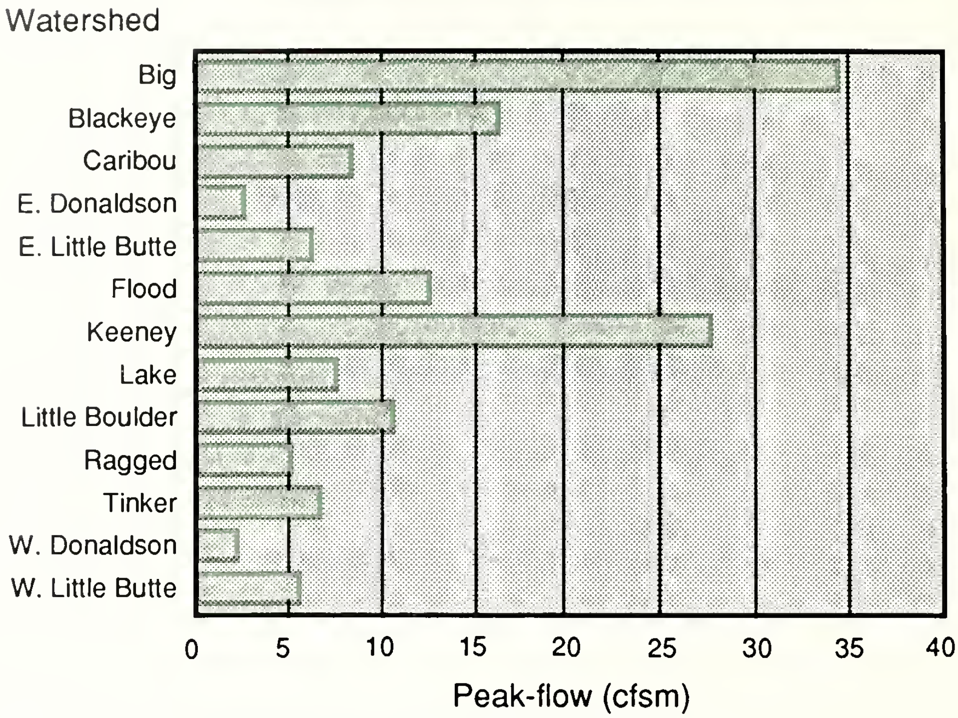

Figure 5-5—Average annual peak flows (cfsm) for 13 small watersheds in the Blue Mountains of Oregon, by water year.

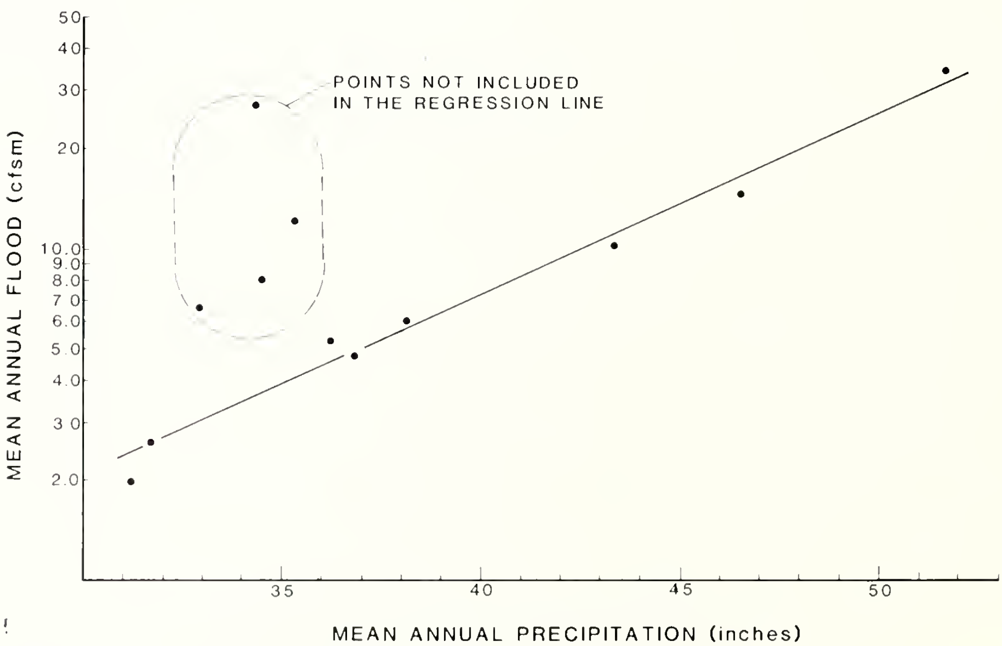

Figure 5-6—Relation of mean annual flood with a 2.33-year interval to mean annual precipitation for 8 small watersheds in the Blue Mountains of eastern Oregon.

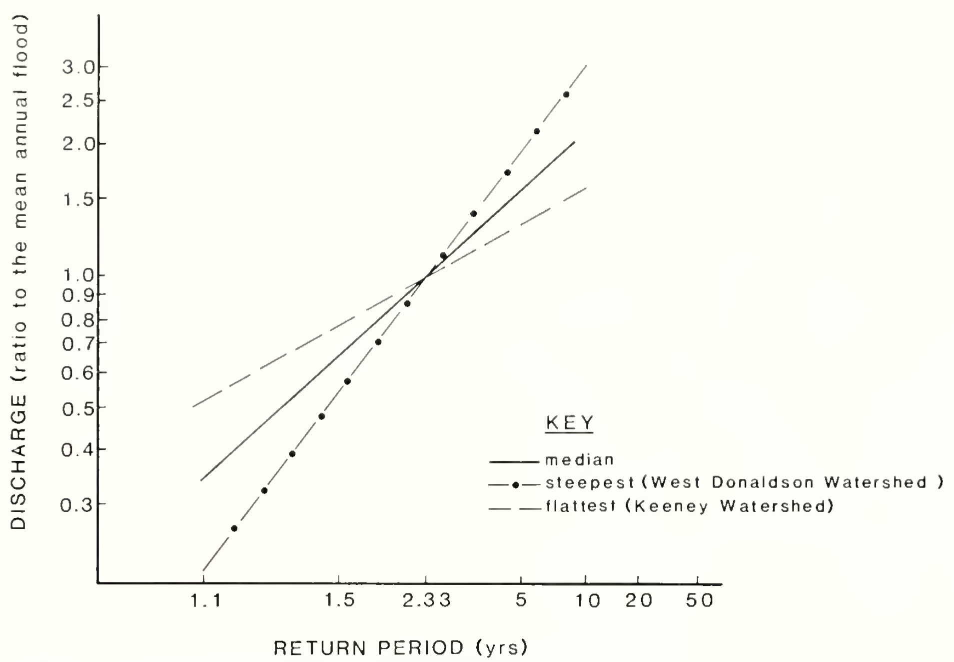

Figure 5-7—Flood frequency curves for small watersheds in the Blue Mountains of eastern Oregon, water years 1978-84.

Low Flows

Low flows determine the minimum habitat available for resident and anadromous fish populations, minimum water volumes available for livestock watering facilities, and local irrigation needs. Annual 7-day low flows covered a range of 0.002 to 0.323 cfsm and averaged 0.065 cfsm (fig. 5-8; appendix D, table 3). Annual 7-day low flows occurred from July to February with 86 percent concentrated in the months of August (18 percent), September (37 percent), and October (31 percent). Low-flow periods occured well after snowmelt was complete and coincided with the end of the period of major evapotranspirational loss (fig. 5-9). Few low flows were observed during winter because late fall rainstorms and melt from occasional winter thaws tend to increase baseflow. Low flows observed during winter occurred during periods of extreme cold. The median, steepest, and flattest 7-day low-flow frequency curves are presented in figure 5-10. The prediction equation for mean annual 7-day low flow with a recurrence interval of 2.33 year ($LQ_{2.33}$) is complex and requires data on relative relief, net radiation, and mean annual rainfall.

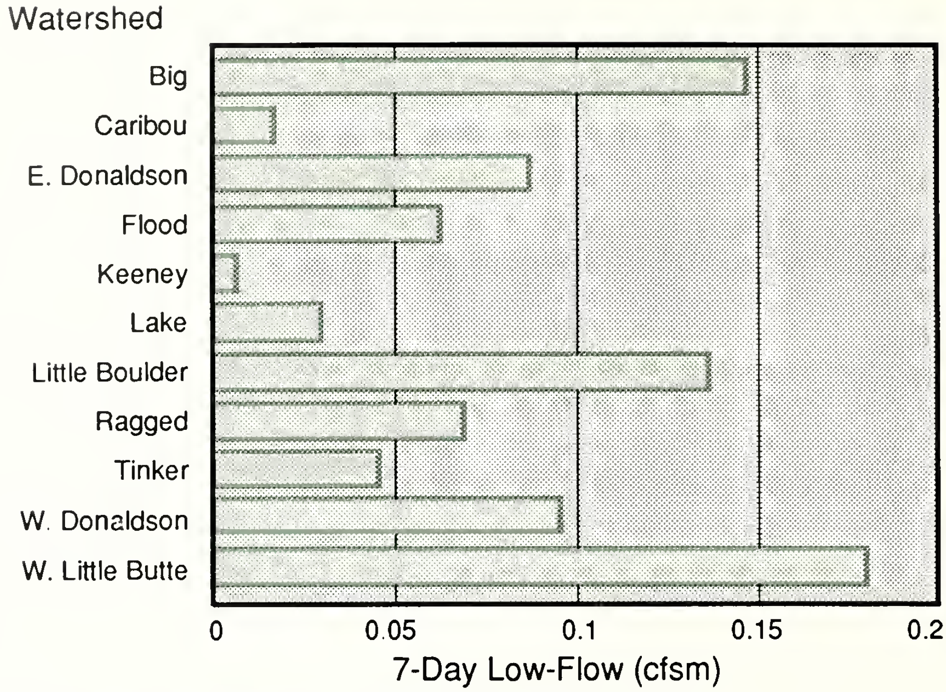

Figure 5-8—Average annual 7-day low flows (cfsm) for 11 small watersheds in the Blue Mountains of Oregon, water years 1978-84.

Figure 5-9—Low-flow period on Flood Meadow in October.

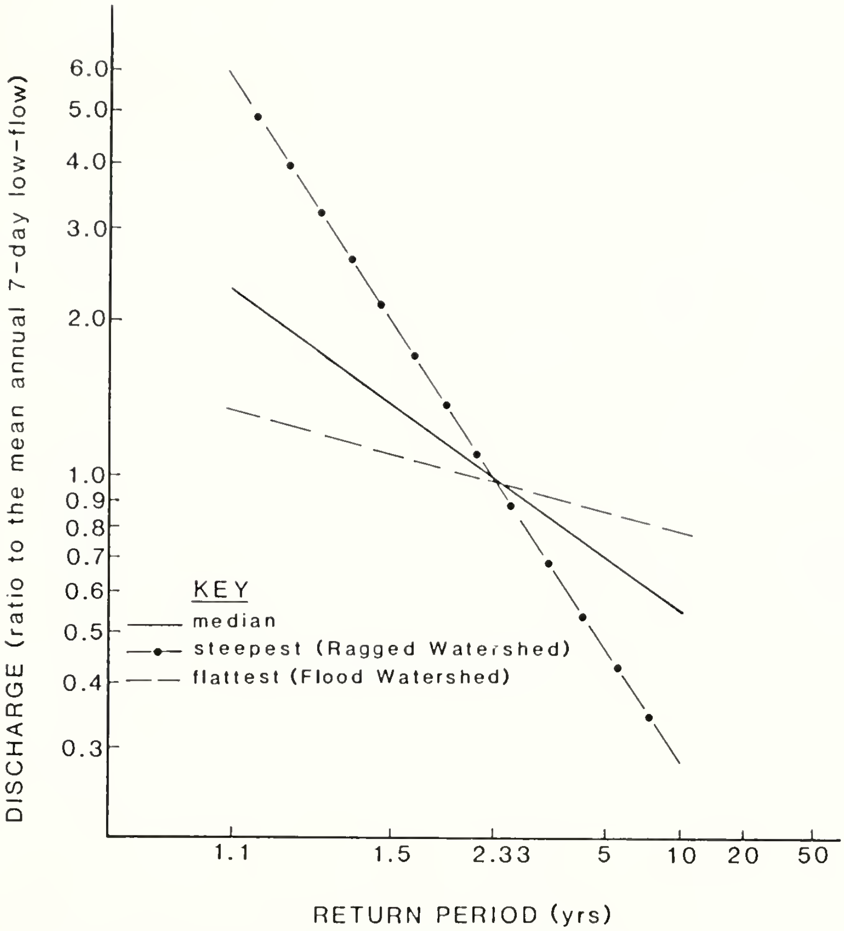

Figure 5-10—Seven-day low-flow frequency curves for small watersheds in the Blue Mountains of eastern Oregon, water years 1978-84.

Flow Duration Curves

The slope of a flow duration curve is a reflection of the hydrologic storage capacity of a watershed. A steep slope indicates a highly variable flow regime and minimal storage capacity. A flat slope indicates greater storage and more stable flows. The curves are useful in planning or evaluating fish passage at culvert sites, hydroelectric power, and water quality. Median flow duration curves for the 13 EVAL watersheds and the two extremes of watersheds are shown in figure 5-11. Discharge is expressed as a ratio to the mean annual flow, to factor out differences in the amount of runoff and allow comparison of flow distributions and hydrologic storage capacities among watersheds.

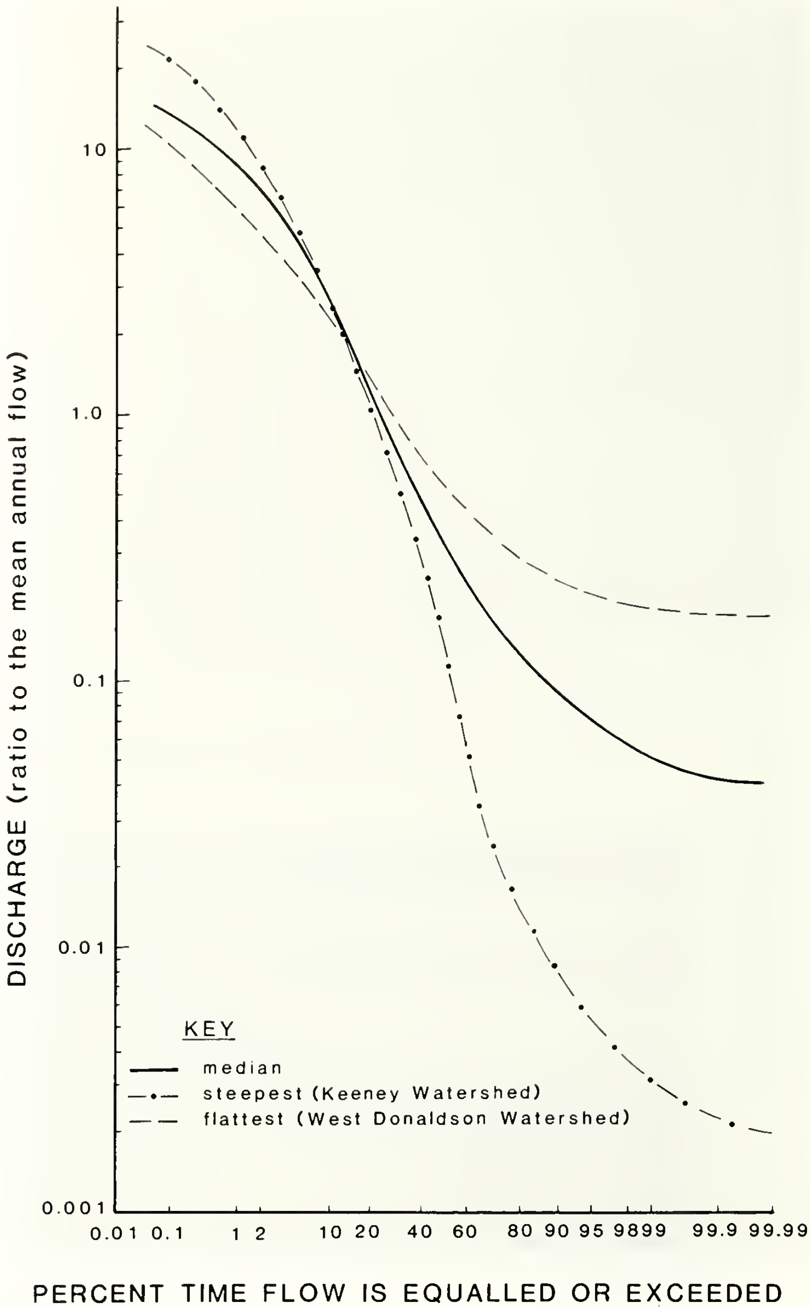

Figure 5-11—Flow-duration curves for small watersheds in the Blue Mountains of eastern Oregon, water years 1978-84.

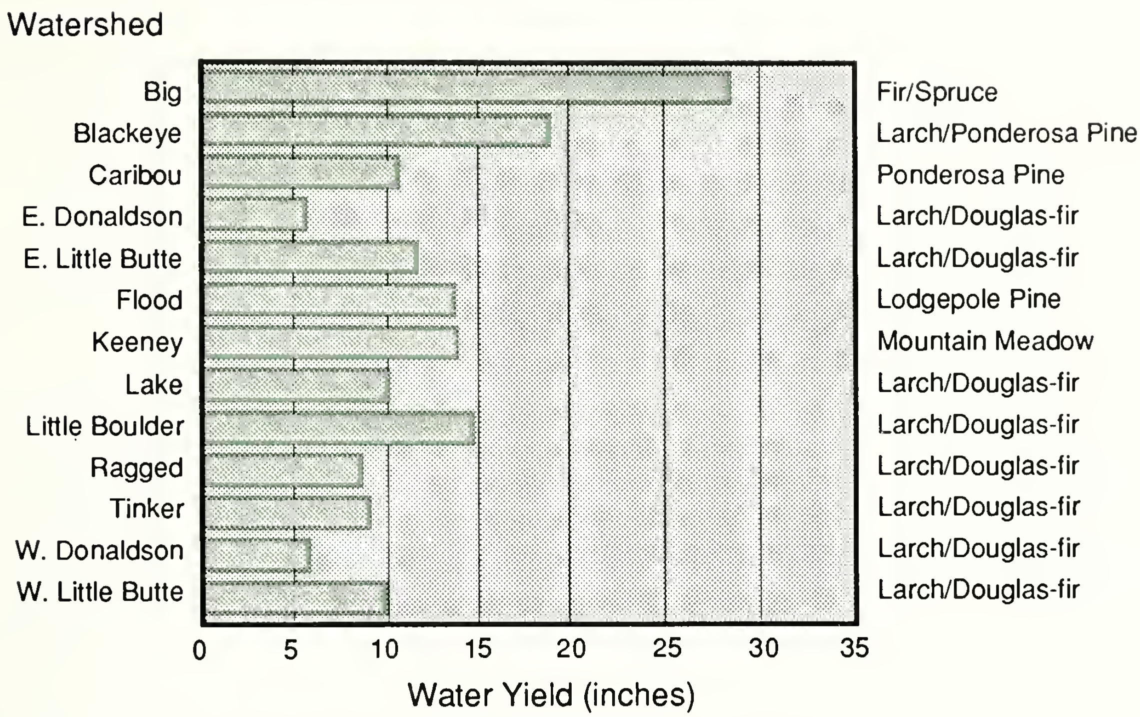

Figure 5-12—Average annual water yield (inches) for 13 small watersheds in the Blue Mountains of Oregon, water years 1978-84.

Ecosystem Differences in Water Yields

Average annual water yields from the nine western larch-Douglas-fir watersheds ranged from 5.6 to 18.9 inches (fig. 5-12; appendix D, table 1). Yields from the fir-spruce dominated watershed were greater (28.1 inches) than from any other ecosystem. Yields from ponderosa pine, lodgepole pine, and meadow dominated watersheds were 10.9, 13.9, and 14.0 inches, respectively. We compared the western larch-Douglas-fir watersheds to watersheds dominated by "other" ecosystems. Yields were statistically greater for the other ecosystems (16.7 inches) than for western larch-Douglas-fir (10.3 inches). Other ecosystems, with the exception of ponderosa pine, tended to yield more water than western larch-Douglas-fir for equal amounts of rainfall. This difference may be a result of lower interception losses, less hydrologic storage capacity, or less evapotranspiration for the watersheds of other ecosystems. Average annual peak discharges were also greater for watersheds dominated by other ecosystems (20.9 cfsm) than for western larch-Douglas-fir (6.8 cfsm).

Effects of Range Management Strategy

Increasing intensity of management did not result in a statistically measurable effect on average annual water yields, average annual peak flows, average annual low flows, flood frequency curves, 7-day low-flow frequency curves, or flow duration curves. This result can probably be attributed to the low to moderate grazing intensities applied, maintenance of adequate ground cover, and widely differing watershed characteristics. Results were also likely confounded to an unknown degree by a prior grazing history of nearly 100 years imposed on several of the watersheds.

Storm Runoff[2]

Runoff that results from discrete rainfall events is referred to as storm runoff. This form of runoff is separate from what results from snowmelt or baseflow from the watershed. Storm runoff is characterized by a rise in the baseflow of the stream, followed by a sharp rise in flow (rising limb of the hydrograph) to a peak, and succeeded by a rapidly falling recession limb. It is distinguishable as a separate runoff component on the hydrograph.

Increased storm runoff is associated with unstable flows that can cause flooding and erosion at high rates and may not provide adequate water for fish, wildlife, recreation, and agriculture at low rates. As the ratio of storm runoff to rainfall increases, local flooding becomes more frequent; less water infiltrates and is available for plant growth or maintenance of streamflow during dry periods.

Wildland managers must understand the effects of management on storm runoff if they are to maintain water quality and favorable streamflow regimes. Grazing can alter storm runoff through compaction and soil disturbance: both may act to reduce infiltration and increase storm runoff and erosion (Gifford and Hawkins 1978, Blackburn 1984). Few studies have focused on the effect of specific grazing strategies on storm runoff and on watershed conditions. Results of studies of the relation between grazing, storm runoff, and erosion generally show that heavy grazing increases storm runoff and erosion; effects from light and moderate grazing are difficult to distinguish from each other but tend to be intermediate between no grazing and heavy grazing (Gifford and Hawkins 1978). Interpretations are complicated by the climatic regime and the fact that heavy grazing intensity in one region may not be equivalent to heavy grazing in another region because of differences in forage productivity.

The objectives were to determine storm runoff volumes and peak discharges for the Blue Mountains of eastern Oregon and to determine if storm runoff and peak discharges differed among range management strategies and the dominant ecosystems on the EVAL watersheds. Comparison of storm runoff with other regions was also an objective of the study because baseline information on this form of stream discharge is not well quantified for the interior western United States.

Volume of flow that results from storm runoff was determined by use of a hydrograph separation technique: storm runoff volume and duration are determined by separating the baseflow volume from the storm hydrograph. The rate of rise of baseflow is determined as a straight, upward sloping line extended from the initial rise in storm runoff until it intersects the falling limb of the storm hydrograph (fig. 5-13). We determined a single baseflow rise rate for each watershed. These rates were much smaller than those documented for most watersheds of the humid eastern United States (Hewlett and Hibbert 1967). Our greatest rate was 0.013 cfsm/h and was as low as 0.002 cfsm/h for storms on some watersheds. The normal rate of increase in eastern U.S. watersheds is 0.05 cfsm/h.

The criteria for storms used in this analysis were the storm must produce at least 0.0001 inches of storm runoff; both streamflow and rainfall data must be available; melting snow was not an influence; and the storm runoff hydrographs must be discrete with a single peak. Most of the storms meeting these criteria occurred June to October.

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[2] See footnote 1.

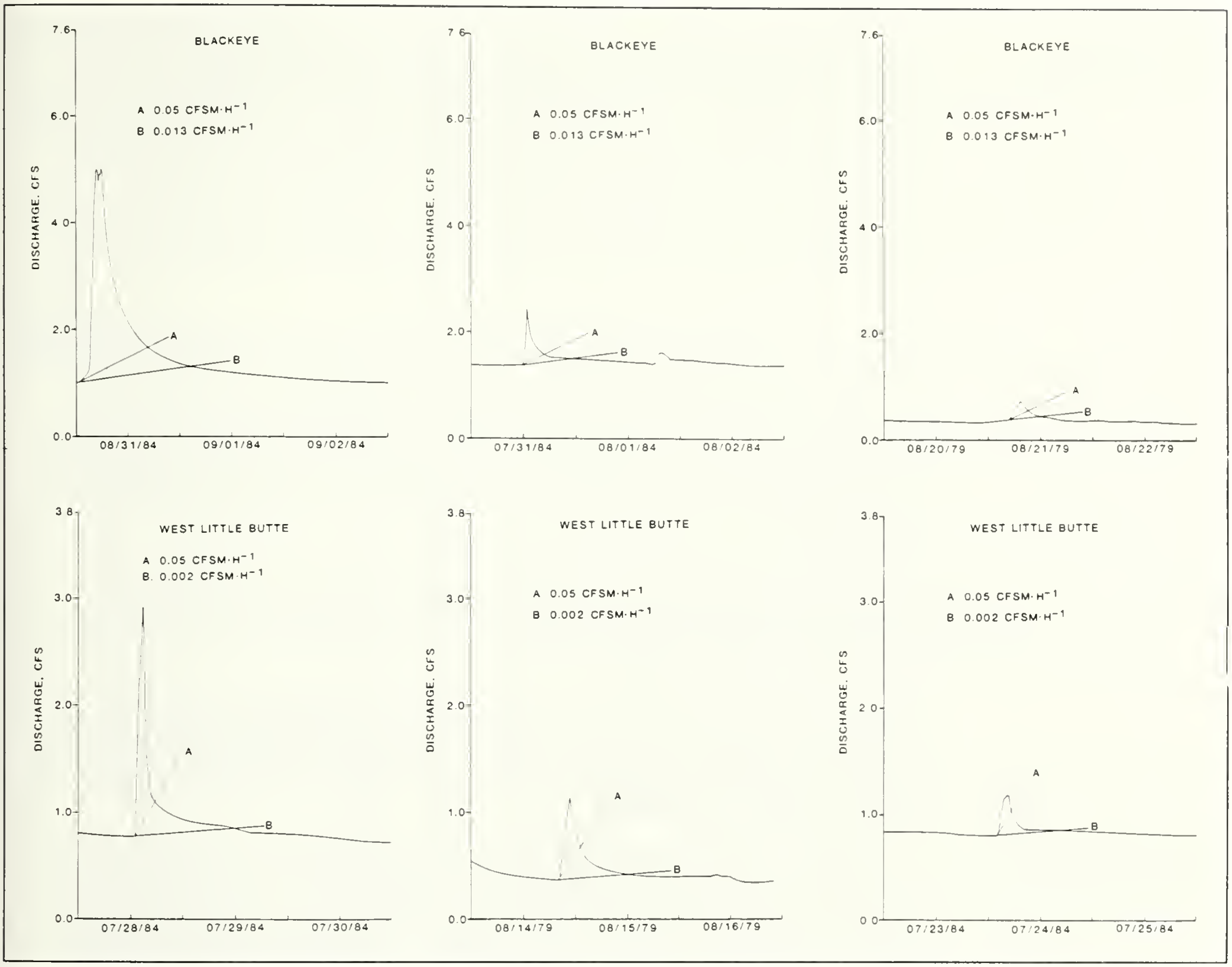

Figure 5-13—Storm runoff hydrographs for large, medium, and small storms on 2 watersheds in the Blue Mountains of eastern Oregon.

Rainfall Characteristics

Even though convective summer thunderstorms produced most of the summer rainfall, amounts and intensities were among the lowest that occur in the United States. The median rainfall was 0.37 inches, and 95 percent of storms had less than 1 inch. The largest storm observed during the 6 years of study was 2.5 inches. A typical storm lasted 4 hours and had maximum 30-minute and 60-minute intensities of 0.28 and 0.20 inches per hour, respectively. The maximum 30-minute intensity is an order of magnitude less than that observed during 20 years of record in Arizona of 3.21 inches/hour (Baker 1982). A similar disparity exists for comparison with a 30-year record in the Appalachians (Hewlett and others 1977).

Storm Runoff Characteristics

The median storm runoff volume was only 0.0014 inch, and 95 percent of all runoff producing storms produced less than 0.0175 inch. Thus, storm runoff accounts for about 0.1 inch of water yield—two orders of magnitude less than the average annual yield of 12.3 inches. As a general rule, storm runoff accounted for about one-fourth of the total flow during the storm runoff period; increased baseflow accounted for the remainder. The storm runoff fraction was slightly less for smaller storms and slightly greater for larger storms. Storm runoff accounted for less that 2 percent of the rainfall received for 95 percent of the storms. The median response of 0.4 percent was about an order of magnitude less than the average hydrologic response observed in the eastern United States (Hewlett and Hibbert 1967).

Peak flows from storm runoff are also small compared to those that are generated by snowmelt runoff. All annual peak flows were the result of snowmelt runoff or rain on snow events. Peak flows that result from snowmelt runoff ranged from 0.6 to 55.3 cfsm. Storm runoff peak discharges ranged from 0.043 to 15.9 cfsm, with a median of 0.43 cfsm. The highest storm runoff of 15.9 cfsm, was a single event on Big watershed that resulted from a 1.8-inch storm in a 24-hour period when soil moisture was high because of recent snowmelt. The next highest value on the same watershed was 7.2 cfsm.

The small storm-runoff responses on our watersheds can be attributed to the low rainfall, dry soil conditions in the summer, and, with exception of Keeney, generally high infiltration rates of the soils.

Several measurable variables of flow and rainfall may affect storm runoff. These variables include amount of initial flow, amount of rainfall per storm, rainfall intensity for 30 and 60 minutes, and duration of rainfall. Amount of initial flow and total amount of rainfall per storm accounted for most of the variability and are the two most important variables to measure.

Ecosystem Effects on Storm Runoff

In determining differences among ecosystems, we were only able to compare the nine western larch-Douglas-fir watersheds as a group with the four watersheds dominated by other ecosystems as a group. Western larch-Douglas-fir watersheds were less responsive to storm runoff than the other watersheds. Differences were probably a result of more ground cover on larch-Douglas-fir watersheds, greater soil water-storage capacity, more rainfall interception, and, perhaps, a history of less impact from grazing disturbance than the other watersheds.

Effects of Range Management Strategies on Storm Runoff

No differences were found in any of the storm runoff characteristics as a consequence of increasing intensity of grazing management. Some evidence indicated that grazing may have altered storm runoff on Keeney meadows. It was grazed at more than twice the intensity of the other watersheds. We would have expected this large meadow to be less responsive to storm runoff than other watersheds because it is large and has deep soils (> 5 feet) to store water and regulate flows. Instead, Keeney had the greatest storm runoff response of any watershed. In addition to heavier subsoils than those on other watersheds, we suspect that surface soils in the meadow may have been compacted by nearly 100 years of grazing use. Compaction and heavy subsoils may be restricting infiltration and percolation of moisture, thereby causing Keeney to respond like a watershed with little hydrologic storage capacity. In one study by Dadkhah and Gifford (1980), livestock trampling reduced infiltration rates and was the most important factor influencing infiltration.

One problem with this study was that grazing occurred on the watersheds many years before EVAL was started. The effects of prior grazing on the results of this study are not known, but we think it did not have a large confounding effect because the relative order of watersheds from lowest to highest grazing intensities probably did not change much with EVAL. Strategy A watersheds did not receive much livestock use before EVAL because they are heavily forested and only produced minor amounts of forage. Watersheds with meadows were selected for strategy D watersheds because seeding and fertilizing treatments could be implemented there. These watersheds probably received the highest intensity of grazing before EVAL.

Sediment and Turbidity

Sediment transport and yield is determined by complex relations between availability of sediment, sediment particle sizes, streamflow rate, and the transport capacity of a stream. Small sediment particles that move in suspension are known as suspended sediment; bedload refers to large sediment particles that move on or near the streambed by rolling, sliding, or saltation (jumping). Concern about sediment as a pollutant arises from its potential effects on fish, esthetics, and facilities. Fingerling and adult trout can survive high sediment concentrations for short periods with little harm, but sediment deposition can seriously reduce egg survival, reduce aquatic insect fauna, and reduce available habitat by filling pools (Cordone and Kelly 1961). Turbidity is an optical property that indicates the degree to which light penetration in water is impeded by suspended material. High turbidity makes water less desirable for recreation and esthetically. Sediment deposition can fill reservoirs and clog irrigation canals. Objectives of the sediment studies were to characterize suspended sediment concentrations, turbidities, suspended sediment yields, and bedload yields for the Blue Mountains of Oregon.

Depth-integrated grab samples for suspended sediment concentration (mg/L) and turbidity, in nephelometric turbidity units (NTU) were collected at the mouth of each watershed from 1979 to 1984. Sample intervals were 2 to 4 weeks during baseflow periods and more frequently during snowmelt or storm runoff. During the 1984 snowmelt season, bedload samples were collected with a Helley-Smith bedload sampler. Instantaneous streamflow rate was determined at the time of each suspended sediment and bedload sample. For each watershed, suspended sediment and bedload yield were estimated from average daily streamflows by use of a regression equation that related suspended sediment concentration or bedload transport rate to streamflow rate. These relations are referred to as rating curves. Suspended sediment concentrations were not related to streamflow rate at Lake, so yields there were estimated from average concentration.

Suspended sediment concentrations were low most of the time, but ranged widely in response to streamflow rates and sediment availability. The range for all samples was 0.1 to 2605.5 mg/L and the median was 4.0 mg/L. Of the 1,044 samples, 90 percent were less than 23.4 mg/L. Maximum concentrations for each watershed ranged from 21.0 mg/L at Big to 2605.5 mg/L at Caribou. The highest concentrations were of short duration (hours to a few days) and typically occurred near peak snowmelt when streamflow was rising. Median concentrations for watersheds ranged from 1.3 for Blackeye to 7.7 mg/L for West Donaldson. Turbidities were 0.1 to 83.0 NTU with a median of 2.1 NTU; 90 percent of the samples were less than 13.0 NTU. Watershed maximums ranged from 2.6 NTU for Big to 83.0 for Blackeye.

The suspended sediment rating curves were weak but statistically significant for all watersheds except Lake. The coefficient of determination (R^2), which represents the proportion of variation in sediment that is accounted for by streamflow rate, ranged from 0.22 for Keeney to 0.47 for Flood and Little Boulder. These weak relations are typical for small forested watersheds (Ketcheson 1986). The statistical significance is probably attributable to a definite but weak correlation between suspended sediment and streamflow rate and also to the large sample size; the rating curves are based on from 60 to 104 samples. Estimated suspended sediment yields averaged 0.013 tons/acre/year, with a range of 0.002 to 0.038 tons/acre/year.

Bedload rating curves were generally stronger than the suspended sediment rating curves, but fewer were statistically significant because of small sample sizes (4 to 9 samples per watershed). Bedload movement at Keeney and Lake was minimal and was not related to streamflow rate. When Lake and Keeney were eliminated, six of the rating curves were statistically significant and five were not; R^2 values ranged from 0.48 for Big to 0.94 for Ragged. Estimated bedload yields averaged 0.004 tons/acre/year, with a range of 0.000 to 0.038 tons/acre/year. Most bedload movement occurred during short periods (hours to a few days) at the highest streamflow rates.

The sum of estimated suspended sediment and bedload yield provides an estimate of total sediment yield for each watershed and water year. Estimated total sediment yields averaged 0.017 tons/acre/year with a range of 0.002 to 0.060 tons/acre/year. These yields are at the low end of the range of sediment yields reported for 80 small watersheds in the western United States (Patric and others 1984).

Stream Temperatures[3]

The headwaters of the John Day River provide spawning and rearing habitat for one of the few remaining wild runs of chinook salmon and steelhead trout in the Columbia Basin (Platts 1981). These streams also contain resident populations of rainbow trout, cutthroat trout, and bull trout. Stream temperature plays an important role in the survival, distribution, and productivity of these species because of their low thermal tolerance (Brown 1969). Rainbow trout prefer temperatures between 55 and 66 °F and have an upper lethal temperature of about 80 °F (Ames 1977; Grimes 1980). Chinook salmon fry prefer temperatures between 54 and 57 °F and have an upper lethal temperature limit of 77 °F (Brown 1969). As stream temperatures increase above the optimum for salmonids, species that can tolerate warm temperatures also compete more effectively for available space.

Stream temperature also affects concentration of dissolved oxygen (DO) in streamwater. As temperatures increase, DO declines. As temperatures increase, oxygen demands of aquatic organisms and decomposer organisms also increase, thereby exerting an additional impact on availability of oxygen.

Water quality criteria to protect aquatic life include two upper limiting temperatures; a short-term maximum for survival and a maximum weekly mean for growth. The U.S. Environmental Protection Agency (1986) has established these values for rainbow trout at 75 and 66 °F, respectively. Oregon State standards reflect these criteria by stating that increases in stream temperature will not be allowed when stream temperatures are 68 °F or higher (State of Oregon 1986).

[3] This section is based on a manuscript in preparation by Maloney and others; on file at the Forestry and Range Sciences Laboratory, La Grande, Oregon.

Grazing can increase stream temperatures through two primary mechanisms: removing shade provided by riparian vegetation and caving overhanging stream banks. Both result in greater exposure of the stream surface to direct solar radiation, the major factor responsible for stream temperature increases (Brown 1970, Gibbons and Salo 1973, Rishel and others 1982).

Several studies relate grazing to water quality parameters and watershed condition (Blackburn 1984, Gifford and Hawkins 1978, Meehan and Platts 1978, and Platts 1978). Information is not available on the effects of increasing intensities of grazing management on stream temperature, however, grazing effects need to be addressed because riparian areas are generally used more than upland areas (Gillen and others 1984). Cattle appear to prefer the diversity, quality, and succulence of vegetation in the riparian zones (Ames 1977). In addition to a lack of understanding of the relations among grazing management, shade, and stream temperatures, baseline levels and variability of stream temperatures have not been well characterized for eastern Oregon.

Specific objectives of our stream temperature studies were to describe the summertime stream characteristics; determine relations between stream characteristics and summer stream temperatures; compare stream temperatures with established criteria and standards; and evaluate the effects of ecosystem differences and four range management strategies on summertime stream temperatures.

To be consistent with these Oregon standards and fish thermal tolerances, we report hourly (short-term) and weekly mean temperatures with 66, 68, and 75 °F as comparison thresholds.

Stream Temperature Characteristics

Temperatures of streamwater had summertime hourly maxima of 55 to 82 °F. Daily ranges within a stream were as high as 23 °F. Maximum mean weekly temperatures ranged from 52 to 64 °F (table 5-2). Watersheds were clustered into three groups based on maximum temperatures to help explain variability among watersheds (table 5-3). Maximum temperatures were used for separation because minimum temperatures were too similar among groups. Group 1, with the lowest maximum temperatures, had the highest mean percentage of shade and the least mean travel time. Group 3 had the highest maximum temperatures, lowest mean percentage of shade, and greatest mean travel time. Maxima observed in group 3 are more than 2 times greater than those observed at high elevations in northeast Oregon (Fowler and others 1979). Cumulative frequency curves were developed for each watershed by determining the number of hours that water temperature exceeded specific levels. Figure 5-14 shows a representative cumulative frequency curve for each of the three temperature groups.

When we evaluated factors that influence mean weekly stream temperatures, the variables, in decreasing order of importance, were shade, week of the year, elevation, travel time of the stream, and weekly flow.

Ecosystem Differences

The dominant ecosystem within a watershed was an important determinant of mean weekly water temperatures. Watersheds dominated by western larch-Douglas-fir and fir-spruce had lower temperatures than watersheds with ponderosa pine, lodgepole pine, or mountain meadow. This difference can be explained by the greater amount of forest cover associated with the western larch-Douglas-fir and fir-spruce ecosystems that provided shade to the stream.

Table 5-2—Stream temperature characteristics, June 21 to September 19, for 13 small watersheds in the Blue Mountains of Oregon, water years 1978-84

Watershed	Temperature		
	Maximum monthly	Maximum weekly	Mean[a]
	°F		
Big	60.3	54.7	48.2
Blackeye	54.5	51.6	46.0
Caribou	79.0	64.0	57.2
East Donaldson	59.4	55.8	50.5
East Little Butte	64.6	57.4	51.3
Flood	75.2	61.9	56.3
Keeney	82.0	63.9	57.4
Lake	61.9	53.4	48.6
Little Boulder	64.4	57.6	50.5
Ragged	66.4	57.9	52.0
Tinker	78.4	62.2	55.4
West Donaldson	60.4	56.3	50.2

[a] Mean is the mean of the daily means.

Table 5-3—Summer stream temperature (°F) groups for small watersheds in the Blue Mountains of Oregon, 1978-84

Group[a]	Maximum temperature range	Strategy	Mean		Percentage of shade
			Elevation	Travel time	
	°F		Meters	Hours	Percent
1	54.5-60.4	A/C	1616	9.1	83.0
2	61.2-66.4	A/C	1518	11.8	81.5
3	75.2-82.0	D/C	1581	12.9	40.0

[a] Group 1 contains Big, Blackeye, East and West Donaldson; Group 2 contains East Little Butte, Lake, Little Boulder, and Ragged; and Group 3 contains Caribou, Flood, Keeney, and Tinker.

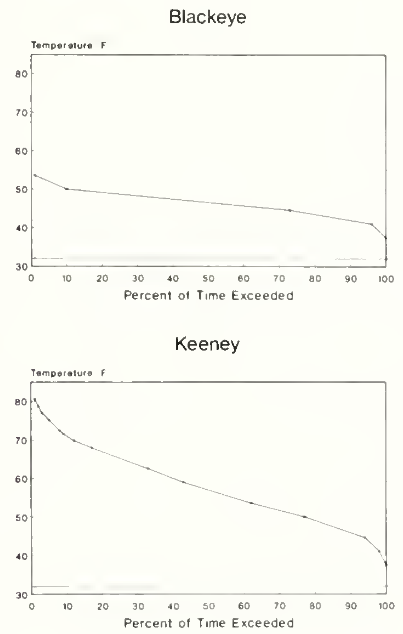

Figure 5-14—Representative cumulative frequency-distribution curves for three groups of stream temperature clusters in the Blue Mountains of eastern Oregon, water years 1978-84. Group 1, Blackeye; group 2, East Little Butte; group 3, Keeney.

Effect of Range Management Strategy

Weekly mean temperatures for strategy D (53.6 °F) were statistically greater than for strategy A (47.6 °F); strategy C (49.9 °F) was intermediate and not statistically different from strategy A. The temperature difference is attributable to differences in stream shade and is compounded by watershed characteristics and pre-EVAL management strategies. Watershed characteristics played an important role in the effect of range management strategy. The three strategy D watersheds have open meadows with little tree cover over streams. Caribou Creek, strategy C, also has an open stream channel and stringer meadows that result in high stream temperatures. These meadow areas are very susceptible to temperature increases from grazing because once grasses and shrubs are removed or stream banks are rounded, no tree canopy is left to shade the stream. Nearly 100 years of grazing use and logging activities have likely had a strong influence on stream temperatures of these watersheds through removal of streamside shrubby vegetation and caving of overhanging stream banks. Strategy A watersheds, in contrast, are more heavily forested and probably received less previous grazing use. Except for Caribou, strategy C and B watersheds are also more forested than strategy D watersheds and have received less previous grazing use.

Comparison with Oregon Standards and Fish Thermal Tolerances

All strategy D (Keeney, Flood, Tinker) and one strategy C watershed (Caribou) exceeded the 68 °F threshold in State of Oregon water quality standards (State of Oregon 1986) and the recommended short term maximum for rainbow trout of 75 °F (U.S. Environmental Protection Agency 1986). Criteria for maximum weekly mean temperature (66 °F) was not exceeded by any watershed. Daily and weekly means were considerably lower than maximum stream temperatures because the small headwater streams were cooled at night by low air temperatures and inflow of cold water. Bowers and others (1979) recommend at least 75 percent stream surface shade from June to September to provide optimum temperatures. Our results tend to substantiate this general recommendation for small streams in the Blue Mountains; all streams with more than 75 percent shade had maximum stream temperatures below 68 °F. Maximum temperatures in Keeney, Caribou, Tinker, and Flood approached or exceeded the lethal level for rainbow trout. The populations in these streams have survived but were probably stressed by the higher temperatures. Trout either move to a cooler reach or find deep pools. Caribou and Tinker had the highest biomass of trout per square foot but these were primarily age 0 (Grimes 1980). These trout either originated from mature trout that moved in to spawn or moved upstream from the North Fork of the John Day River. Both of these streams were more accessible from the river than streams of other watersheds, and both have shallow riffles over spawning-size gravel. The trout population in Flood Meadow is smaller but the fish are larger than at Caribou and Tinker. Flood lacks spawning gravel but offers some physical cover for larger trout in the form of logs and streambanks.

Stream Chemistry[4]

The chemical composition of streams has been used as one indicator of the effect of livestock grazing on water quality. Doran and others (1981) and Schepers and Francis (1982) have observed increases in concentrations of nitrate-nitrogen (NO_3-N), total phosphorus (P), and soluble P in runoff during livestock grazing, compared with the period before grazing was initiated. Other researchers have found that they could not detect a change in stream chemistry in response to livestock grazing (Gary and others 1983; Owens and others 1983). Our review of the available literature indicated that information is limited on the chemical water-quality responses to various grazing systems or various intensities of grazing management.

Our primary objective was to determine the influence of increased intensity of grazing management and increasing cattle use on chemical constituents in streamflow.

We measured NO_3-N, and orthophosphate (PO_4) on water samples collected at about monthly intervals from 1979 to 1984 from the 13 EVAL watersheds. Cations, calcium (Ca^{++}), magnesium (Mg^{++}), potassium (K^{+}), and sodium (Na^{+}) were measured only on samples collected in 1979 and 1984.

Chemical Characteristics of Streamflow

Concentrations of chemical constituents from these watersheds indicated chemical purity typical of small Western U.S. wildland watersheds (Tiedemann 1981). Average concentrations of NO_3-N ranged from 0.001 to 0.015 parts per million (ppm) among watersheds (table 5-4). Maximum observed concentrations of NO_3-N among watersheds ranged from 0.008 to 0.186 ppm. Average PO_4 concentrations ranged from 0.008 to 0.054 ppm among watersheds (table 5-4). Both average and maximum concentrations of NO_3-N and of PO_4 were similar to those observed in streamwater from undisturbed watersheds in the interior Northwest (Tiedemann 1973, Tiedemann and others 1978) and for other watersheds in the Blue Mountains of eastern Oregon (Hicks 1976, Tiedemann and others 1988b).

[4] Information on stream chemistry is condensed from Tiedemann and others [in press].

Table 5-4—Average concentrations of chemical constituents and pH in stream water from 13 wildland watersheds in eastern Oregon, 1979-84

Watershed	Strategy	NO_3-N[a]	PO_4[a]	Ca	Mg[a]	Na	K[a]	pH
Big	A	0.001	0.009	3.9	1.7	1.8	0.7	5.7
Blackeye	A	.002	.008	7.4	4.8	2.4	.7	6.1
Lake	A	.001	.042	16.6	6.7	6.9	1.6	6.4
Ragged	A	.001	.028	9.8	5.8	6.1	1.2	6.1
West Little Butte	B	.001	.022	9.9	2.8	3.5	.8	6.2
Caribou	C	.003	.015	9.0	10.1	4.8	1.0	6.2
East Donaldson	C	.008	.054	13.7	7.3	5.5	1.0	6.3
East Little Butte	C	.001	.022	6.4	2.2	2.9	.7	6.3
Little Boulder	C	.001	.017	9.1	7.1	3.5	.8	6.2
West Donaldson	C	.015	.052	13.1	8.6	5.4	1.0	6.2
Flood	D	.002	.039	5.2	2.1	5.7	2.0	6.0
Keeney	D	.006	.028	8.9	4.2	3.4	1.1	6.1
Tinker	D	.002	.036	14.3	6.7	6.3	1.6	6.3

[a] Geometric means.

Nitrate-N and PO_4 concentrations were higher in east and west Donaldson streams than in streams from the other watersheds. We found several dense stands of Sitka alder adjacent to the streams on these two watersheds. Although alder was present on other watersheds, stands were not as dense and well developed as those on east and west Donaldson. Alder is a nitrogen-fixing species that may contribute to NO_3-N content of streamwater (Coates and others 1976). Deposition of leaves in the stream and subsequent leaching probably accounts for higher concentrations of PO_4 than in other streams. Tiedemann and others (1988b) reached a similar conclusion when substantially greater pretreatment NO_3-N and PO_4 concentrations were observed in streamwater of one small watershed compared to three adjacent watersheds in the Blue Mountains of northeast Oregon. A large stand of alder was found at the point of origin of surface flow on the watershed with high NO_3-N and PO_4 concentrations.

Calcium is the predominant cation in these streams, with average concentrations among watersheds ranging from 3.9 to 16.3 ppm. Cation concentrations were typically, in descending order, Ca, Mg, Na, and K. In these streams, concentrations of Ca and Mg are substantially greater than were observed in other studies in the interior northwest (Hicks 1976, Tiedemann and others 1978, 1988b).

Concentrations of chemical constituents, NO_3-N, PO_4, and the four measured cations are well below limits proposed by the U.S. Environmental Protection Agency (1973) for surface waters. Maximum concentration of NO_3-N, the ion of major concern, was 0.18 ppm on Flood Meadow and Tinker Creeks. The recommended standard maximum is 10 ppm (U.S. Environmental Protection Agency 1973).

Effects of Increasing Intensity of Grazing Management

No differences were found among grazing strategies for any chemical constituent after we removed effects of average daily streamflow. Therefore, no apparent relation exists between intensity of grazing management as practiced in this study and the concentrations of measured chemical constituents in streamflow. Actual concentrations used for the 4 strategies (averaged over the period of study) were 0, 20.2, 17.7, and 6.9 acres/AUM for strategies A, B, C, and D, respectively. Actual numbers of livestock, however, may not be indicative of animal use in the riparian area (Tiedemann and others 1987).

We were concerned that the constituents we chose to measure may not be the most sensitive to the presence of livestock. Because fecal material is high in organic nitrogen and organic phosphate, concentrations of these constituents in streamflow may be expected to be more responsive to deposition of fecal material in the stream channel and to overland transport by surface runoff than those we measured. The work of Owens and others (1983) suggests that this may be true for organic nitrogen and total organic carbon. Even though concentrations remained low, these constituents increased markedly with grazing in their study. Our stocking rates may also have been too low for a detectable response; stocking rates studied by Owens and others (1983) were about 10 times greater (0.6 acres/AUM) than that for our strategy D watersheds (6.9 acres/AUM).

Pollution Indicator Bacteria (Fecal Coliforms)[5]

Implementing intensified grazing management practices carries the risk of adverse stream pollution effects with consequences for public health. Fecal coliform (FC) organisms, primarily *Escherichia coli*, in streamwater indicates contamination by warm-blooded animals (U.S. Environmental Protection Agency 1976). Although not a disease-causing organism (pathogen), this species indicates potential for pathogens also to be present. At FC concentrations from 1 to 200/100 mL, the percentage of occurrence of *Salmonella* disease organisms is 27.6 percent (Geldreich 1970). Occurrence of *Salmonella* increases to 85.2 percent at FC concentrations of 201 to 2000/100 mL and to 98.1 percent when the concentrations are higher than 2000 FC/100 mL. The concentration (number of organisms in a given quantity of streamflow sample, usually 100 mL) of these organisms in streamwater is the currently accepted means of assessing bacterial water quality (U.S. Environmental Protection Agency 1976). For example, water quality standards in Oregon for primary contact recreation require less than a log mean of 200 FC organisms/100 mL of streamwater based on at least five samples collected within a 30-day period (State of Oregon 1986). Also, no more than 10 percent of the samples can exceed 400 FC organisms/100 mL. Bacterial counts have not been compared to State water quality standards in any of the studies we reviewed. Sampling was generally not frequent enough to allow comparisons. Also, some studies were conducted before State standards were established (about 5 to 10 years ago).

[5] This section is a condensation from Tiedemann and others (1987, 1988a).

Several studies have shown a direct relation between cattle grazing and fecal coliform concentrations in streamwater (Coltharp and Darling 1973, Doran and Linn 1979, Gary and others 1983, Skinner and others 1974). In these studies, grazing increased FC organism counts as much as 10 times; concentrations apparently depended on stocking density (Gary and others 1983). Although many studies have been reported on the response of FC indicator bacteria in streamwater to the presence of grazing livestock, information is sparse on effects of various grazing systems or intensities (strategies) of range management on FC concentration. Skinner and others (1984) compared bacterial water quality between deferred rotation and continuous grazing systems in Wyoming. When differences between grazing systems were significant for FC, the deferred rotation had higher counts than continuous grazing. Stocking rate of the deferred rotation was only slightly higher than continuous (3.3 acres/AUM compared to 3.9 acres/AUM).

In addition to immediate contamination effects from the presence of livestock, elevated FC counts in streamwater may remain high for many months after cattle are removed (Jawson and others 1982, Stephenson and Street 1978). Some viable FC organisms may remain in animal wastes for up to 1 year (Clemm 1977); consequently, a source of organisms can enter streamwater long after the animals have left the watershed. Fecal coliform organisms may survive up to 2 weeks in soil (Van Donsel and others 1967) and up to 6 weeks in surface waters (Clemm 1977). Sediments also serve as a reservoir of FC and *Salmonella* organisms (Kunkle 1970, Stephenson and Rychert 1982, Van Donsel and Geldreich 1971).

The ratio of FC to fecal streptococcus (FS) has been proposed as a way to determine the source of bacterial contamination in wildland streams and lakes (Geldreich 1967). Geldreich introduced the concept by noting a FC/FS ratio of 4 in human and domestic waste and 0.7 in runoff and waste from livestock and poultry in feedlots and stockyards. Geldreich and Kenner (1969), Van Donsel and Geldreich (1971), and Geldreich (1976) later established ranges of FC/FS in feces for humans, >4; cattle, 1.2 to 0.08; cattle and wildlife, 0.08 to 0.04; and wildlife, <0.04. Applying the ratios to pasture and wildland settings has met with various results. Doran and Linn (1979) observed ratios of 0.04 to 1.2 in streamflow from grazed pastures compared to 0.001 to 0.08 from ungrazed pastures. On irrigated sites in Colorado, Kunkle and Meiman (1968) found ratios <1.0 on ungrazed land and 1.7 to 5.5 on grazed land. Others have attempted to use the ratio concept on wildland streams but were unable to distinguish human contamination from nonhuman and cattle contamination from wildlife (Messley and Kingsbury 1973, Skinner and others 1974).

The primary objective of this study was to determine the responses of FC bacteria in streamwater of 13 forested range watersheds to four grazing management strategies and to relate the findings to State of Oregon water quality standards for the John Day River Basin. Our second objective was to determine if streams had elevated concentrations of FC organisms after animals left a watershed for B through D grazing strategies and to determine if responses among these strategies were different for FC carryover from season to season. Our third objective was to determine the source of bacterial contamination in streamwater.

Determination of effects of increasing intensities of grazing management on FC counts and carryover effects are based on samples collected monthly at the control structure of each watershed in 1979-84. Comparisons with Oregon State Standards and the FC/FS ratios are based on samples collected weekly during the summer of 1984.

Concentration data are presented as geometric (log) means. The geometric mean is obtained by converting data to $\log_{10}$. The antilog of the mean of the log values is then used to obtain the geometric mean concentration (with original units).

Effects of Increasing Intensity of Grazing Management on FC Counts

Presence of livestock on the study watersheds exerted a significant effect on the bacterial quality of the surface waters. Time trends of FC counts for representative watersheds of each strategy are presented to show differences among strategies, seasonal trends, year-to-year differences, and the relations of presence or previous presence of livestock (fig. 5-15, a-d). Mean FC counts by strategy responded about as expected. Strategy A had the lowest mean FC count (2.9/100 mL) (fig. 5-16); however, FC counts on one sampling occasion in Blackeye Creek exceeded 500/100 mL (fig. 5-15a). Mean FC counts on strategies B and C watersheds (10.4 and 5.7 FC/100 mL, respectively) with actual cattle use averaging 20.2 and 17.7 acres/AUM were statistically greater than those in strategy A.

No statistical difference was found between strategy C and strategy B, however, counts in strategy C watersheds were generally less than 200/100 mL but on one sample occasion the count exceeded 300/100 mL. Watersheds with strategy D averaged 6.9 acres/AUM and had statistically higher FC counts (30.2/100 mL) than all other strategies. Counts in excess of 200/100 mL were common. The maximum count on a strategy D watershed was 3900/100 mL and counts in excess of 2000 were observed on three sampling occasions.

Physical and vegetation characteristics of individual watersheds played a major role in the degree of impact cattle had on water quality and also explain much of the variability observed among watersheds within strategies. Strategy A watersheds were not grazed by livestock during the study and were primarily forested. Uniformly low FC counts were anticipated. Fecal coliform counts in three of the strategy C watersheds—East Little Butte, West Donaldson, and East Donaldson—responded to grazing with FC counts intermediate between strategies A and B (fig. 5-17). Caribou, in strategy C, had the highest FC counts despite the fact that actual grazing use was the same as the average of the strategy C watersheds. Except for the lack of cultural treatments, this watershed was similar to the strategy D watersheds: it has stringer meadows with an open forest type (ponderosa pine) that does not restrict cattle access to the stream. Little Boulder Creek, the strategy C watershed with counts comparable to the strategy A watersheds, is at a higher elevation and provides only limited access to the stream channel. Steep, well-forested sideslopes adjacent to the stream channel discourage cattle use. Concentrations of FC in the single strategy B watershed were intermediate between strategies C and D. Watersheds with the highest FC counts (primarily in strategy D) have distinct meadows with riparian zones that tend to attract cattle (fig. 5-18). The large meadows on Keeney and Flood watersheds also provided the best opportunity to achieve strategy D management because they were areas where cultural treatments, such as fertilizing and seeding, could be used to enhance forage production. This resulted in an increase in stocking rates. Tinker, the other strategy D watershed, has a small meadow (about 2 acres) about 1200 feet above the sample collection site. Cattle were observed to concentrate in this meadow on numerous occasions during the study.

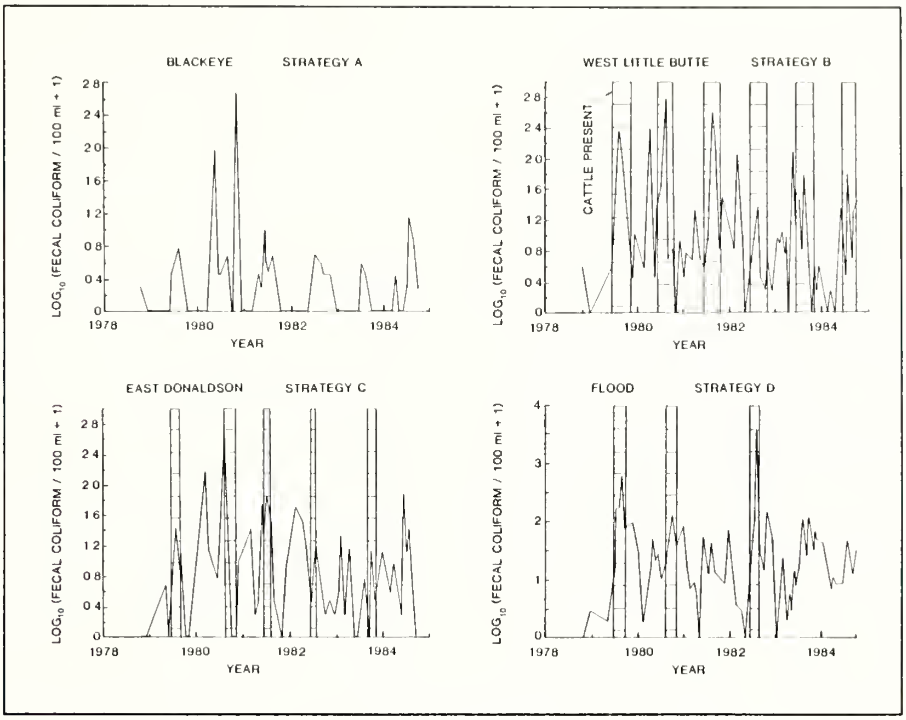

Figure 5-15—Time trends of fecal coliform counts (log_{10} FC counts+1) for representative strategy A, B, C, and D watersheds. Grazing periods are indicated by vertical bars.

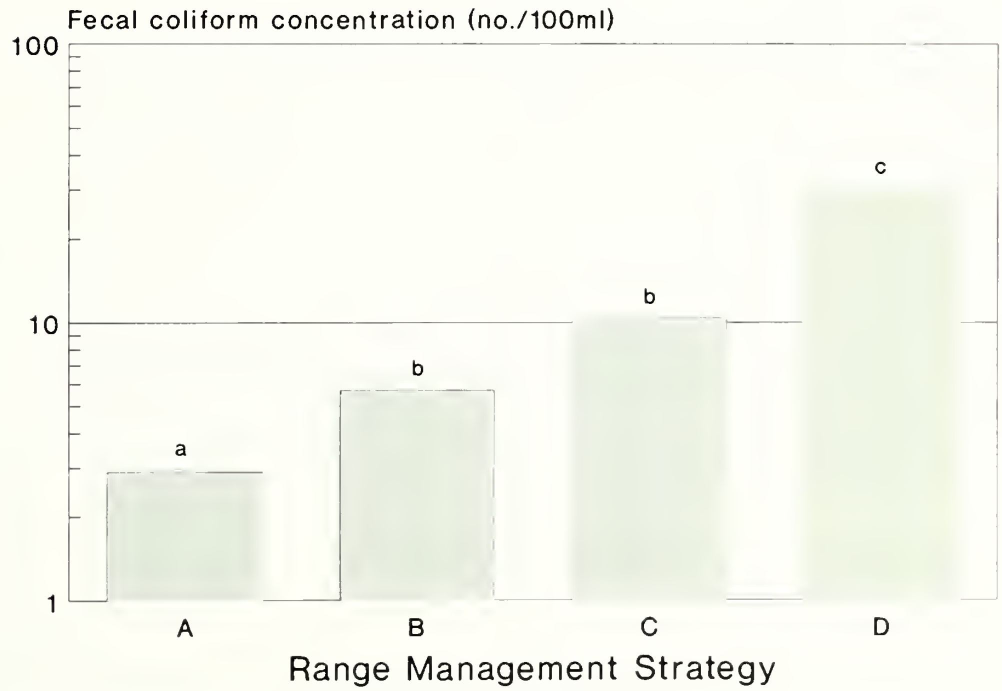

Figure 5-16—Geometric mean fecal coliform concentrations by range management strategy, water years 1979-84. Bars with the same lower case letter are not significantly different at $P<0.05$.

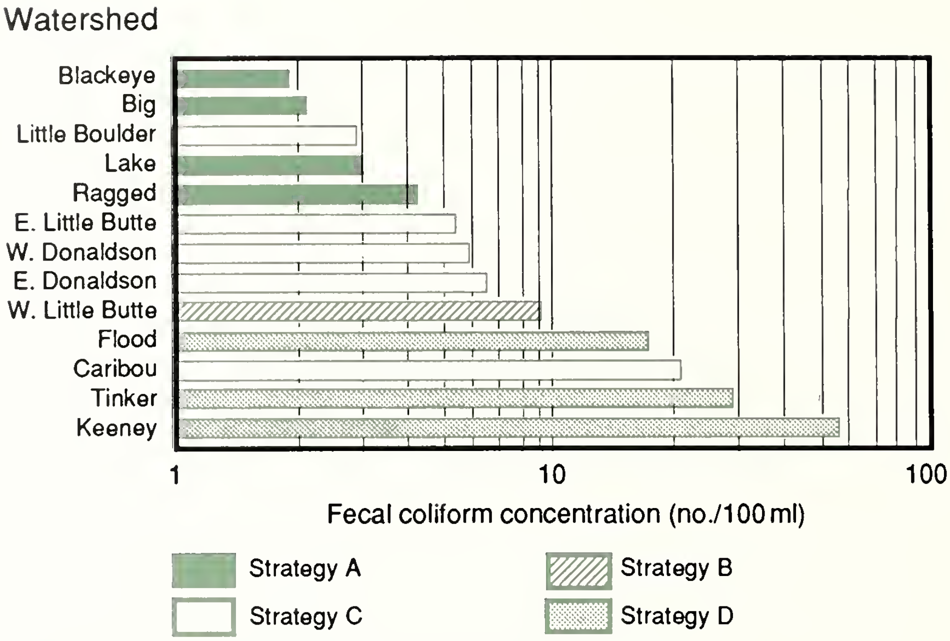

Figure 5-17—Geometric mean fecal coliform concentrations by watershed, water years 1979-84.

Figure 5-18—Cattle grazing in a riparian zone.

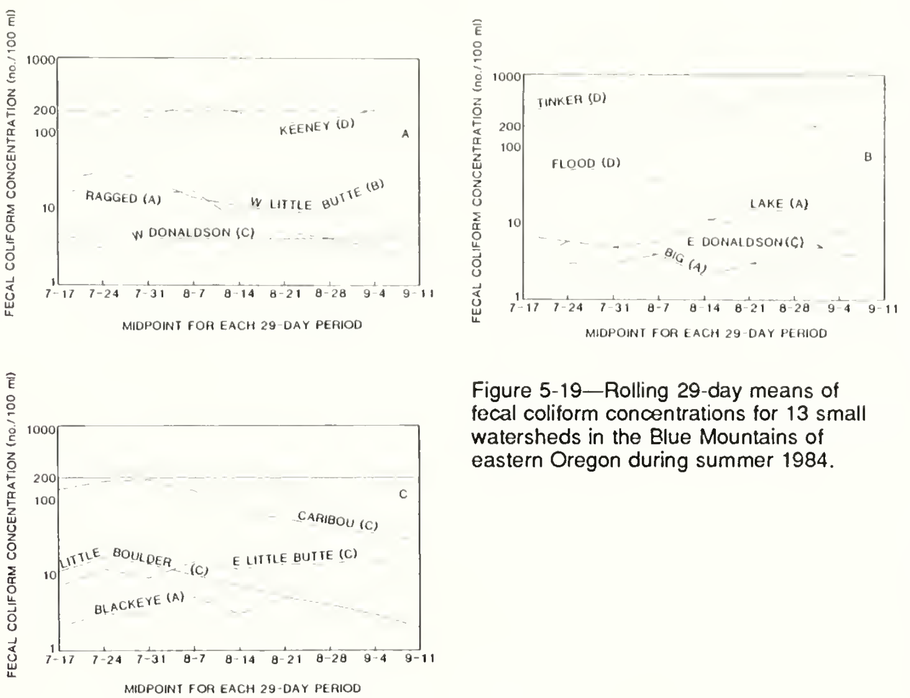

Figure 5-19—Rolling 29-day means of fecal coliform concentrations for 13 small watersheds in the Blue Mountains of eastern Oregon during summer 1984.

Comparison With Oregon Water Quality Standards

Results were compared with Oregon water quality 200 FC bacteria/100 mL $\log_{10}$ standard for the John Day River basin by calculating 29-day rolling means (five weekly samples). The 13 samples collected from July 3 through September 25 were used to establish mean FC concentrations for nine periods. Rolling means were determined by taking values for the first five sample dates referenced by the middle date of the 29-day period and by advancing one sample date to determine the mean of the next period. Individual samples were also compared to the 400 FC/100 mL standard to determine if 10 percent of the total samples collected on any individual watershed exceeded this standard. Two strategy D watersheds, Keeney Meadows and Tinker, violated the 30-day $\log_{10}$ Oregon standard of no more than 200 FC/100 mL. Keeney violated the standard for two periods, those measured with a midperiod of August 7 and September 11 (fig. 5-19a). Tinker was in violation for the major part of the sampling period, with midperiods of July 17 to September 28 (fig. 5-19b). Flood Meadow, the other strategy D watershed, was not grazed by livestock in 1984 and remained well below the standard. Caribou Creek, strategy C, approached the standard between July 24 and 31 but counts then declined rapidly (fig. 5-19c). This decline coincided with removal of the cattle from the pasture (August 8). All other watersheds were well below the recommended standard during the 3-month sampling period.

Counts in excess of 400 FC/100 mL were observed in more than 10 percent of the samples collected from Keeney Meadows and Tinker. The intensive grazing strategy D imposed on these watersheds resulted in violation of this standard. On Caribou (strategy C), one sample exceeded the 400 FC/100 mL standard.

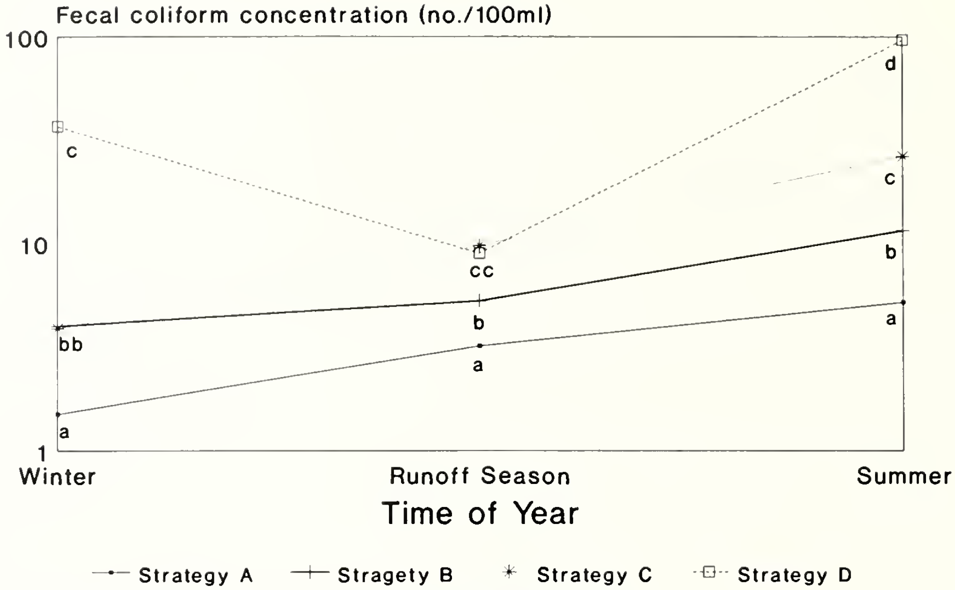

Figure 5-20—Strategy-by-season interaction for geometric means of fecal coliform concentrations, water years 1979-84. Strategies within a season with the same lower case letter are not significantly different at $P<0.05$.

Seasonal Responses of Fecal Coliforms in Streamwater

Comparisons among seasons for mean FC concentrations (average across strategies, watersheds, and years) showed that counts were not statistically different for winter (3.5/100 mL) and snowmelt runoff (4.5/100 mL) seasons; however, summer concentrations (18/100 mL) were statistically greater than concentrations during either winter or snowmelt runoff. Counts of FC organisms on watersheds with strategies A, B, and C generally increased from winter to summer (fig. 5-20). On strategy D watersheds, counts declined from statistically greater (38 FC/100 mL) than those for any other strategy in the winter to the same as strategy B in the runoff season (9 FC/100 mL). By summer, however, FC counts for strategy D were again greater than for any other strategy (90 FC/100 mL). Counts of FC in the winter were A < B = C < D. During the runoff season, the array was A < C < B = D. The summer array was A < C < B < D. Increasing counts during the summer are related to the presence of livestock in strategies B, C, and D. Summer wildlife activity probably accounts for the increased counts in the strategy A watersheds. Walter and Bottman (1968) observed higher coliform and enterococci counts in a watershed closed to grazing and recreation than in a watershed open to the public in Montana. They attributed their results to greater wildlife activity in the closed watershed than in the open watershed.

Higher winter mean FC counts in strategy D watersheds suggest a substantial carryover effect of cattle presence from summer into winter. We speculate that the elevated winter FC concentrations on strategy D watersheds are related to the presence of fecal material in or near the stream channel. Fecal material is carried into streamwater as discharge rises in the winter and by overland flow from melting snow.

Source of Fecal Coliform Organisms

Comparisons of cattle present versus not present in 1979-84 indicated that cattle were the primary source of FC organisms in streamwater of grazed watersheds. Counts of FC organisms in streamwater were statistically greater (nearly six times) when cattle were present than when cattle were absent (34/100 mL compared to 6/100 mL). The largest difference in FC counts between presence and absence occurred with strategy D (246/100 mL compared to 7/100 mL). Differences were lowest for strategy C (15/100 mL compared to 5/100 mL). Strategy B was intermediate (34/100 mL with cattle present compared to 7/100 mL with cattle absent).

Cattle presence was further tested during the intensive sampling period of summer 1984. In this test, we examined the effects of three categories; cattle not present, cattle present, and cattle previously present. The category, cattle not present, was represented by samples collected from ungrazed strategy A watersheds and from watersheds before cattle entry for the current season for the other strategies. The cattle-present criterion was represented by those sample dates when animals were actually in the pasture. The last category, cattle previously present, was represented by samples collected after animals had been removed during the current grazing season. The cattle-not-present criterion for grazed watersheds is probably confounded to some degree by elevated FC concentrations from grazing the previous year, especially on strategy D watersheds (Tiedemann and others 1987). Although results were not statistically different among the three categories, the numerical comparisons were striking, with a ninefold greater FC count when cattle were present than when they were not (46.9/100 mL compared with 5.6/100 mL). Average FC count after cattle were removed (cattle previously present category) was 18.5/100 mL. The comparison among the three categories was particularly striking for strategy D. Average counts of FC were 27, 269, and 155/100 mL for cattle not present, cattle present, and cattle previously present categories, respectively. Large differences were found among strategies for each category. For example, counts of FC in Keeney Meadows (strategy D) for the four sample dates before cattle were present (cattle not present) averaged 134/100 mL. For Lake Creek (strategy A, cattle not present), counts for the same period averaged 3.5/100 mL. Results of both cattle presence studies indicate that cattle are the primary source of FC organisms in strategy D watersheds and that FC concentrations may remain elevated up to 9 months after the animals have been removed from the watershed.

Ratio of Fecal Coliforms to Fecal Streptococci

Concentrations of fecal streptococcus were used for calculating the FC/FS ratios to determine the source of bacterial contamination based on FC/FS ratios proposed in the literature.

On strategy A, B, and C watersheds, most (72 percent to 90 percent) of samples had an FC/FS ratio <0.04, indicating that wildlife was the primary source of bacterial contamination (fig. 5-21). The large number of samples (22 percent) indicating cattle pollution in strategy C was mainly the result of a large number of samples (10) with this ratio for Caribou Creek. On strategy D watersheds, in contrast to those under the other strategies, cattle appear to be the main source of bacterial contamination. Most (76 percent) of samples had FC/FS ratios between 1.2 and 0.08.

When we plotted the number of samples with a ratio of FC/FS between 1.2 and 0.08 against actual FC counts, a direct relation indicated that cattle are the predominant source of contamination. This finding lends additional support to the ratios proposed for distinguishing bacterial contamination from wildlife and cattle.

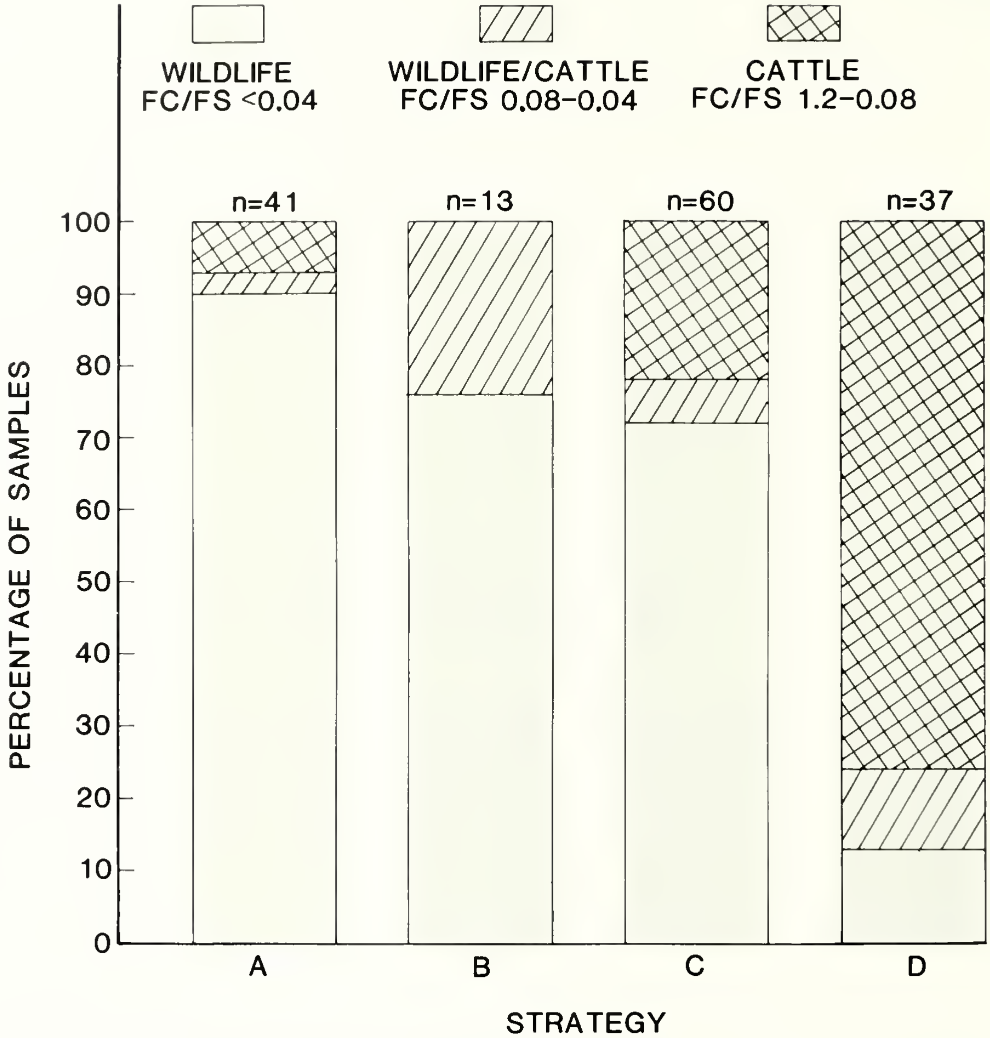

Figure 5-21—Ratios of fecal coliforms to fecal streptococii by range management strategy for summer 1984.

Summary

Hydrology of the Blue Mountains is dominated by snow, with about 70 percent of the 20 to 50 inches of precipitation received in that form. The 13 study watersheds yielded an average of 31 percent of the precipitation received. Average annual peak flows, ranging among watersheds from 2.0 to 34.7 cfsm, occur as snowmelt runoff from April through June, depending on the elevation and orientation of the watershed. Snowmelt runoff accounts for most of the total annual yield (79 percent). Low flows are more than two orders of magnitude smaller than peak flows. Storm runoff is a minor component of the total annual water yield. Increasing intensity of grazing management imposed on the watersheds did not exert a measurable effect on water yield characteristics or storm runoff. Sediment yields were at the low end of the range of yields for 80 other small watersheds in the western United States. Average suspended sediment and bedload yield was 0.017 tons/acre/year. Stream temperatures in watersheds dominated by meadow ecosystems exceeded the 68 °F threshold established by the State of Oregon and the U.S. Environmental Protection Agency short-term maximum tolerances recommended for rainbow trout, but temperatures could not be attributed to the grazing systems imposed during the study. Measurements of chemical constituents indicated chemical purity similar to that for other watersheds in the Blue Mountains. The intensity of range management strategy did not affect the measured chemical parameters. Bacterial water quality was influenced by grazing. One of the study watersheds with a large meadow managed at the highest intensity had fecal coliform counts exceeding Oregon State standards for much of the summer of 1984. Moreover, bacterial counts were related to the presence of livestock on the watershed and to the intensity of management.

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6 Effects of Management Strategies on Other Resources

H. Reed Sanderson

When EVAL project began in 1976, one of the objectives was to evaluate the effects of management strategies on related resources. But, in 1982 when project funding decreased, the number of values that could be evaluated also decreased. Evaluation of most of the "related resources"—wood production and all of the quantitative measures of other resources (Chapter 1, table 5) had to be discontinued. Most of the values were being assessed by cooperating research institutions, many of which had completed their work—generally to develop evaluation methods and provide pretreatment data—by 1982. Sufficient data had been gathered that some treatment effects could be evaluated.

Wood Production

Tree height and diameter at breast height (d.b.h.) measurements were sampled in 51 paired plots in 1977 through 1979 and resampled in 1985 to determine the impact of livestock grazing on wood fiber production. One plot in each pair was grazed, and the second plot was fenced and protected from livestock grazing. The initial impact of grazing on timber growth was difficult to assess because the plots were established in different years, trees less than four inches d.b.h. were not measured at the time of remeasurement, and extensive mountain pine beetle infestation caused tree mortality on some plots. The first problem was solved by using periodic annual growth rates and projecting all trees forward from the same year, 1984. Tree mortality was subjectively segregated in two categories for analysis: plots with and plots without significant mortality during the remeasurement period.

Twenty-four paired plots without significant mortality or measurement errors were analyzed. The average annual growth was 91.6 cubic feet per acre on the unfenced plots and 80.6 on the fenced plots (Appendix E). The average annual cubic-foot growth and percentage of cubic-foot change were not significantly different between fenced and unfenced plots. The observed differences were more likely due to site differences because no indication of livestock grazing was found on unfenced plots during the remeasurement period. Therefore, no differences in tree growth could be attributed to livestock grazing. Trees less than 4 inches d.b.h. were not assessed, which prevented projection of growth differences between fenced and unfenced plots.

To assess the impact of grazing on forest land in the Blue Mountains, more but smaller plots are needed to describe the variety of environmental conditions. Information is also needed on the understory vegetation and overstory cover, in addition to data on trees less than 4 inches d.b.h. and tree reproduction (Chapman 1986, Cline 1984).

Birds and Small Mammals

The effects of grazing management strategies on birds and small mammals was studied on the mountain grassland, sagebrush, ponderosa pine, and larch ecosystems. Strategy B was used to represent minimum impact by livestock and management; strategy D represented a high impact, which was primarily seeding the grassland and sagebrush and thinning the forested area. Life form and indicator species were used to determine the effects of grazing management strategies on the density of bird and small mammal populations from 1977 through 1979.

The methods used—life form and indicator species—did not appear sensitive enough to detect changes in grazing management strategies for several reasons. The decision to apply management practices was based on costs, expected benefits, and environmental considerations, which resulted in practices being applied only where they were most beneficial. Consequently, seeding and thinning practices were generally applied on relatively small areas that did not include the total area of an ecosystem. Therefore, the more mobile birds and small mammals were not sufficiently affected for the sampling techniques to detect population change. The small treatment areas also increased the variation within and between sites.

This study showed that life forms are not significantly changed by the practices applied to affect bird and small mammal populations. Further, monitoring only indicator species was not an advantage because as much time is required to record all the species observed, especially in censusing bird populations (Skirvin 1981).

Although the study suggested that the EVAL range management strategies did not affect birds and small mammal populations, additional information would be needed for confirmation (deCalesta and Skirvin 1980).

Figure 6-1—Fish populations were estimated with a capture, mark, and release method using a backpack electro-shocker to stun the fish and a dip net to capture stunned fish.

Fish

Rainbow trout populations were monitored in 11 streams in the EVAL area to determine the effects of grazing management strategies on fish populations. From 1977 through 1980, methods were developed and tested to obtain baseline population data before implementing management strategies. Each study site was characterized by several stream characteristics, such as flow, gradient, and channel stability; trout habitat features, such as water temperature, pool and cover assessment, and spawning gravel; and cattle activity. Trout populations were estimated and correlated with environmental data to develop quantitative trout habitat values (fig. 6-1).

Trout populations varied as much as 119 percent from 1978 through 1980; up to 9 years may be needed to develop adequate baseline data to evaluate the effects of management strategies. Grimes (1980) recommended that methods need to be developed to evaluate long-term livestock activity near streams because one season of recording hoof marks did not appear to measure cattle activity adequately. The smallest stream surveyed consistently produced the highest numbers and densities of age-0 trout. This indicates a need for research on trout-rearing habitat before attributing the differences in trout populations to livestock activities. Research is also needed to determine how different grazing management strategies influence aquatic habitat.

Riparian Habitat

The spotted frog, nine bat species, and the vagrant shrew were studied to gather baseline data on the effects of range management activities on their food habits and population characteristics. The study was also designed to develop methods to collect food habits and determine the relative value of insectivorous vertebrates as indicator species for monitoring management activities. During the summers of 1977 and 1978, techniques were developed and tested at six mountain meadow sites and two larch sites. The mountain meadow sites used livestock grazing to represent management intensity. The assumption was that as management intensity increased, livestock activities also increased in the riparian habitat.

Figure 6-2—Riparian habitat used by the spotted frog in forested ecosystems.

Population estimates were difficult to obtain on all species except the spotted frog, which was relatively abundant and easy to capture, and stomach samples could be obtained without harm to the animal. To obtain stomach samples from shrews, the animals were kill-trapped, which did not allow for accurate population estimates. Not enough bats could be captured and marked for recapture to obtain accurate population estimates. Although food habits were obtained by holding the bats overnight and collecting the scat for analysis, the results were not reliable because food could not be shown to be from the sample site.

Each species studied could be used as a monitor of insect populations in different habitat management conditions: the shrew to mountain meadows, the spotted frog to riparian-aquatic habitats in either mountain meadow or forested ecosystems (fig. 6-2), and the bats to extensive areas of continuous habitat such as forest, sagebrush-steppe, or grassland.

This study suggested three hypotheses:

- Heavy cattle grazing compacts the soil in the mountain meadow ecosystem, which makes the habitat unsuitable for some invertebrates. Consequently, the shrews and frogs that feed on such invertebrates must either change their food habits or populations decrease.

- Intensive management practices that decrease plant diversity in the mountain meadow ecosystem, such as applying herbicides or reseeding, cause a decrease in diversity of the invertebrate population that causes a reduction in shrews and frogs or a change in their food habits.

- Precommercial thinning changes the forest structure, which in turn changes the insect fauna and the pattern of use by bats. Further research is needed to test these hypotheses by using replicated sites to explore the variability among insect prey and predator populations.

The spotted frog is recommended as having the best potential for additional research. It has low mobility, is easy to capture, and its stomach contents can be removed for food habit studies without harming the population (Cross and McMahon 1979, Whitaker and others 1981a, Whitaker and others 1981b, Whitaker and others 1983a, and Whitaker and others 1983b).

Dispersed Recreation and Scenic Beauty

Dispersed recreationists were interviewed to determine the impact of range management strategies on their activities and their concept of scenic beauty. Dispersed recreationists are those that do not use developed campgrounds. Although a few sites may have a picnic table or pit toilet, most sites have no facilities.

The recreation study indicated several relations between range management activities, the visitor, and the scenic qualities of the visual resource. Dispersed recreationists perceive differences in scenic beauty and are highly aware of the general environment as well as the specific environmental demands of their primary activity. The findings also suggested that the perception of visual quality differs among subgroups of recreationists interviewed. Anglers tended to be more sensitive to range management practices—they especially favored fences that kept livestock away from the stream, even though fences made it more difficult to pursue their activity. Hunters favored many practices that disturbed the landscape—such as seeding, brush control, and thinning—whereas anglers tended to object to such practices.

Visitors' familiarity with National Forests is directly related to their willingness to accept intensive management practices. The public in general, however, is not aware of the requirements for efficient managing of the forest-range environment for increased forage. Intensive range management activities have a definite impact on dispersed recreationists. Land managers should use this information to balance the need for forest-range products with the perceived needs of dispersed recreationists to pursue their activities (Sanderson and others 1986).

Cultural Heritage

An archaeological survey was conducted on all public and private lands where EVAL management practices were applied. Cultural resources were identified at 86 locations: 35 were archaeological resources associated with Native American activities, and 49 were historic properties (fig. 6-3). Five sites were nominated to the National Register of Historic Places.

Archival investigations provided ethnographical, historical, archaeological, and environmental information on the cultural resources of the EVAL area. These investigations provided an overview of the prehistory of the area through the period of use by Native Americans and early settlers to the present time. Range management strategies were found not to affect the cultural heritage. Contemporary cultural heritage is being threatened, however, by outside factors beyond the control of the project (Patterson 1982, Patterson and others 1982).

Figure 6-3—An abandoned cabin that was part of an early settlement established by logging and mining activities on the upper Middle Fork of the John Day River.

Infiltration Studies

A Rocky Mountain infiltrometer was used to simulate convectional rainstorms equivalent to 4 to 5 inches per hour for 28 minutes to generate potential sediment losses on 10 ecosystems. Potential losses in mountain meadow ecosystems were similar to forested ecosystems and ranged from 13 to 194 pounds per acre. The mountain grassland ecosystem produced a potential loss of 385 pounds per acre and was similar to all the forested ecosystems except larch. The sagebrush and juniper ecosystems had more potential sediment loss than all other ecosystems at rates of 1,146 and 1,203 pounds per acre, respectively. Potential sediment loss also changed within ecosystems as the condition classes or production rates changed (Buckhouse and Gaither 1982).

Infiltration rates tended to increase as the site changed from dry to mesic and ranged from 2.4 (ponderosa pine) to 3.5 inches per hour (larch). On forested ecosystems, infiltration rates appeared to increase as the number of stems per acre decreased. On the range ecosystems, infiltration rates increased as productivity increased and conditions improved (Gaither and Buckhouse 1983).

Potential sedimentation on sites that were disturbed by such range management practices as, seeding, mechanical brush removal, and precommercial thinning was most sensitive to the amount of standing vegetation and litter. Infiltration was also influenced by soil compaction: as compaction increased, infiltration rates decreased. The relative hydrologic balance of disturbed rangelands depended on severity of soil disturbance and compaction from equipment traffic, success of reestablishing an adequate vegetation cover, and the time since the site was disturbed (Buckhouse and Bolognani 1982).

The influence of vegetation cover and litter are clearly important in these ecosystems; this study illustrates the need to maintain and enhance ground cover to ensure optimal infiltration rates (Gaither and Buckhouse 1983).

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7

Determining Grazing Capacities

Thomas M. Quigley

One important objective of the EVAL project was to obtain information on the grazing capacities (in AUM's) resulting from various management intensities. These capacities were needed for ecosystems because information on pasture capacities were not sufficient for economic analysis.

The approach was to develop a simulation model to estimate the capacity for the ecosystems within a pasture. The simulation model provided an initial estimate of grazing capacity; a team of professionals (range planners, managers, scientists, and ranchers) examined ecosystem maps of the pastures and use patterns, studied actual use records, and, using personal knowledge of the areas, estimated the grazing capacity by ecosystem in each pasture. Data used to drive the simulation model was derived from a geographic information system (GIS) and parameters from prior studies in the Blue Mountains of eastern Oregon.

EVAL Geographic Information System

Geographic information system (GIS) is a generic term used to describe the computer storage, retrieval, and analysis of mapped and tabular information. The GIS system in EVAL used commercially available software products and custom programs developed specifically for the EVAL project. Each pasture was initially mapped by ecosystem on orthophotos and entered into the GIS system by digitizing ecosystem boundaries (fig. 7-1). The mapped information was converted from lines on the map to numerical information that can be stored in the computer, recalled as a map, and overlaid on other maps to produce a composite map of more than one geographic feature. The process of digitizing the initial maps and obtaining the overlays was described by Coe and Quigley (1986). The evolution and description of the software and hardware used in the EVAL project was described by Cimon and Quigley (1986).

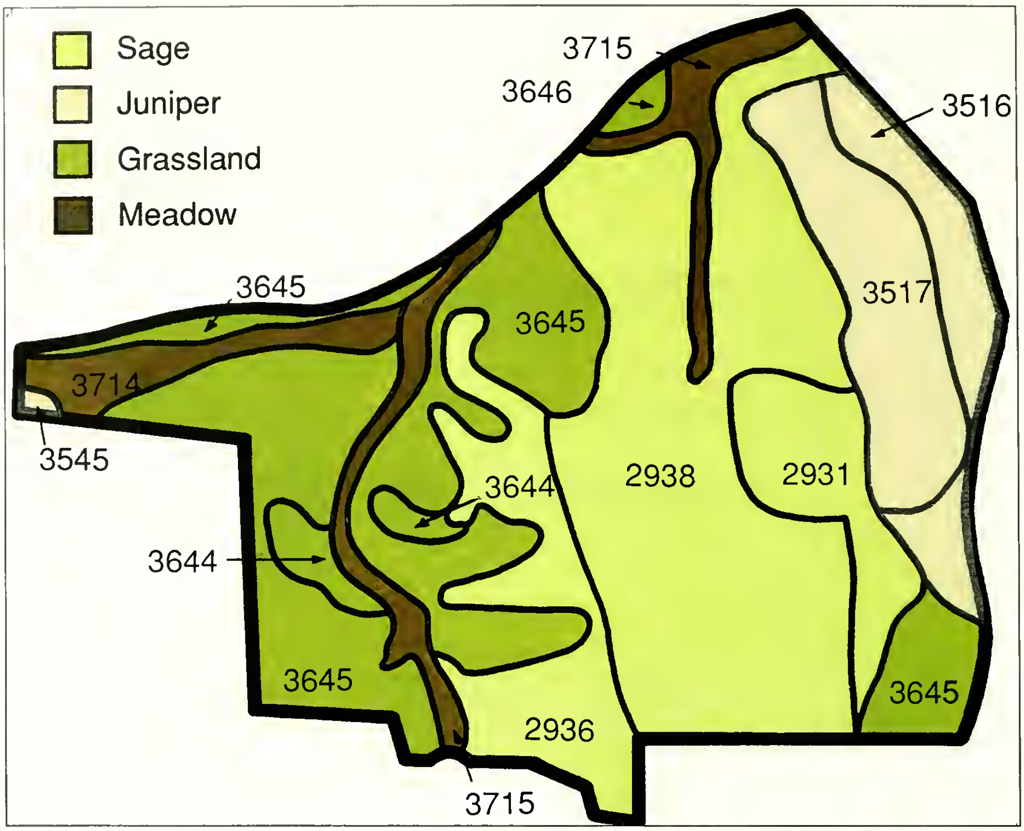

Figure 7-1—Example resource unit map.

Resource unit (Map code)	Ecosystem	Productivity	Condition	Total Area
2931	Sage	mod, low	sprayed	60
2936	Sage	mod, low	poor	100
2938	Sage	mod, low	sprayed	314
3516	Juniper	high	poor	59
3517	Juniper	high	controlled	93
3545	Juniper	low	fair	2
3644	Grassland	low	good	17
3645	Grassland	low	fair	281
3646	Grassland	low	poor	6
3714	Meadow	high	good	32
3715	Meadow	high	fair	59
Total				1023

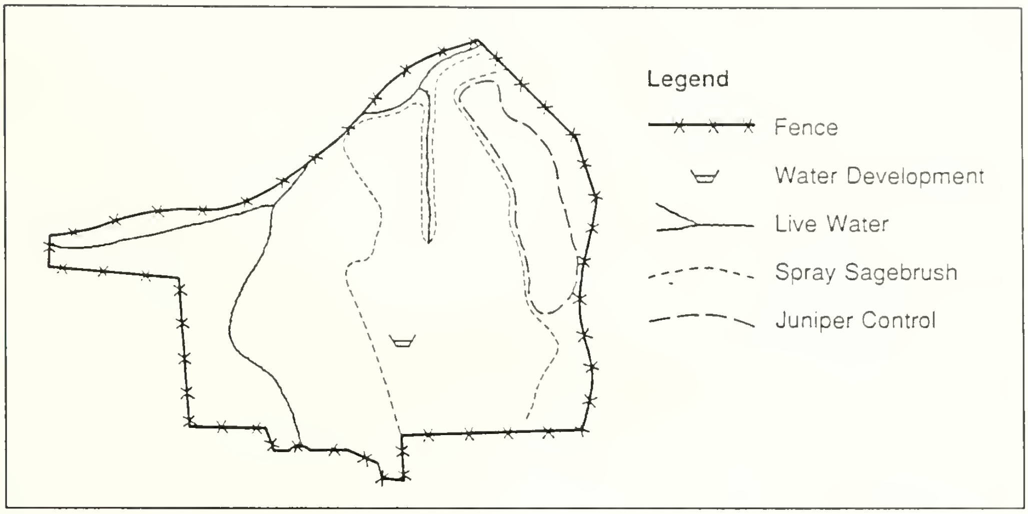

Figure 7-2—Example improvement map.

With the ecosystem maps as a base, improvements (fig. 7-2) and distance from water maps (fig. 7-3) were generated. Slope maps (fig. 7-4) were derived from U.S. Geological Survey maps. Each map was digitized into the GIS system for further analysis. Overlay maps (fig. 7-5) and tabular reports (table 7-1) were derived from the ecosystem, distance from water, and slope maps. The tabular information served as input directly into the simulation model. The example maps shown here are simple in comparison to large, diverse pastures found on Federal land. The complexity of obtaining acreages for each overlay region necessitates computer analysis.

Ecosystem Maps

Each pasture was mapped according to ecosystem, productivity, and condition class (resource unit) by range conservationists using aerial photos and ground validating. The minimum mapping unit was considered to be 40 acres, except in mountain meadows where 10-acre minimums were used. Mapping was by Forest Service range personnel on Federal land and by Soil Conservation Service personnel on private land.

Slope Maps

Slope categories were mapped by using four groupings including 0-5 percent, 6-15 percent, 16-45 percent, and >45 percent. The slope maps were generated from the Forest Service Fort Collins Computer Center by using the Defense Mapping Agency data. The resulting maps were digitized into the EVAL GIS system for further processing.

Distance-To-Water Maps

Lines of equal distance to water were drawn on the improvement maps for each pasture. Five categories were used to classify the pasture into areas of equal distance to water. The categories included <200 meters, 201-400 meters, 401-600 meters, 601-1,500 meters, and >1,500 meters.

Map Overlays

With the resource unit map as the base, slope and distance-from-water maps were overlaid to generate a new map with unique polygons of similar classification and tabular data describing the resultant map.

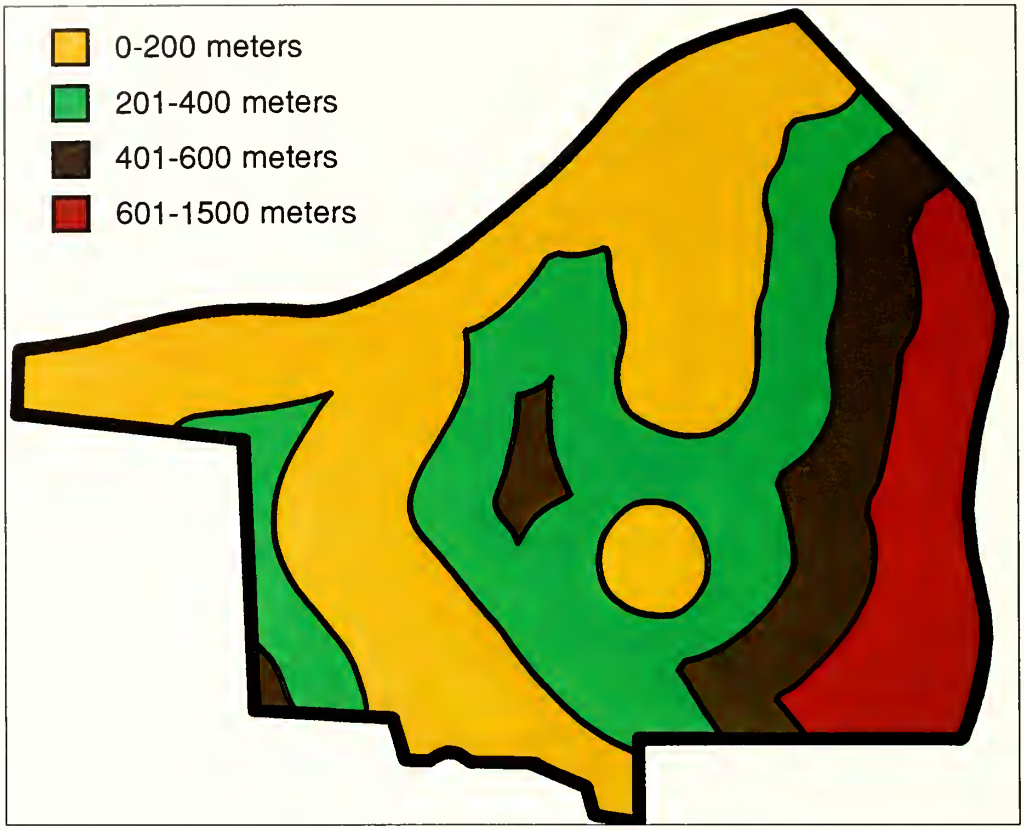

Figure 7-3—Example distance-from-water map

Distance from Water Category	Total Area
0-200 meters	434
201-400 meters	312
401-600 meters	130
601-1500 meters	147
> 1500 meters	0
Total	1023

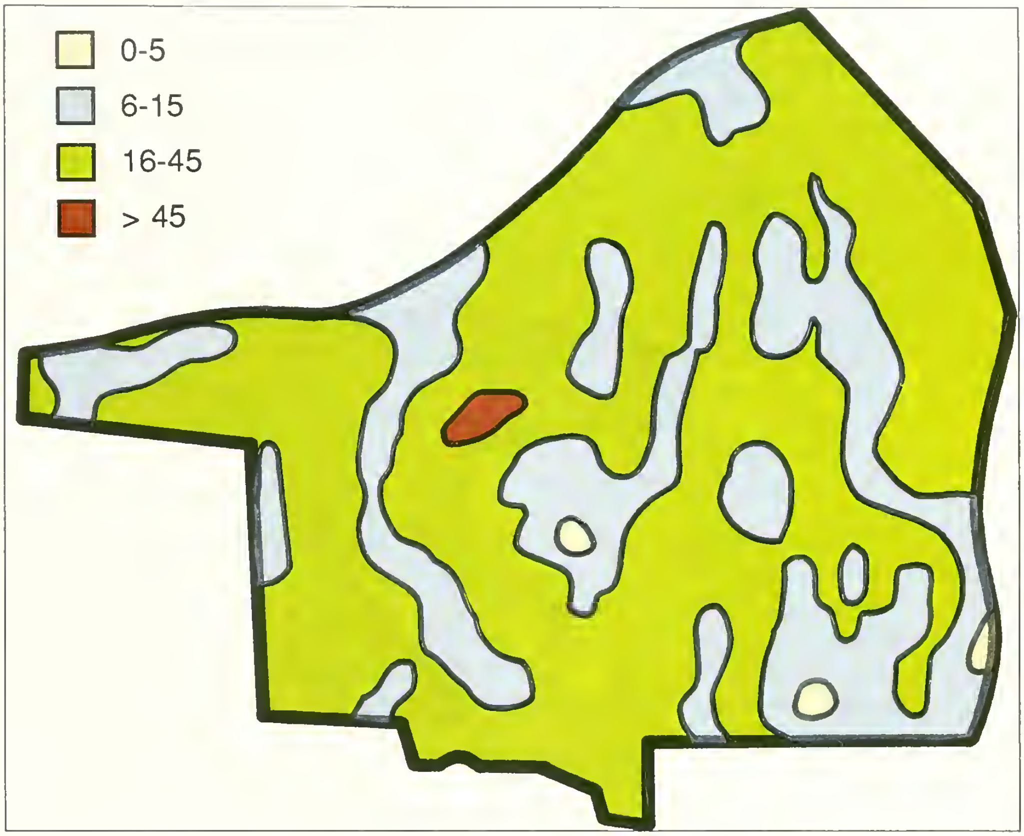

Figure 7-4—Example slope category map.

Slope Category	Total Area
0-5	9
6-15	304
16-45	704
> 45	6
Total	1023

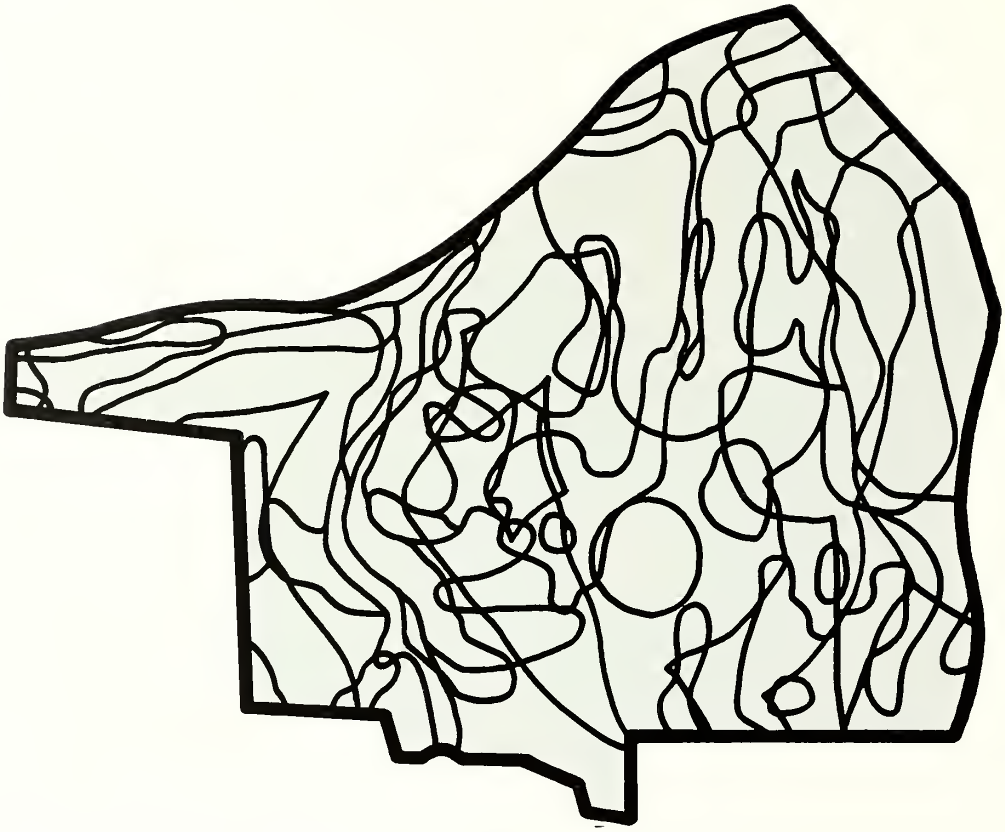

Figure 7-5—Example overlay map.

Table 7-1—Example of a tabular report generated through the simulation model from data derived from the overlay process

Resource unit	Actual acres	Usable acres	Simulated AUM's	Simulated live weight gains
	---- Acres ---			Pounds
2931	60	48.4	7	471
2936	100	85.6	8	540
2938	314	278.1	59	3,816
3516	59	43.7	4	291
3517	93	71.4	14	920
3545	2	1.8	<1	11
3644	17	15.4	1	73
3645	281	241.9	18	1,190
3646	6	6.1	<1	22
3714	32	30.3	37	2,373
3715	59	55.5	23	1,520
Total	1,023	878.2	171	11,227

Simulation Model

The specific information needed on grazing capacity and beef production was by ecosystem within pastures; limited meteorological and biological data for each site were all that was available (fig. 7-6). No existing models could provide the necessary information with these data. The simulation model developed specifically for use in EVAL had two primary outputs: potential AUM's of grazing capacity and pounds of beef production. The model was designed to operate in different modes depending on the desired output. When estimates of AUM's were desired, the model would provide an estimate of grazing capacity derived from the assumptions and calibration factors provided. When estimates of beef production were desired, the model would accept a known grazing capacity (in AUM's) and force the model to the known capacity. The grazing capacity estimation mode was used to estimate the capacity for each ecosystem within pastures, and the beef production mode was used to provide information to the overall economic analysis for the study. The simulation model required data on the area within each pasture that was within an ecosystem, distance-from-water, and slope category (McInnis and others 1986).

Model Structure

Model structure follows two main paths, one for determination of AUM's and the other for the determination of beef production (fig. 7-7). Data requirements for the model include the area within each unique resource unit, distance-from-water, and slope category, and the grazing seasons of anticipated use. The model uses peak standing crop for grass, forb, and shrub components for each mapped unit, and the proper use factors for each season to determine seasonal available forage.

The model initially calculates the seasonal forage availability within each resource unit. Forage availability is compared to the dry matter forage requirement of a 1,000 pound animal unit to calculate AUM's of grazing potentially available. Seasonal forage availability is also compared to seasonal dry matter intake of a yearling heifer to estimate heifer unit days (HUD's) of grazing capacity as an intermediate step to estimating beef production. The average daily gain (ADG) of a yearling heifer is determined from estimates of daily intake of crude protein and digestible energy. Beef production is calculated as the product of heifer unit days and average daily gain.

Figure 7-6—Cattle grazing in a productive mountain meadow.

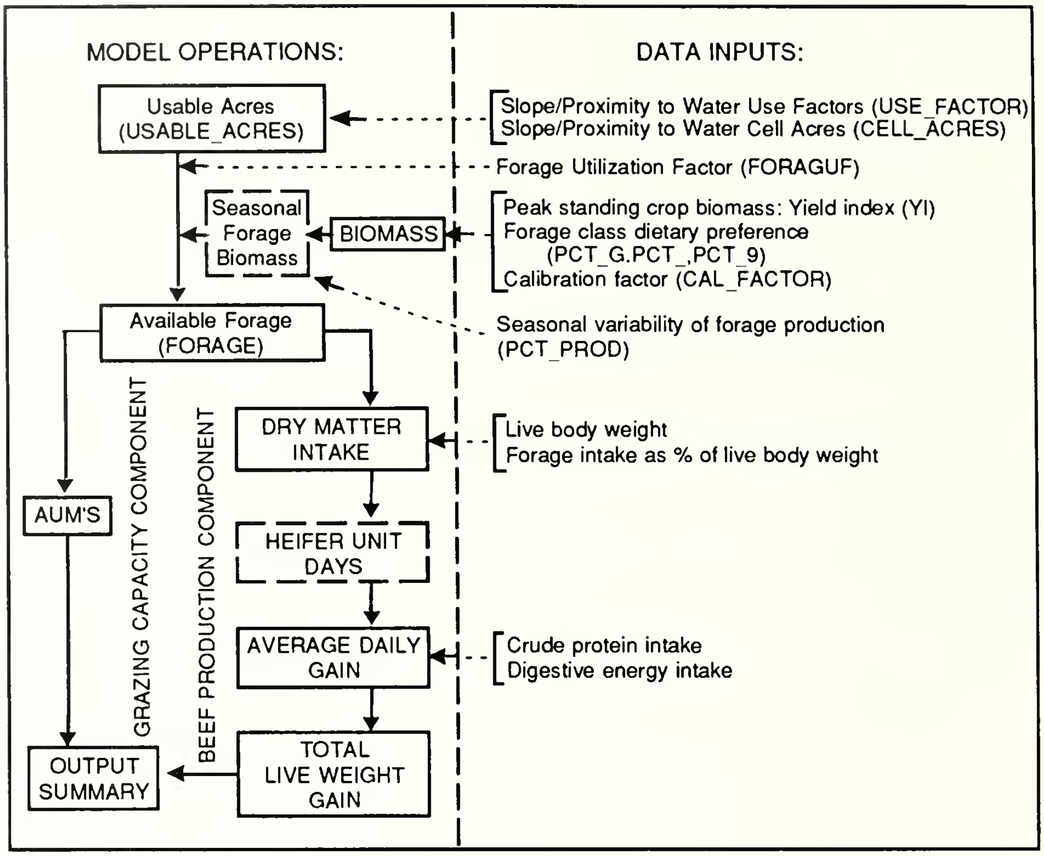

Figure 7-7—Grazing capacity simulation model structure.

Grazing Capacity Subroutine

Cattle use of an area is influenced by its terrain (especially slope) and distance-from-water. Forage use decreases as percent slope and distance-from-water increase (Gillen and others 1984, Roath and Krueger 1982). Cattle "use factors" (percentage of the total area used for grazing) were estimated for each combination of slope and distance-from-water (table 7-2). The total area within each mapping unit that was estimated as usable by livestock was calculated by multiplying the total area within each slope, distance-from-water, and ecosystem cell by the appropriate use factor.

Forage biomass available for use was determined by using the peak standing crop estimates for each forage class (grass, forb, and shrub) and multiplying it by the forage-use factor that reflects the proper rate of use of the forage by livestock. The forage-use factors were assumed to be 50 percent during periods of plant growth and 65 percent after maturation of plants. Adjustments were also made to account for the seasonal dietary preference for specific forage classes. Five grazing seasons were used to represent the grazing periods most typically used in the EVAL area (May 15-June 14; June 15-July 14; July 15-August 14; August 15-September 14; and September 15-October 14). The model calculated AUM's by dividing the available forage by the dry matter forage requirements of a 1,000 pound animal unit for 30 days. This amount was assumed to be 2.5 percent of live body weight per day, or 750 pounds of forage per month.

Table 7-2—Cattle "use factors" for slope and distance from water

Distance from water	Amount of use by percent slope			
	0-5%	6-15%	16-45%	45+%
Meters	Percent			
0-200	100	100	90	60
201-400	100	100	80	50
401-600	100	90	70	50
601-1500	90	80	70	50
+1500	75	60	50	40

Beef Production Subroutine

Beef production in the simulation model was estimated as the pounds of beef gained by heifer yearlings over the grazing period. The amount of available forage calculated through the grazing capacity routine was divided by the pounds of dry matter intake consumed by a heifer in 1 day. This value was multiplied by the average daily gain of heifers to yield pounds of beef produced within the mapping unit. Daily dry matter intake was calculated as the product of live body weight and forage intake, expressed as a percentage of live body weight. Live body weights of yearling heifers grazing forest and grassland communities in northeastern Oregon were obtained during each grazing period from 1977 through 1980, and the corresponding values of forage intake expressed as a percentage of live body weight were obtained from Holechek and Vavra (1982). Holechek (1980) provided a relationship for average daily gain based on intake of crude protein and digestible energy. Using data from Holechek and others (1981), values of crude protein and digestible energy intake were provided as inputs to the model.

Grazing Capacity

The simulation model indicated that the capacity of forested ecosystems were generally overestimated by <25 percent and the capacities of nonforested ecosystems were underestimated by <25 percent (table 7-3). The estimation of grazing capacity within the Douglas-fir ecosystem was the least accurate, and the estimates for the ponderosa pine ecosystem were the most accurate. The simplicity of the model permitted its application on a wide set of areas and under different seasons of use, yet still provided useful information in the allocation of AUM's within pastures to the resource units of the pasture. The model was calibrated to the known capacities before its use was continued in the beef production runs.

Table 7-3—Mean ratio of simulated to actual AUM grazing capacity by ecosystem

Ecosystem	Ratio of simulated AUM to actual AUM: Mean	Ratio of simulated AUM to actual AUM: Standard error	N (seasons)[a]
Douglas-fir	0.4	0.1	4
Ponderosa pine	1.0	.1	5
Larch	.8	.1	4
Sagebrush	1.1	.1	5
Juniper	1.2	.1	5
Mountain grassland	1.2	.1	5
Mountain meadow	1.1	.1	5

[a] Douglas-fir and larch communities are not normally grazed during the first season (May 15-June 14).

AUM Allocation Process

In the spring of 1985, the EVAL project began the process of determining the grazing capacity of each pasture monitored during the project and allocating the AUM's among the mapping units within the pasture. Records of actual use were obtained and forage utilization maps drawn for each pasture in the study at the end of each grazing season. On Federal lands, Forest Service personnel were responsible for gathering and interpreting this information. On private land, Soil Conservation Service personnel had responsibility. Each agency made recommendations on the next year's stocking rate and management plan based, in part, on this information.

A team of planners, managers, scientists, and EVAL personnel most knowledgeable about the study areas assembled to make the final allocation of AUM's. This process used ecosystem and forage utilization maps, actual-use records, personal knowledge of practices and management, estimates of capacity from the simulation model, and the personal experience of the team members (fig. 7-8). The total number of AUM's for each pasture was estimated and then allocated to the ecosystems represented in the pasture (appendix F). Results were summarized by strategy and ecosystem for private and Federal land (figs. 7-9 and 7-10).

Figure 7-8—Cattle grazing in a mountain grassland ecosystem.

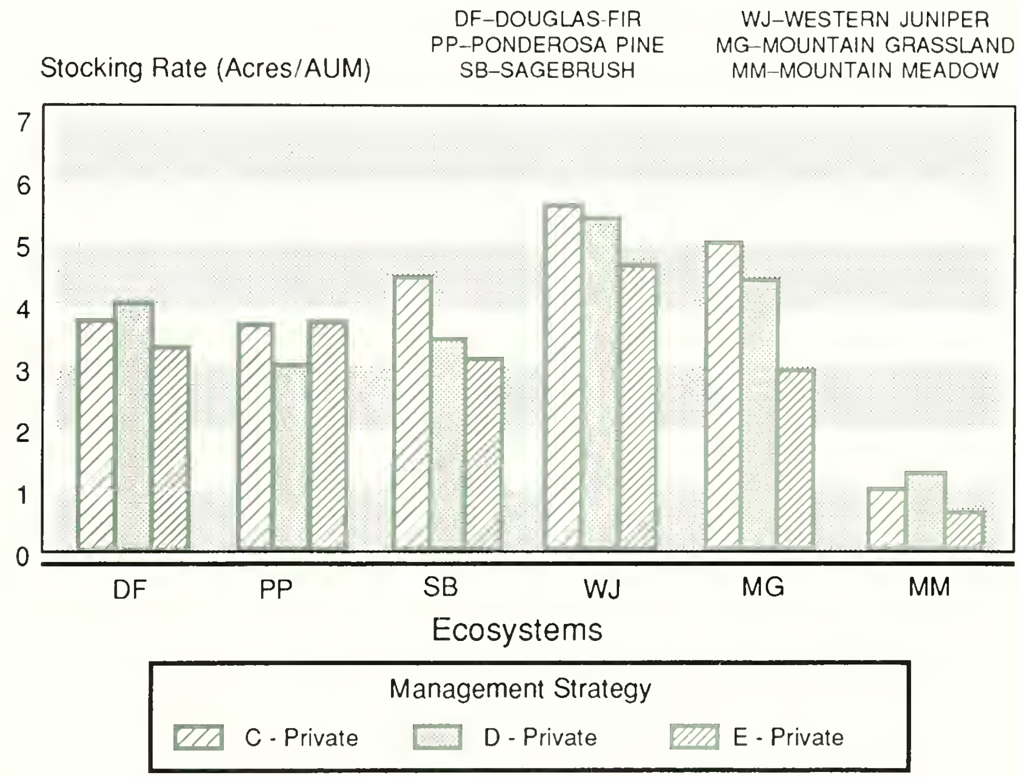

Figure 7-9—Stocking density by strategy and ecosystem for private land.

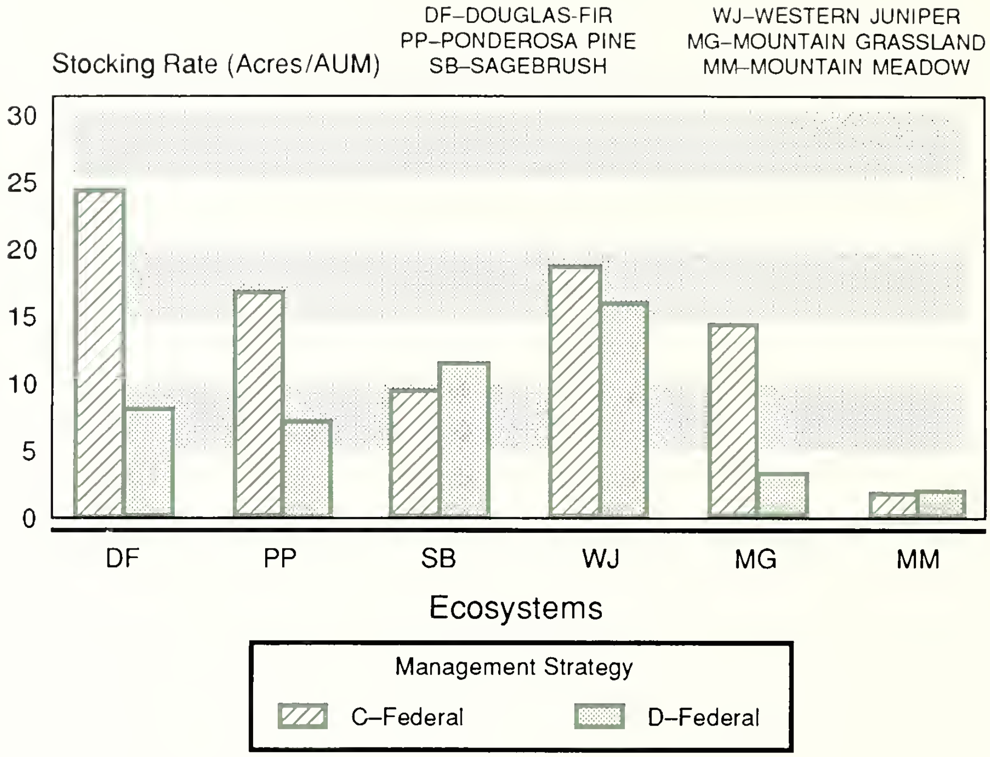

Figure 7-10—Stocking density by strategy and ecosystem for Federal land.

Grazing Capacities

Grazing capacities on private land were generally higher than those on public land, ranging from a 530 percent difference on extensively managed (strategy C) Douglas-fir to a 32 percent increase on intensively managed (strategy D) mountain meadow. The exception was the intensively managed (strategy D) mountain grassland where stocking was 25 percent greater on Federal than on private land; however, only two pastures of Federal land with mountain grassland were observed under intensive management. Greater stocking densities on private land reflected the difference in pasture size (Federal pastures were generally 4 to 10 times larger than private pastures), which resulted in increased livestock distribution and more improvements per acre.

The anticipated pattern of less land required per AUM as management intensity increased was generally observed. Exceptions on Federal land included lodgepole pine, sagebrush, and mountain meadow ecosystems. These exceptions related to the way strategies were assigned to pastures. All ecosystems within a pasture received the same strategy regardless of whether or not practices were implemented within all ecosystems. For example, timber treatments of Douglas-fir, ponderosa pine, and larch resulted in increased capacity for the treated acres, but the entire pasture (all ecosystems) was placed in the intensive (strategy D) management strategy. Use may, however, shift away from other ecosystems, such as lodgepole pine, sagebrush, and mountain meadow, within that pasture, which resulted in a relative reduction in grazing use.

Private land stocking rates were greater with strategy E (maximizing commodity production) than with strategy C (extensive) on all but the strategies for the ponderosa pine ecosystem, which were similar (3.77 acres/AUM vs. 3.81 acres/AUM). Private land pastures were generally smaller than Federal pastures and tended to have more uniform treatment on all ecosystems within a pasture. When strategy E was implemented on a pasture with Douglas-fir, mountain meadow, and juniper, improvements included all three ecosystems with such practices as thinning, juniper control, and seeding. Thus, increased capacities were generally noted in all ecosystems within pastures with the E strategy. Under strategy D (intensive), implementing cultural treatments may not have been for all ecosystems within a pasture—especially on public land. This different treatment is likely the reason for decreased capacity between strategies C and D on Douglas-fir and mountain meadow ecosystems on private land.

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Economics of Management Strategies

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The EVAL project was guided to a great extent by economic objectives. Concern about the use of scarce budgets by private ranchers and public land managers was an important influence behind funding the project in Grant County, Oregon. Rural communities like those of Grant County depend on the use and management of natural resources. Local community leaders were influential in convincing Congressional leaders that Grant County should be the site of the EVAL project initially. The interest of the community leaders in the importance of natural resource use and management was evident before EVAL. Grant County had previously been the subject of economic studies examining the interrelations among economic sectors of the county. Bromley and others (1968) and Haroldsen and Youmans (1972) had developed input-output models of the Grant County economy.

The economic EVAL objectives changed as the project budget changed. The primary objectives reported here are those that were emphasized during the later stages of EVAL. The objectives can be generally expressed as describing: the dependency that the local ranching community has on Federal forage, the changes in ranching operations undertaken by ranchers who are given increases in Federally permitted forage, the relations and interdependencies that exist among economic sectors in the local economy, the range improvements needed in implementing economically optimal grazing strategies on private and Federal land, and the economically optimal grazing strategies for ecosystems on private and Federal lands.

Dependency on Federal Forage

In 1981 in cooperation with the Departments of Rangeland Resources and Agriculture and Resource Economics at Oregon State University, the Oregon Cattlemen's Association, and the Oregon State Office of the Bureau of Land Management, the EVAL project cosponsored research that examined the dependency of ranchers on Federal forage. Specific objectives were included in a broader study that addressed the differences between dependencies of EVAL cooperators and the ranchers in Grant County that did not participate in the EVAL program. The larger study examined those holding Federal grazing permits in central and eastern Oregon counties and was reported by Bedell (1984) and Bedell and Stringham (1984).

Figure 8-1—Ranch headquarters typical of the Evaluation area.

Data from the 1980 grazing year was gathered from 19 EVAL cooperators and 26 non-EVAL Grant County ranchers that had permits for grazing on Federal land (fig. 8-1). Information was gathered on all the forage sources used during the 1980 grazing year. Ranching operations were stratified according to size of herd maintained (0-99, 100-199, 200-499, 450-749, and more than 750). Livestock operators were asked to estimate where their cattle were at all times of the year. Categories were deeded range (seeded, open native, timbered), private rented range, BLM, Forest Service, State/other public sources, deeded or rented meadow, deeded or rented hay/crop aftermath, and hay fed. Data were aggregated for reporting into the following categories: deeded range, BLM range, Forest Service range, State range, irrigated pasture, aftermath, and hay. No attempt was made to account for differences in class of livestock; all cattle data were considered as AUM's.

Results indicate that the EVAL cooperators average herd size was 309 adult animals (cows plus bulls) and 156 yearlings. Non-EVAL permittees sampled had an average herd size of 252 adult animals and 45 yearlings. Under the assumption that firms carrying yearlings at 50 percent or more of the cow numbers are primarily in the business of selling yearlings, EVAL cooperators had 10 percent greater yearling operations than the non-EVAL permittees (37 percent vs. 27 percent). Comparing the total number of AUM's within the county for ranchers with grazing permits to those of the EVAL cooperators showed that 17.7 percent of the total AUM needs of the county were by EVAL cooperators. Breaking this down by herd size showed: 0-99 cows, 11.7 percent; 100-199, 17.1 percent; 200-449, 18.3 percent; 450-750, 22.3 percent; and over 750 cows, 15.5 percent.

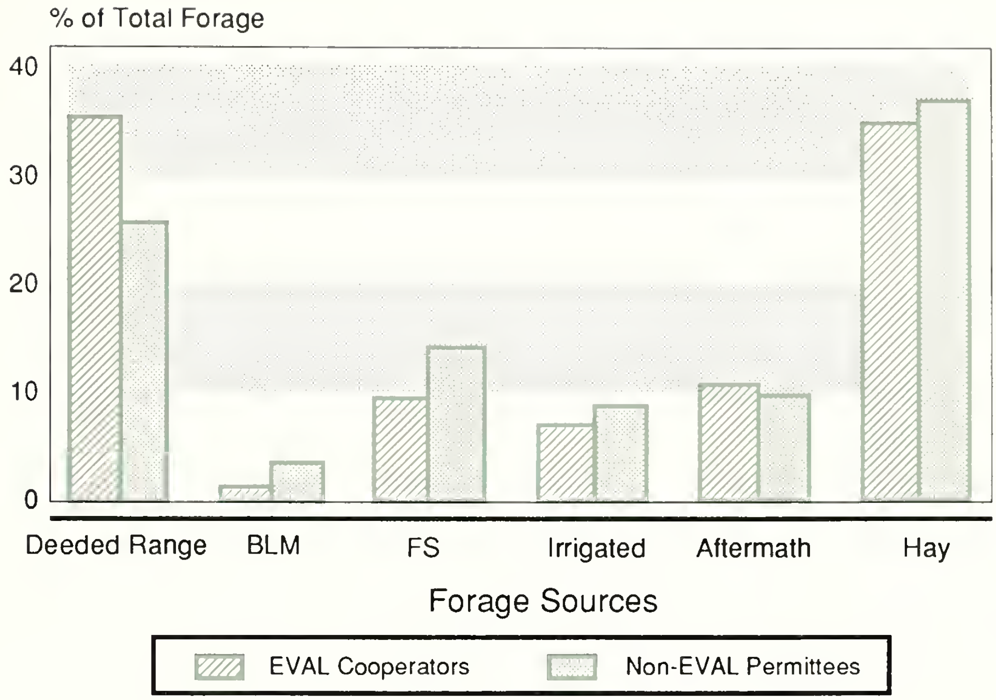

Figure 8-2—Annual forage needs for EVAL cooperators and non-EVAL permittees by forage source.

Forage requirements by herd size were fairly similar for EVAL cooperators and non-EVAL permittees for ranches of fewer than 450 cattle (appendix G, table 1). Variations seldom exceeded 2 percent of the forage consumed in any 1 month for operations with herd sizes less than 450 cattle. For operations with herd sizes between 450 and 750 cattle, the contrasts were greater. Variations ranged to nearly 10 percent, with the EVAL cooperators using a larger percentage of forage than the non-EVAL permittees. On ranches with over 750 cattle, the variations were typically greater than 5 percent, with the non-EVAL permittees representing the greater use of forage. Combining all herd sizes into one composite and comparing the monthly percentages resulted in little difference between the EVAL cooperators and the non-EVAL permittees (fig. 8-2).

Deeded range provided 35.5 percent of all forage requirements for the EVAL cooperators, but it provided only 25.9 percent of the forage requirements for the non-EVAL permittees (appendix G, table 2). Deeded range included deeded land, leased private land, and land owned by grazing associations. On average, non-EVAL operators leased slightly more (3.5 percent) AUM's on private rangeland compared to EVAL operators (2.2 percent), but EVAL AUM's for grazing associations were 3.6 percent as compared to only 0.7 percent for non-EVAL operations. Bureau of Land Management and State owned land contributed less than 5 percent combined to the total forage needs of either EVAL or non-EVAL operators. Forest Service lands provided nearly 5 percent more of the total forage requirements of non-EVAL permittees than of the EVAL cooperators (14.4 percent vs. 9.5 percent). The overall average reflected little difference in the use of hay, a 23 percent difference was observed in the use of hay in April. The contrast was also found with the use of deeded range in April. The apparent difference is refected in the shift from hay to the use of deeded range earlier by EVAL cooperators. The Forest Service provided over 40 percent of non-EVAL forage in July and August but never over 28 percent of EVAL cooperator forage for any month.

Several differences were found in grazing season forage provided on rangeland alone (appendix G, table 3). Deeded range for the EVAL cooperators was relatively more important in June through September, by providing 20 percent or more forage than that consumed by cattle from non-EVAL ranches (figs. 8-3, 8-4, and 8-5). The Forest Service provided nearly 20 percent more forage to non-EVAL ranches in June through September.

Both the EVAL cooperators and the non-EVAL permittees depended on Federal forage, but the non-EVAL permittees were more so. The importance of this forage source as a resource to the local ranching community is evident. These numbers represent what was actually grazed or used in the 1980 grazing year. They are an indication of the impact that changes in availability of Federal forage can bring about in ranching operations.

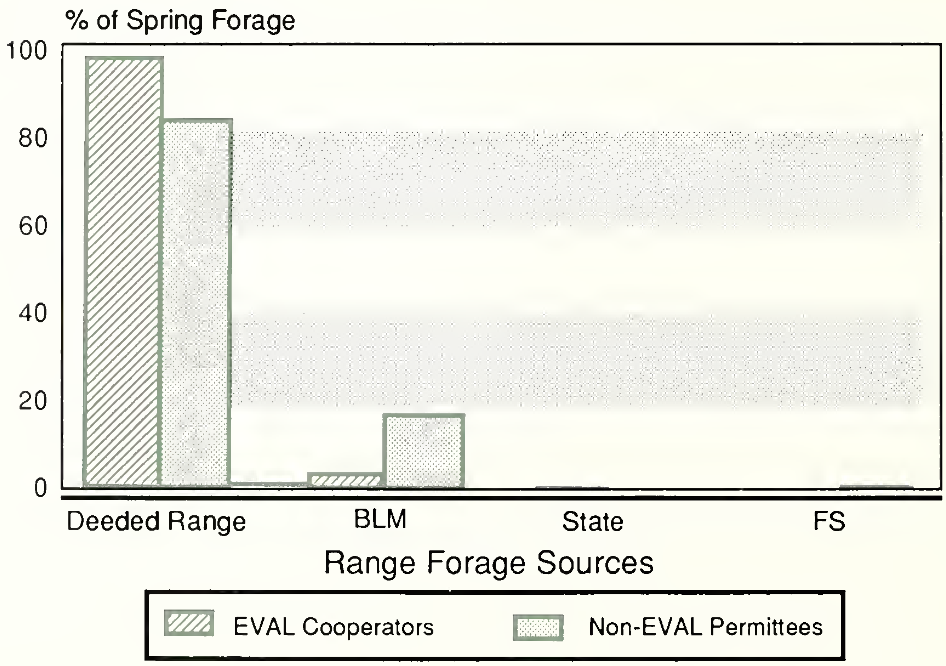

Figure 8-3—Spring range forage needs for EVAL cooperators and non-EVAL permittees by range forage source.

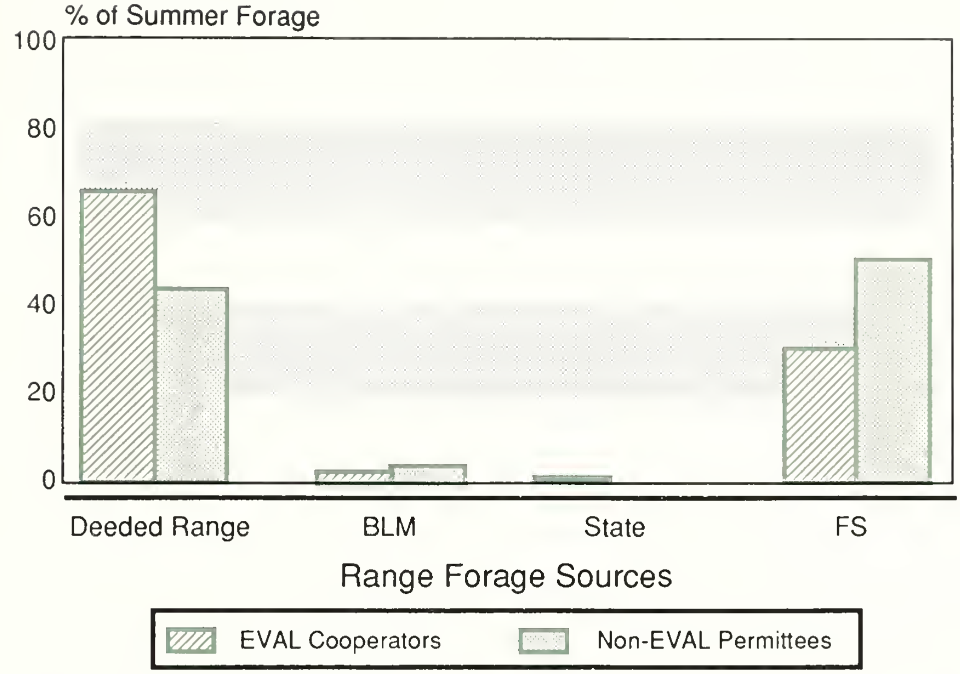

Figure 8-4—Summer range forage needs for EVAL cooperators and non-EVAL permittees by range forage source.

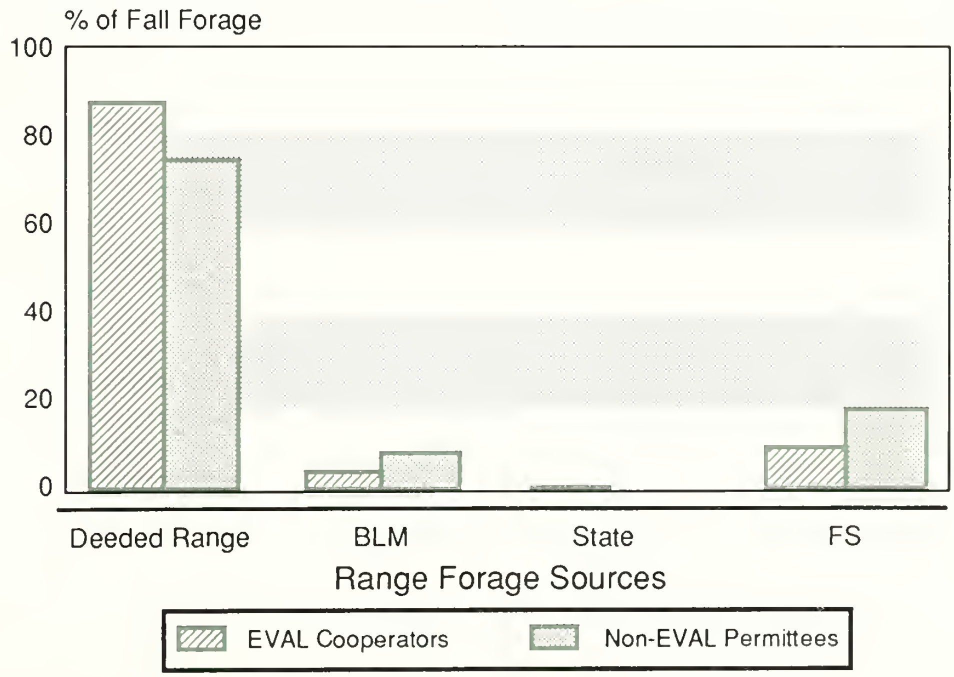

Figure 8-5—Fall range forage needs for EVAL cooperators and non-EVAL permittees by range forage source.

Changes in Ranch Operations With Federal Forage Availability

As part of the EVAL project, actual changes in ranch operations were observed in relation to shifts in the availability of Federal forage. The changes implemented by permittees as a result of increases in permitted use on the Malheur National Forest were evaluated. In addition, the EVAL cooperators who did not receive an increase in permitted use were asked what changes they would make as a result of a hypothetical decrease or increase in permitted use. Details concerning this study have been documented (Quigley and others 1986).

All Malheur National Forest allotments that received an increase in permitted use during the EVAL project were identified. Subsequent to increases in permitted use, the permittees of these allotments were asked through a questionnaire and subsequent interview to provide information as to the changes in management and resource use that would be caused by the increase and to a hypothetical 25 percent decrease in permitted use. In addition, EVAL cooperators with Federal permits but no increase in permitted use were similarly asked to respond to a hypothetical 25 percent increase and a 25 percent decrease in Federal permitted use.

The responses were summarized to reflect the actual response of ranchers to a shift in permitted use and the response to hypothetical shifts. An analysis was performed to determine possible differences between anticipated and actual changes.

Range improvement practices and management changes resulted in a 20 percent increase in permitted use on two allotments, a 15 percent increase on one allotment, a 10 percent increase on one allotment, and a 5 percent increase on another allotment after completion of the EVAL analysis. Twenty-one ranchers agreed to participate in the study. Fourteen received an increase in their permitted use on the allotments and 7 were cooperators with permits who did not receive an increase in permitted use. Together, they represent 16 percent of the total permittees in Grant County, Oregon.

Ranchers who had been given an increase and ranchers who were hypothesizing response to an increase responded similarly in the likely changes they would undertake (table 8-1). The three most frequent responses were to increase cows, increase yearlings, and raise more hay on deeded land; the ranking was the same in both groups. More ranchers actually increased yearlings (71 percent) when given a permit increase than thought they would if provided an increase (43 percent). Another contrast was that all ranchers who did not receive an increase thought they would undertake one or more of the changes shown, whereas 21 percent of those receiving an increase took no action except to summer additional base herd livestock on the National Forest.

All ranchers were asked what changes they would make with a 25 percent decrease in permitted use of Federal forage. Responses were quite different between ranchers with and without increases (table 8-2). Both groups would decrease the number of cows they own. The number of effects foreseen as a result of reductions in forage are clearly greater for the ranchers who had recently received increases. All ranchers with increases in forage availability predicted changes in operation if reductions occurred, but, 14 percent of the other ranchers predicted no shifts in operation.

Table 8-1—Response of ranchers to an actual increase in Federal grazing and to a hypothetical 25-percent increase in Federal grazing

Rancher response	Actual increase[a] Changes considered	Changes implemented	Hypothetical increase[a]
	----------- Percent -----------		
Increase number of cows	79	79[b]	71
Increase number of yearlings (including replacements)	50	71[c]	43
Raise more hay on deeded acres	50	43	29
Irrigate more deeded acres for pasture	0	7	0
Lease more spring or fall pasture	21	21	14
Sell less hay	7	7	14
Buy more hay	36	36	14
Lease more land for hay	7	21	0
Lease less summer range	0	14	14
No changes	7	21	0

[a] Figures will not total 100 percent because ranchers were allowed more than one response.
[b] Ranchers increased their cow herd by 14 percent.
[c] Ranchers increased their yearlings by 15 percent.

Table 8-2—Anticipated changes in ranch operation if Federal grazing were decreased by 25 percent

Ranch operation	Ranchers receiving allotment increase[a]	Ranchers not receiving allotment increase[a]
	----------- Percent -----------	
Decrease number of cows	71	43
Decrease number of yearlings	50	14
Sell more hay	29	0
Buy less hay	29	14
Lease more summer range	29	43
Lease less spring or fall pasture	14	0
Raise less hay on deeded acres	14	0
Discontinue federal allotment	7	0
No changes	0	14
Irrigate fewer deeded acres for pasture	0	0
Lease less land for hay	0	0

[a] Figures do not total 100 percent because ranchers were allowed more than one response.

Table 8-3—Response of ranchers to factors limiting their ability to expand herd size by 25 percent

Factors	Ranchers receiving allotment increase	Ranchers not receiving allotment increase
	Percent	
Amount of hay raised	31	43
Financial ability to purchase cattle or other variable costs	15	29
Amount of spring pasture	15	14
Amount of fall pasture	8	14
Amount of summer pasture	15	0
Financial ability to purchase winter feed	8	0
All the above	8	0
Total	100	100

Ranchers were also asked what factor most limited their ability to expand herd size by 25 percent. Both groups of ranchers saw the availability of winter feed (amount of hay raised) as the most limiting factor (table 8-3). Ranchers who did not receive an increase were limited first by financial considerations and then by the availability of spring and fall pasture. Ranchers considered raising hay an alternative for providing winter feed, but not purchasing hay because of their financial situation.

Although the most likely response to changes in Federal forage is a shift in herd size, planning agencies must consider the entire ranch operation, as well as effects induced by an increase in herd size. The most important induced effect is impact on winter feed. If the herd size increases, more winter feed is needed; if the herd size decreases, less winter feed is needed. Another important consideration in planning the changes anticipated from shifts in permitted use is the one-fifth of the operators who only change location of their summered livestock.

Interdependencies Among Economic Sectors

The Grant County economy has been the subject of numerous economic studies (Bromely and others 1968, Haroldson and Youmans 1972, Obermiller 1980, Obermiller and Miller 1983). The relatively isolated economy and the dependency of the area on its natural resources for economic activity have made it a prime candidate for studying the impacts of various resource policies. Early work by Bromely and others (1968) used input-output analysis to study the effects of changes in Federal land use on Grant County. Data were collected directly from businesses and households in Grant County to describe the economic transactions that occurred in 1964 within and among economic sectors. The model consisted of 18 economic sectors.

The information showed that the agricultural sectors of the county are largely exporters with the lumber industry being the greatest. Exports from the agricultural and lumber sectors accounted for 75 percent of the basic income brought into the county in 1964. Bromely and others also found that household incomes within the economy were most responsive to changes in income within the agricultural sectors.

Grant County was again the subject of an input-output analysis in 1970. Haroldsen and Youmans (1972) updated the original 1964 model of Grant County and analyzed the structure of the economy. The updated model reflected essentially the same structure of the economy that the earlier model had demonstrated. Differences in values reported reflected the inclusion of household and local government expenditures within the model as well as shifts in price. Household income and business multipliers demonstrated the importance of the natural resource base to local economic activity.

Another input-output model was developed from original data for Grant County using 1977 data. This study was funded by the EVAL project to examine the interrelations among economic sectors and determine business multipliers for the county. The model was used to evaluate the economic consequences of changes in timber production (Obermiller and Miller 1983) and projections of changes under different wilderness land allocation scenarios (Obermiller 1980). Information on net trade balance (exports minus imports) indicated that the basic and traditional resource-using industries—timber, ranching, and mining—bring more income into the county than they spend outside the county (table 8-4). Lodging, cafes and taverns, and local government have positive net trade balances but are small in comparison to the resource-dependent sectors. Other business sectors, including households, import more than they export. The structure of Grant County clearly depends, to a large extent, on the use and management of its natural resource base (fig. 8-6).

Table 8-4—Net trade balances among sectors of the Grant County, Oregon, economy, 1977

Sector	Net trade balance (exports– imports)	Value of sector output
	Thousand dollars	Percent
Timber hauling and harvesting	-1,192	-18.9
Dependent ranching	6,340	67.2
Other ranching	1,933	59.3
General agriculture	-147	-11.7
Mining	1,890	36.7
Lumber and wood products processing	23,527	61.5
Food processing	-233	-18.9
Other manufacturing and processing	-176	-28.3
Transportation	-766	-62.3
Communications and utilities	-3,310	-53.4
Finance, insurance, and real estate	-2,591	-53.5

Table 8-4—Net trade balances among sectors of the Grant County, Oregon, economy, 1977 (continued)

Sector	Net trade balance (exports–imports)	Value of sector output
	Thousand dollars	Percent
General construction	-840	-31.9
Agricultural services	-1,333	-73.9
Professional services	-66	-2.1
Automotive sales and services	-4,925	-41.7
Lodging	829	65.1
Cafes and taverns	141	9.3
Wholesale and retail services	-84	-6.5
Wholesale and retail trade	-11,709	-71.3
Households	-11,955	-25.6
City and county government	1,440	18.9
Local agencies of State and Federal government	-4,080	-30.4
Total	-7,307	-4.0

Figure 8-6—Lumber mill operations in the John Day, Oregon Valley.

The multiplying effect of business activity within the county economy is demonstrated by the business income multipliers (table 8-5). These multipliers reflect the total income generated in all sectors of the economy if one additional dollar of revenue is given to the stated sector from outside the economy (that is, new economic activity). Nine of the twenty-two sectors had multipliers greater than 2.3, including the agricultural and timber sectors (fig. 8-7).

Table 8-5—1977 Grant County business income multipliers in descending order, by sector

Rank	Sector	Gross business income multiplier
1	City and county government	2.79
2	Wholesale and retail services	2.72
3	Timber hauling and harvesting	2.59
4	Lumber and wood products processing	2.55
5	Professional services	2.45
6	Cafes and taverns	2.41
7	Dependent ranching	2.39
8	Other ranching	2.36
9	Lodging	2.35
10	General construction	2.09
11	Households	2.07
12	Local agencies of State and Federal government	1.94
13	Finance, insurance, and real estate	1.87
14	General agriculture	1.85
15	Automotive sales and service	1.78
16	Other manufacturing and processing	1.72
17	Food processing	1.71
18	Communication and utilities	1.65
19	Transportation	1.63
20	Mining	1.61
21	Agricultural services	1.45
22	Wholesale and retail trade	1.42

Figure 8-7—Timber is a major contributor to the Grant County economy.

The total value of 1977 export, inventory, and capital investment sales by each sector times the sector's multiplier equals the "base" amount of total business activity in Grant County for which that sector is responsible. With this economic base approach the two most important economic sectors are timber and ranching (table 8-6). Over two-thirds of all business activity in Grant County was directly or indirectly attributable to these two basic, resource-dependent industries.

The 1977 model was updated to 1979 by using price information and the approach described by Moses (1974). The basic assumption was that the underlying structure of the local economy had changed little since the original 1977 model was developed. The 1977 model was updated by using relative price relations. A comparison of the resulting business income multipliers between the 1977 and 1979 models show similar relative rankings of sectors (table 8-7). As was shown for the 1977 data, the 1979 model also demonstrated the importance of the resource-dependent industries. Collectively, they were responsible for over 60 percent of all business activity in the county.

Table 8-6—Contribution of final demand sales by each sector of the Grant County, Oregon, economy total county business activity, 1977

Sector	Value of final demand sales	Business income multipliers	Value of induced business activity	Portion of Total county business activity
	Thousand dollars		Thousand dollars	Percent
Timber harvesting and hauling	1,557	2.59	4,084	2.20
Dependent ranching	8,895	2.39	21,259	11.47
Other ranching	2,645	2.36	6,242	3.37
General agriculture	630	1.85	981	.53
Mining	5,153	1.61	8,296	4.48
Lumber and wood products processing	36,180	2.55	92,259	49.78
Food processing	525	1.71	898	.48
Other manufacturing and processing	173	1.72	298	.16
Transportation	117	1.63	191	.10
Communications and utilities	900	1.65	1,485	.80
Finance, insurance, and real estate	879	1.87	1,644	.89
General construction	1,279	2.09	2,673	1.44
Agricultural services	261	1.45	378	.20
Professional services	988	2.45	2,421	1.31
Automotive sales and services	2,900	1.78	5,162	2.79
Lodging	1,066	2.35	2,505	1.35
Cafes and taverns	836	2.41	2,015	1.09
Wholesale and retail services	191	2.72	520	.28

Table 8-6—Contribution of final demand sales by each sector of the Grant County, Oregon, economy total county business activity, 1977 (continued)

Sector	Value of final demand sales	Business income multipliers	Value of induced business activity	Portion of Total county business activity
	Thousand dollars		Thousand dollars	Percent
Wholesale and retail trade	1,627	1.42	3,368	1.82
Households	7,960	2.07	16,477	8.89
City and county government	2,585	2.79	7,212	3.89
Local agencies of State and Federal government	3,054	1.94	5,925	3.20
Total	80,321	2.31	185,343	100.00

Table 8-7—1977 versus 1979 Grant County business income multipliers, by sector

Sector	1977 multiplier	1979 multiplier
Ranching	2.39	2.30
Other agriculture	1.85	1.79
Food processing	1.71	1.66
Agricultural services	1.45	1.37
Wood products	2.55	2.19
Timber harvesting and hauling	2.59	2.29
Mining	1.61	1.56
Construction	2.09	1.99
Communication, transportation, and utilities	1.65	1.59
Finance, insurance, and real estate	1.87	1.80
Automotive sales and services	1.78	1.73
Professional services	2.45	2.37
Lodging	2.35	2.24
Cafes and taverns	2.41	2.33
Wholesale and retail trade	1.42	1.35
Wholesale and retail services	2.72	2.64
Households	2.07	2.02
Local government	2.79	2.70
Local agencies of State and Federal government	1.94	1.88

The Mix of Practices Used in Grazing Strategies

A general planning guide for rangeland managers to assist them in determining expected mix of practices and investment costs when managing at different intensities was developed. Information concerning practices implemented, management strategy, acreage, and AUM capacity in each pasture was recorded. Each improvement was assumed to benefit the whole pasture and was allocated on a physical unit basis to ecosystems within the pasture based on the ecosystem's AUM contribution to the pasture. The allocation procedure followed the method used to allocate joint costs (Gittinger 1982). Allocated units were expressed on a per 1000-acre basis for convenience of comparison. The allocated units of an improvement practice in an ecosystem were averaged over the total number of pastures at a given strategy and ownership class. These averages were compiled in a table showing the units of an improvement practice per 1000 acres for public and private land for each strategy. The coefficients represent the amount of an improvement practice expected to occur in a given ecosystem at a given management strategy.

Using the tables derived through this process, a manager can project the expected AUM's in each ecosystem within a pasture and project the average units of each improvement type and average expected cost per AUM. The information is useful in projecting potential costs and improvements for pastures with alternative management strategies.

Projected Units of Improvements

Average units for each range improvement practice by ecosystem and strategy are given in tables 8-8 and 8-9. Because benefits were assumed to accrue to the entire pasture for each improvement practice, improvement units spread across ecosystems within pastures. For instance, juniper control units occur in nonjuniper ecosystems. This apparent discrepancy is related to the allocation procedure and the fact that the other ecosystems occurred in association with the juniper ecosystem. By use of average costs per unit for all practices except fencing and water developments, the expected investment costs can be projected. Costs for fencing and water developments were determined from information specific to an ecosystem (fig. 8-8).

Table 8-8—Average units of range improvement practices per 1000 acres, by management strategy for each improvement-ecosystem combination on privately owned pastures

Improvement[a] (unit of measure)	Ecosystem[b]					
	DF	PP	SB	WJ	MG	MM
Extensive (C) management strategy:						
Water (number)	0.23	0.79	0.60	0.91	1.48	0.25
Fence (miles)	1.80	2.37	3.56	3.49	7.04	5.31
Intensive (D) management stragegy:						
Fert (acres)			5.91		6.52	8.50
JPN (acres)	.78	7.13	2.13	16.67	20.15	
SSN (acres)			5.00		3.16	
SBN (acres)			4.33	1.74		
RC (acres)	1.12	2.22		.46	.63	
Water (number)	.75	1.39	.49	1.77	2.00	.17
Fence (miles)	1.06	5.51	5.10	5.98	5.53	5.02
SPDD (acres)			6.38			8.51

Table 8-8—Average units of range improvement practices per 1000 acres, by management strategy for each improvement-ecosystem combination on privately owned pastures (continued)

Improvement[a] (unit of measure)	Ecosystem[b] DF	PP	SB	WJ	MG	MM
JPDD (acres)		.43		.68	.93	
MPDD (acres)			3.97		4.38	5.71
FDDS (acres)	.45	.89		.18	.25	
FTPS (acres)	3.40	5.98		2.24	.86	
Maximum production (E) management strategy:						
Fert (acres)			.29		.73	2.48
JPN (acres)		1.42	.11	.81		
SMN (acres)			9.60	3.80		
SSN (acres)			3.51		.66	
SBN (acres)			2.03	.33		
Weed (acres)				.69	4.55	3.00
Fire (miles)			.10	.02		
Water (number)	.83	.26	2.08	.75	2.87	.42
Fence (miles)	1.98	3.24	6.01	3.59	9.20	6.18
SRD (acres)			6.55			
SPDD (acres)			29.72	3.37	16.15	4.98
JPDD (acres)				.70	4.52	
GMD (acres)		1.09		1.98	17.74	3.00
MPDD (acres)			7.93		2.67	3.44
FDDS (acres)	5.73	1.64			1.64	
FTPS (acres)	.64	4.57	.06	1.40	7.35	
Ditch (acres)			.54		1.34	4.56
Total occurrences:						
Extensive (38 cases)	4	9	11	13	27	6
Intensive (27 cases)	4	13	13	19	16	6
Production (75 cases)	9	18	27	25	46	16

[a] Water = small water development; fence = permanent wire fence; fert = fertilization; JPN = juniper control, no seeding; SSN = spray sagebrush, no seeding; SBN = burn sagebrush, no seeding; RC = rodent control; SPDD = sagebrush seeding, plow, disk, drill; JPDD = juniper seeding, plow, disk, drill; MPDD = meadow seeding, plow, disk, drill; FDDS = debris disposal, broadcast seed; FTPS = thin, pile, broadcast seed; fire = fireline construction; ditch = drainage ditch construction; weed = weed control, chemical; SMN = sagebrush control mechanical, no seeding; trail = livestock trail construction; SRD = sagebrush seeding, rangeland drill; GMD = grassland seeding, mechanical preparation, drill; dam = check dam construction.

[b] DF= Douglas-fir; PP = ponderosa pine; SB = sagebrush; WJ = western juniper; MG = mountain grassland; MM = mountain meadow.

Table 8-9—Average units of range improvement practices per 1000 acres, by management strategy for each improvement-ecosystem combination on publicly owned pastures

Improvement[a] (unit of measure)	Ecosystem[b]							
	DF	PP	L	LP	SB	WJ	MG	MM
Extensive (C) management strategy:								
Weed (acre)	0.04	0.05	0.02	0.03		0.01	0.02	0.06
Water (number)	1.84	2.54	1.14	.24	1.85	1.43	1.62	8.22
Fence (miles)	2.47	3.28	1.24	.28	3.07	1.76	1.89	15.03
Trail (miles)	.03	.07	.01	.02		.01	.002	.85
Intensive (D) management strategy:								
Fert (acres)	14.95		4.55	1.47				43.41
SSN (acres)		2.90			3.59		5.15	5.37
SBN (acres)		11.15			13.79		19.82	20.66
Weed (acres)	2.75	.11	1.00	.73			.08	8.54
Fire (miles)		.09			.11		.16	.17
RC (acres)	.29		.07	.08				.43
Water (number)	4.29	3.63	1.36	2.43	.94	2.38	1.35	8.64
Fence (miles)	3.35	3.28	3.64	1.42	.70	1.48	.66	10.91
Trail (miles)	.20	.30	.08	.16		.13	.03	.54
SRD (acres)	3.55		1.09	.33				10.48
SPDD (acres		.45			.55		.79	.83
JPDD (acres)	5.08	3.79				5.61		5.00
MPDD (acres)	.40		.10	.11				.59
FDDS (acres)	46.76	41.69	48.93	20.33	9.89	39.90	3.54	122.28
FTPS (acres)	.39	.37	.22		.35			2.61
Dam (number)	.25		.07	.03				.67
Total occurrences:								
Extensive (25 cases)	20	21	17	5	7	15	11	15
Intensive (11 cases)	9	8	7	4	3	4	2	9

[a] Water = small water development; fence = permanent wire fence; fert = fertilization; JPN = juniper control, no seeding; SSN = spray sagebrush, no seeding; SBN = burn sagebrush, no seeding; RC = rodent control; SPDD = sagebrush seeding, plow, disk, drill; JPDD = juniper seeding, plow, disk, drill; MPDD = meadow seeding, plow, disk, drill; FDDS = debris disposal, broadcast seed; FTPS = thin, pile, broadcast seed; fire = fireline construction; ditch = drainage ditch construction; weed = weed control, chemical; SMN = sagebrush control mechanical, no seeding; trail = livestock trail construction; SRD = sagebrush seeding, rangeland drill; GMD = grassland seeding, mechanical preparation, drill; dam = check dam construction.

[b] DF = Douglas-fir; PP = ponderosa pine; L = larch; LP = lodgepole pine; SB = sagebrush; WJ = western juniper; MG = mountain grassland; MM = mountain meadow.

Figure 8-8—Spring development with fenced water source and water piped to a trough.

Higher investment costs were expected in range improvement practices as the intensity of management increased. Table 8-10 summarizes the investment results by using the expected acres and AUM's of representative pastures at each strategy. Because averages are used, the actual investment in a specific situation may be greater or less than expected. Annual investment per acre increases as management intensity increases. The reductions in per-AUM costs at the highest management intensity reflect that the increase in AUM's was occurring more rapidly than the increase in costs. This difference points to a relative cost advantage in managing at the highest intensity.

With the extensive strategy on private land, fencing and water developments are the only improvements installed (fig. 8-9). In strategy D, 12 types of improvements were used, and in strategy E, 17 types. Fencing was present in every pasture at all strategies, and small water developments were in the majority of the pastures. Other practices tended to be increased as management strategies became more intensive.

On public land, the major difference was in the variety of improvements used in the strategies. In strategy C, weed control and livestock access trails were found on Federal land. The annual investment per acre appears similar to investment for private land, but, the cost per AUM is much higher on public land. This difference is reflected in the much lower stocking densities observed on Federal land.

Table 8-10—Pasture and investment summary for private and public rangeland. Investment per year per acre and per AUM are based on 7 percent interest and 25-year project lives

	Total acres	Total AUM's	Total investment	Investment per acre	Investment/ yr·acre^{-1}	Investment/ yr·AUM^{-1}
			Dollars			
Private ownership:						
Extensive management	323	74	3,719	11.52	0.99	4.31
Intensive management	323	82	4,949	15.32	1.31	5.18
Maximum production	323	101	5,660	17.52	1.50	4.81
Public ownership:						
Extensive management	3001	172	26,534	8.84	0.76	13.24
Intensive management	3001	325	48,389	16.12	1.38	12.78

Figure 8-9—Fencing was used to control livestock movement.

Economically Optimal Grazing Strategies

Range management strategies were planned and implemented on 140 pastures on private land (21 ranches) and 36 pastures on public land (19 Forest Service grazing allotments). Cost-share arrangements were made to help fund improvements on private land, and Federal funds were used to implement all practices on Federal lands. All practices were monitored for compliance with standards specified by the EVAL team. Specifications were the same on all land ownerships and were developed jointly with private landowners, agency planners, and the county committee for the Agricultural Stabilization and Conservation Service.

The coordinated resource planning process followed that outlined by Sanderson and others (1988). An interdisciplinary team developed a management plan for all rangelands that included an assessment of the improvement potential for each pasture. With guidance from the private landowner (on private land) or land manager (on Federal land), a management intensity (grazing strategy) was selected for each pasture. Specific practices for the management strategy were selected and scheduled for implementation. Practices were implemented between 1976 and 1981. Data gathering and monitoring continued through September 1984.

A relatively straightforward benefit/cost approach was used to determine economically optimal grazing strategies. Benefits were estimated as beef production and converted to monetary values through an estimated price for beef. Costs were estimated for improvements, maintaining improvements, and managing of livestock. Benefits and costs were annualized and the difference—net revenue—determined. Optimal strategies were defined to be those with the largest net revenue.

Practice Selection and Strategy Implementation

Strategies were comprised of a mix of practices selected by the EVAL team through a coordinated resource planning process with landowners or managers (Sanderson and others 1988). The actual selection of a practice was based on best management concept and employed benefit/cost analysis. Practice-level economic analyses were performed before strategies were implemented. Practices were selected on their biological potential and anticipated response to management. Pastures were initially mapped by soil, vegetative type, and soil and vegetation condition. Areas of high productive capacity with low current production were selected for treatment. Each potential treatment within a pasture was analyzed for economic and noneconomic potential effects. Practices with positive net benefits were scheduled for implementing. Areas producing below capacity and with only a small potential for increased production were not selected for treatment.

The objective of implementing strategies was to achieve the best economic returns possible. Costs and potential benefits were considered before practices were implemented, rather than implementing them and then analyzing costs and benefits. This method differs from other studies of range improvement (for example, Pope and Wagstaff 1987 and Heady and Bartolome 1977), where both low and high productive areas were treated and included in the analysis. If a large proportion of the area had low productivity, the analysis would be biased toward a poor benefit-cost ratio. Areas where forage could have been increased through treatment but where the costs exceeded the benefits were generally excluded from treatment in this study. Exceptions included treatments where not all benefits could be quantified in economic terms yet were considered important to the EVAL team and manager or owner.

Strategies were selected to provide representation and replication across ecosystems and ownerships within the EVAL area. Maximizing commodity production (strategy E) was considered only for private land because it excluded multiple-use constraints. Under all strategies, basic resource values were protected.

Figure 8-10—Constructing a stock pond with a bulldozer.

Cost Determination

Cost accounting procedures were implemented to track the resources used in installing range practices. This process, described in detail in Chapter 3, included tracking labor, equipment, and materials. For example, miles driven, hours and type of equipment used, number of fence posts, rolls of barbed wire, amount of seed applied, and so on were recorded for all resources. These items were converted into dollar amounts by using 1978 costs (f.o.b. John Day, OR). Cost information was separated by skilled labor, unskilled labor, equipment, and material expenses for each type of practice (fig. 8-10). More than 800 individual practices were monitored.

All direct implementation and maintenance costs of the practices were assessed to the grazing strategy. When costs were incurred for purposes other than grazing, the separable costs-remaining benefit approach (Gittinger 1982) was used to assign only those costs of the practices that provided range benefits to the grazing strategy. An additional cost allocation process was necessary to provide costs on an ecosystem basis because most pastures included more than one ecosystem. Benefits from a practice that occurred in only one ecosystem may spread to the entire pasture; for example, a pasture with three ecosystems, each with one-third of the area might be served by only one water development. The cost associated with constructing, maintaining, and managing the single development was allocated proportionally to all three of the ecosystems contributing grazing capacity. The same argument holds for all other improvements. We totaled all grazing costs within a pasture and proportionally allocated them to the ecosystems within the pasture based on the ecosystem contribution to the total grazing capacity.

Each pasture in the EVAL study was inventoried and existing improvement practices (installed before EVAL) were recorded and evaluated. Old seedings that were viable, old water developments, and existing fences were included in the inventory. Improvement costs were estimated for all existing improvements in each pasture and allocated to the ecosystems present. This allocation was also based on the proportional contribution of grazing capacity (AUM's) by each ecosystem to the total grazing capacity of the pasture. For example, if a pasture consisted of two ecosystems of equal area, one contributing 75 AUM's and the other 25 AUM's, 75 percent of the costs of management and improvements would be allocated to the first, and 25 percent of the costs would be allocated to the second. Costs were annualized with a planning horizon of 50 years.

Fixed costs were not measured or estimated in this study. Fixed costs represent costs that do not vary with changing production and are important in the decision of whether to produce but not in the rate of production (Workman 1986). Research in North Dakota has shown that implementing short duration grazing systems increased fixed costs an average of 5 percent (Mack 1985). The EVAL strategies were less intense than a short duration grazing system and would likely result in a smaller increase in fixed costs. Therefore, the potential bias associated with excluding fixed costs should have minimal effect on the optimal management strategy at the intensities used in the EVAL program.

Fencing costs—Each pasture was mapped by ecosystem, and all fences (new and old) used to manage the pasture were measured to determine total length in each ecosystem. Average fence economic life was estimated at 25 years. Total costs of pasture fence construction were calculated by applying the average costs observed in implementing EVAL and reported in Chapter 3. Fence length in each ecosystem was multiplied by the cost per unit length and summed to find fencing cost by pasture. Fences were assumed to form the boundary of two pastures; thus, costs of each fence length were divided equally between the adjoining pastures. Annual maintenance costs were estimated at 1 percent of the construction cost and were added to the annualized cost of fencing.

Water developments—Water development costs were estimated by multiplying the total number of water developments in a pasture by the "weighted" unit cost of water developments for that pasture. The method assumes that the probability of a water development occuring in an ecosystem is directly related to the proportion of the pasture area occupied by that ecosystem. Weighted unit costs were calculated by averaging the cost for spring development and pit tank construction for each ecosystem, multiplying by the proportion of area each ecosystem is to the total pasture, and summing over all ecosystems in the pasture. This approach was necessary because the inventory of water developments was not specific as to type and ecosystem. The total costs for water developments in each pasture were then allocated proportionate to grazing capacity of each ecosystem. The average practice life was assumed to be 25 years.

Seeding, fertilizing, and rodent control—Seeding, fertilizing, and rodent control costs were applied by area. Costs were from the EVAL cost study. Fertilizing and rodent control were generally applied as a method to aid seeding establishment. Where fertilizer was applied to increase forage production, it was generally found not to be economically justified and, therefore, was not repeated for the 50-year planning horizon of this analysis. Seeding costs included treatment costs for seedbed preparation and application. On sites requiring sagebrush control before seeding, the treatment was considered a part of the seeding cost. Each pasture was inventoried for existing and new seeding treatments, and the average cost for seeding in each ecosystem was applied by area as a treatment cost if the practice was still usable for pasture management. The average practice life was assumed to be 25 years.

Figure 8-11—A ponderosa pine site that has been thinned.

Timber treatments—Separable cost-remaining benefit techniques were used to determine treatment costs for timber practices (Gittinger 1982). The expenses incurred in timber practices to meet range objectives that were in excess of the expenses normally undertaken for timber were considered range expenses. The only benefits used in the analysis derived from timber treatments were the forage-related benefits. Timber outputs were excluded from the analysis to eliminate the problem of having to include all timber costs, including final harvest and regeneration costs. Thinning practices applied through the EVAL study included wider spacing than recommended for timber purposes only and were followed by seeding (fig. 8-11). Costs were taken from the EVAL cost study and adjusted to reflect only the range portion. Debris disposal practices undertaken for range objectives only were used as direct costs in the analysis. Where debris disposal of old logging slash was undertaken strictly for range purposes the entire cost of the practice was considered a range cost and included in the analysis. The cost used was the average cost of the practice for all timbered ecosystems in the EVAL area.

Management costs—Costs for livestock management were estimated on an AUM basis following the Oregon data reported by Obermiller and Lambert (1984). The costs included expenses for turn-out, gathering and takeoff, routine management, salting, feeding, veterinary services, meetings, death loss, fees, and rent. Separate costs were determined for grazing on Federal and private land. All costs were adjusted to 1978 base year by using the prices-paid index as reported by the Agricultural Statistics and Reporting Service. Multiplying the costs per AUM by the number of AUM's in a given ecosystem resulted in an estimate of the cost of livestock management for the ecosystems in the pasture.

Annualized costs—Costs were annualized at interest rates of 4, 7, and 10 percent to determine the annual amount of money required to implement and maintain the given management strategy for 50 years and pay interest at the selected rate. Because all developments and improvements were assumed to have a useful life of 25 years, they were considered replaced once during the planning period. The selected interest rates represent estimates of the long-term real cost of capital (opportunity cost plus risk, but without inflation).

Benefit Determination

Although management of rangelands can result in many market and nonmarket benefits, we chose to consider only marketable beef benefits for this analysis. Practices implemented through EVAL had more than a single objective, with benefits accruing to other resources—such as wildlife, soil, and water. Although these were important considerations in implementing practices, the selection of grazing strategies for pastures was made primarily on the basis of marketable beef. The procedure required estimates of grazing capacity (AUM's) and marketable beef by ecosystems within pastures.

AUM allocation—AUM allocation is the process of allocating the total estimated AUM capacity in a pasture to the ecosystems within that pasture. Grazing capacities by ecosystem within pastures were presented and the process described in Chapter 7.

Monetary benefits of beef production were taken as the value of the product derived from the use of the forage on private or public lands by livestock. Estimates were made of the amount of beef produced on each ecosystem area within a pasture and was multiplied by the adjusted average price of beef for the United States.

Beef production was simulated for yearling heifers following McInnis and others (1986). The simulation model described in Chapter 7 was used to simulate grazing capacity and as input into the decision process of allocating capacity among ecosystems. In the beef production runs of the model, capacity in AUM's was an input. Data related to the production of beef from ecosystems in the Blue Mountains were available for yearling heifers, but not for steers (Holechek 1980). Few ranchers run all heifers in a given pasture, but comparisons across strategies and pastures using heifer data provided consistent results. The simulation model considered the amount of forage available for consumption in each ecosystem within a pasture and adjusted it for distance to water and slope in each of five periods of grazing in the year. Forage requirements were determined for the heifers and compared to the adjusted available forage in each season. Results of the model were pounds of beef production per acre by ecosystem within pastures. The simulation model was used in a predictive sense to convert the number of AUM's of grazing allocated to each ecosystem within a pasture to beef production. The model was forced to equate AUM production with the AUM's allocated.

Beef prices—Beef prices were taken as the 1977-85 average price received for steer and heifer beef in the United States (USDA 1986) and adjusted to the 1978 base year ($54.32 per hundred weight). To compare how the optimal strategies varied with changes in price values, the analysis was done with the average price, a 25 percent higher value and a 25 percent lower value.

Table 8-11—Ecosystem and pasture combinations by ownership and strategy

Pasture category	Private land	Federal land
Total number of pastures	139	36
Number of pastures with ecosystem:		
Douglas-fir	17	29
Ponderosa pine	39	29
Larch	6	24
Lodgepole pine	0	9
Sagebrush	51	10
Juniper	56	19
Mountain grassland	88	13
Mountain meadow	28	24
Total number of ecosystem-pasture cells	285	157
Number of strategies	3	2
Number of pastures:		
Strategy C	37	25
Strategy D	27	11
Strategy E	75	NA

Optimal Strategies

Optimal strategies were determined for each ecosystem on private and public land by determining the greatest return above variable cost. Averages were taken across pastures with the same strategy. Variable costs were taken as the sum of the annualized costs for improvements, improvement maintenance, and management costs. Fixed costs were excluded from the analysis. Optimal strategies were determined for 27 different combinations of three interest rates, three beef prices, and three management costs. Management strategies implemented through EVAL were successful in providing increased grazing capacity (Quigley and others 1986).

During EVAL, strategies were implemented and monitored on 139 pastures of private land and 36 pastures of Federal land. Within these pastures, eight ecosystems were represented (Douglas-fir, ponderosa pine, western larch, lodgepole pine, sagebrush, juniper, mountain grassland, and mountain meadow) as characterized by Garrison and others (1977) (table 8-11). The lodgepole pine ecosystem was not represented on private land pastures. Western larch ecosystem on private land was excluded because it occurred in only one extensive management (C strategy) pasture on private land. Thus, analysis on private land included six ecosystems and the analysis on Federal land included eight. Sufficient data existed only for extensive, intensive, and maximize-commodity production (C, D, and E) strategies on private land and extensive and intensive (C and D) strategies on Federal land for inclusion in the analysis. The optimal strategies described here are those above environmental management (strategy B).

Costs

Inventories of range projects were made, and a total cost figure for each pasture was calculated that included all workable improvements. Again, improvements were assumed to be repeated once during the 50-year horizon. All costs in a pasture were allocated to the ecosystems within the pasture based on the percentage of AUM's of grazing capacity that ecosystem contributed to the total. Improvement costs were taken from data gathered through the implementation phase of the EVAL project (tables 8-12 and 8-13). Management costs were determined on an AUM basis following Obermiller and Lambert (1984) and deflated to the base year of the analysis, 1978. Management costs in 1978 dollars were $3.67/AUM for private land and $9.79/AUM for Federal land.

Table 8-12—Average fencing and water development costs observed during EVAL implementation, in 1978 dollars

	Fencing costs		Water development costs		
Ecosystem	Construct	Maintain	Spring	Pit tank	Average
	dollars	per mile	dollars per development		
Douglas-fir	3279	32.79	1164	340	752
Ponderosa pine	2946	29.46	1060	391	726
Larch	3617	36.17	1165	247	706
Lodgepole pine	3617	36.17	1691	539	1115
Sagebrush	2328	23.28	703	379	541
Juniper	1880	18.80	923	393	658
Mountain grassland	2074	20.74	617	428	523
Mountain meadow	1899	18.99	998	534	766

Table 8-13—Range improvement costs observed during EVAL implementation, in 1978 dollars

Improvement	Unit	Cost/unit Dollars
Fertilization	Acre	33.00
Juniper control, piled, no seeding	Acre	68.00
Juniper control, no piling, seeded	Acre	18.00
Sagebrush control, mechanical, no seeding	Acre	37.00
Sagebrush control, aerial spray, no seeding	Acre	9.00
Sagebrush control, burn, no seeding	Acre	7.00
Fireline construction	Mile	783.00
Rodent control	Acre	8.00
Livestock access trails	Mile	380.00
Sagebrush control, rangeland drill	Acre	39.00
Sagebrush control, mechanical preparation, drill	Acre	58.00
Juniper control, mechanical preparation, drill	Acre	76.00
Grassland seeding, mechanical preparation, drill	Acre	74.00
Meadow seeding, mechanical preparation, drill	Acre	97.00

Table 8-13—Range improvement costs observed during EVAL implementation, in 1978 dollars (continued)

Improvement	Unit	Cost/unit Dollars
Debris disposal, seeding	Acre	32.00
Thin, seed	Acre	23.00
Drainage ditch	Acre	2.50
Check dams	Each	321.00
Water spreading	Acre	490.00

Costs by strategy and ecosystem at the intermediate interest rate (7 percent) and management cost ($9.79/AUM, Federal, and $3.67/AUM, private) were calculated. Costs were expected to be greater for the D and E strategies than for C. On private land, strategy E costs were greater than strategy C costs for all ecosystems (figs. 8-12, 8-13, and 8-14). But strategy D costs were less than strategy C costs in the Douglas-fir ecosystem, and the strategy E cost less than the strategy D in the ponderosa pine ecosystem (appendix G, table 4). These apparent inconsistencies related to the relative shifts in capacity observed within pastures. If practices within a pasture resulted in a D strategy but shifted the proportion of capacity away from one ecosystem to another, the share of costs allocated to the ecosystem with fewer relative AUM's would decrease even though the strategy was more intense. Costs were statistically different among ecosystems and strategies on private land.

Costs on Federal land followed the anticipated increase with strategy D costs exceeding strategy C costs on five of eight ecosystems (figs. 8-15 and 8-16). Those that had decreases were the nonforested ecosystems (sagebrush, mountain grassland, and mountain meadow) (appendix G, table 5). The lower per-acre cost can be partially explained through the practices undertaken on the strategy D pastures. Treatments related to timber activities, such as seeding after thinning and debris disposal, were the primary improvements resulting in increased capacity within these pastures, and few practices were undertaken in the non-forested ecosystems. These differences resulted in a relative shift in the contribution of AUM's away from the nonforested ecosystems to the forested ecosystems and, thus, less costs were proportionately assigned to these ecosystems. One predominantly sagebrush pasture has a natural boundary, rather than a fence, for a large portion of its boundary. This pasture had considerably lower total costs than other pastures, which helps explain the lower cost on the sagebrush strategy D. A contributing factor to the lower costs of the strategy D management on mountain meadow is the relatively small area represented by stringer meadows and the low proportion of total AUM's it produced compared to the remainder of the pasture which was treated. Costs on Federal land were statistically different among ecosystems.

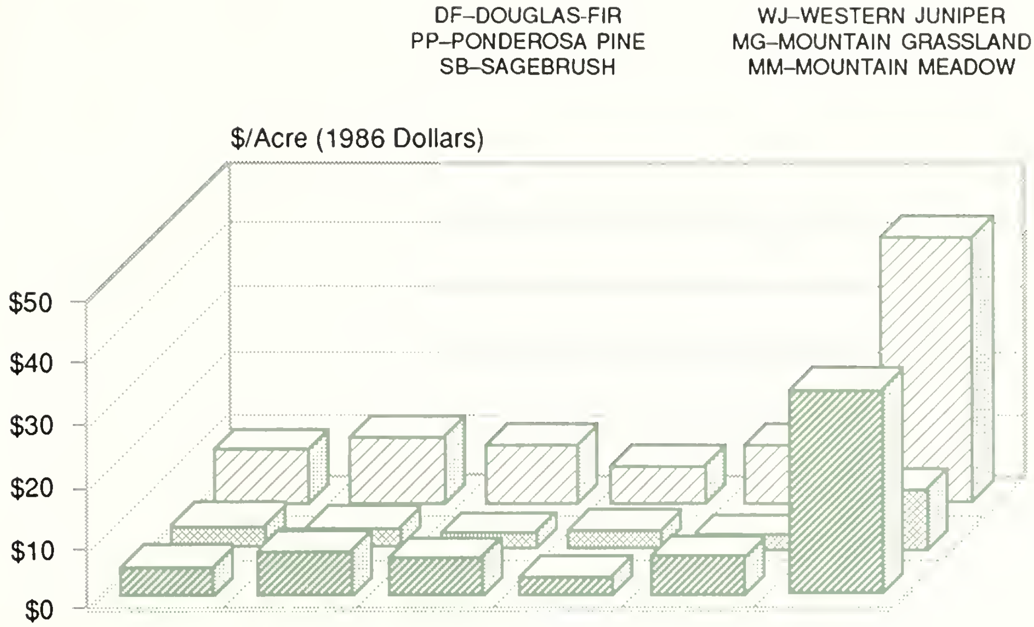

Figure 8-12—Benefits and costs by ecosystem for strategy C on private land.

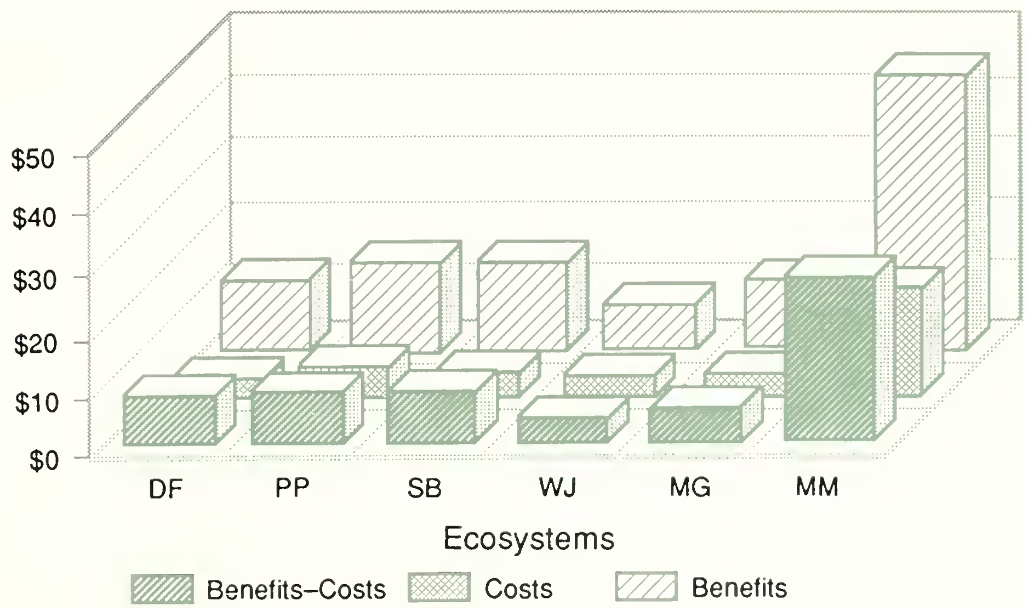

Figure 8-13—Benefits and costs by ecosystem for strategy D on private land.

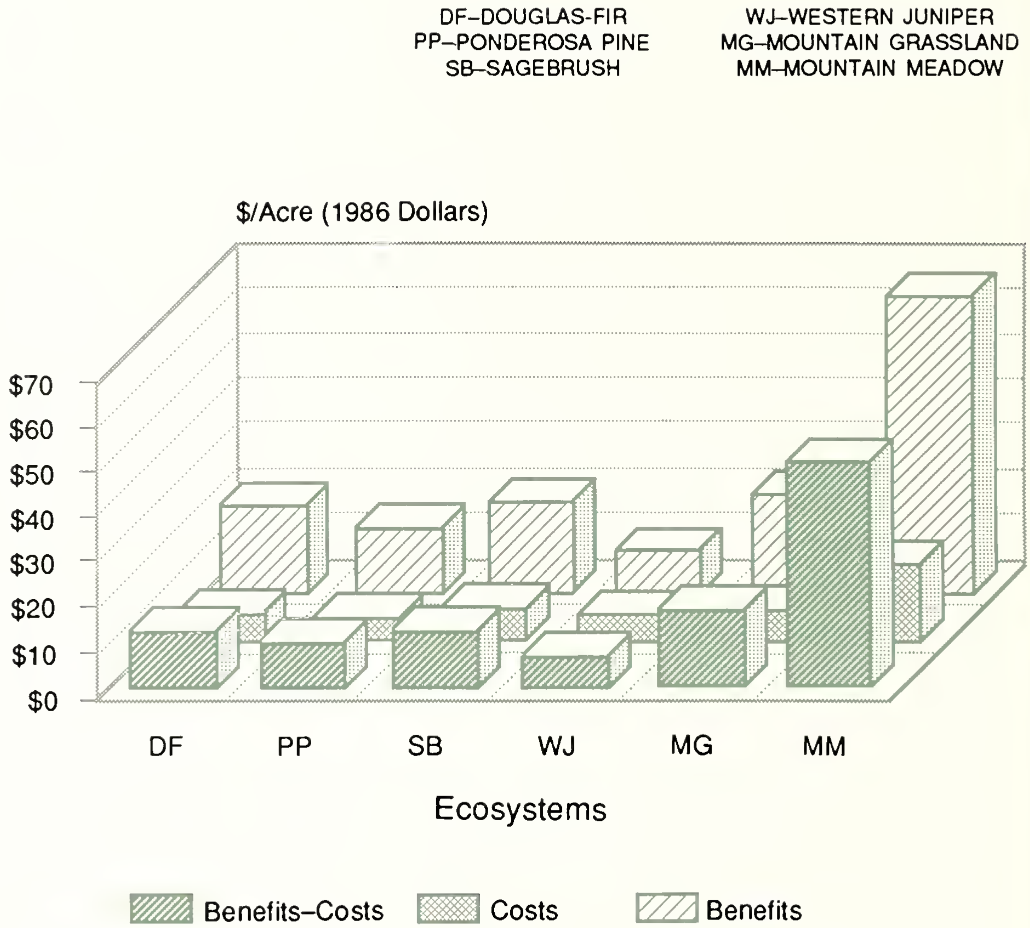

Figure 8-14—Benefits and costs by ecosystem for strategy E on private land.

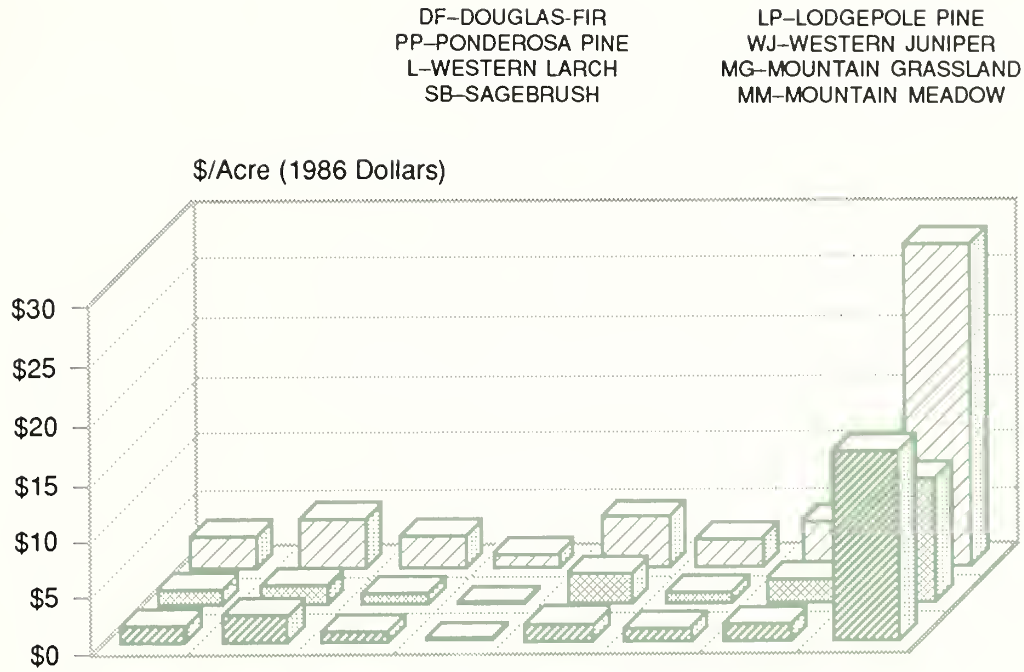

Figure 8-15—Benefits and costs by ecosystem for strategy C on Federal land.

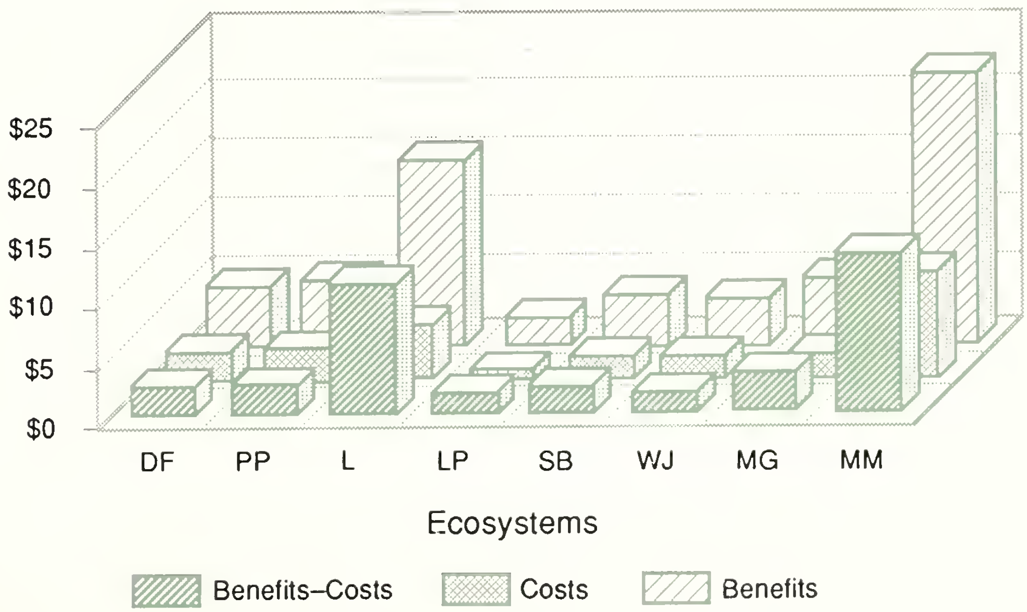

Figure 8-16—Benefits and costs by ecosystem for strategy D on Federal land.

Benefits

The AUM allocation process, summarized in Chapter 7, estimated the grazing capacity for each ecosystem in a pasture. Data from each pasture were run through the beef simulation model (McInnis and others 1986) to provide an estimate of pounds of beef produced within each ecosystem in each pasture.

All ecosystems on private land showed increased benefits as strategy changed from C to D to E (appendix G, table 4). Juniper consistently had the lowest benefits per acre, and mountain meadow consistently had the highest. Benefits were statistically different among ecosystems and among strategies.

On Federal land, the general trend for increased benefits with strategy D was observed on all but the sagebrush and mountain meadow ecosystems (appendix G, table 5). Again, the differential allocation of AUM's to ecosystems with treatments resulted in this apparent inconsistency. Benefits were statistically different among ecosystems.

Optimal Strategies on Private Land

When beef prices, interest rates, and management costs were set at the medium level, strategies C, D, and E average net revenues were \$9.34, \$8.96, and \$17.07 per acre, respectively, across all ecosystems. Strategy E was statistically greater than C and D. Strategy E was optimal on all ecosystems (larch and lodgepole pine were excluded because of too few observations) (fig. 8-17) (appendix G, table 4).

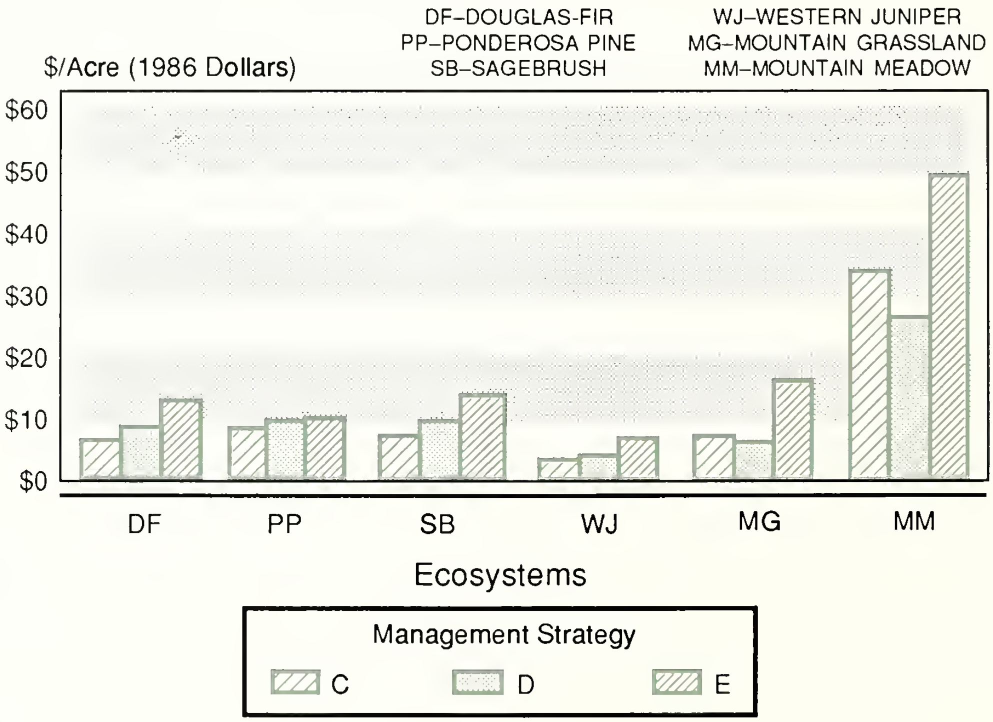

Figure 8-17—Net revenue by ecosystem for strategies C, D, and E on private land.

Varying price, management cost, and interest rates resulted in no changes in optimal strategies. Thus, across the prices and costs studied, strategy E remained optimal on all ecosystems. This strategy is the most intensively managed that we studied. Net revenues from this strategy appear to be optimal over a wide range of prices and interest rates.

The mountain meadow ecosystem resulted in the greatest net revenue per acre. It was also observed that the strategy C net revenue exceeded that of strategy D. The juniper ecosystem had the least net revenue per acre. Nearly a sevenfold difference was found between juniper and mountain meadow net revenue per acre ($7.31 versus $49.68). A general conclusion from this analysis is that seeding, sagebrush control, juniper control, thinning and debris disposal with seeding, and intensive management of private land appear to result in the greatest net revenue.

Optimal Strategies on Federal Land

When beef prices, interest rates, and management costs were set at the medium level, strategy C and D average net revenues (return above variable costs) were $3.82/acre and $5.80/acre, respectively, across all ecosystems. Strategy D was optimal on all ecosystems except mountain meadow (fig. 8-18) (appendix G, table 5). Analysis of variance showed that net revenues were statistically different among ecosystems.

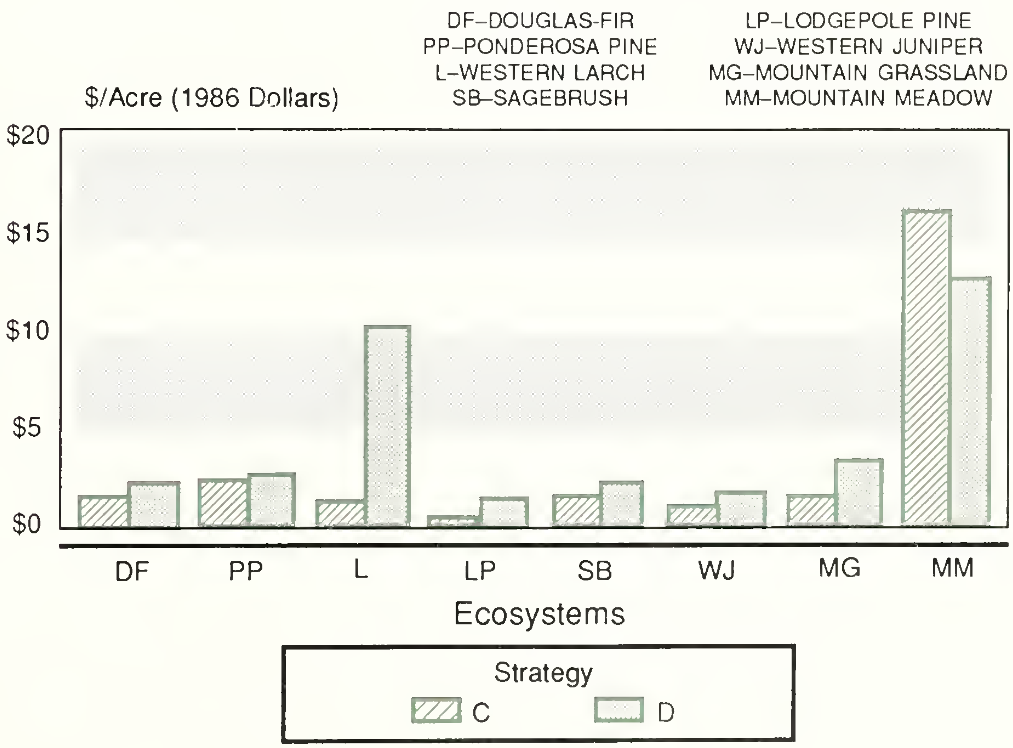

Figure 8-18—Net revenue by ecosystem for strategies C and D on Federal land.

Improvements shown in net revenue under strategy D reflect returns from higher intensities of management. The practices undertaken to achieve this more intense management resulted in increased productivity, forage availability, or grazing capacity that exceeded its cost. In the mountain meadow ecosystem, practices undertaken to achieve strategy D within the pasture resulted in relative shifts in capacity away from this ecosystem. This shift is reflected in lower capacity, lower costs, and lower benefits in this ecosystem in strategy D than in strategy C. Implementing cultural practices on meadows for strategy D on Federal pastures was only undertaken on two of the nine pastures. The remaining seven pastures had no treatment on the meadows within these strategy D pastures. Thus, given the average pasture with mountain meadow ecosystem occurring as stringers, these highly productive ecosystems would be optimally managed without implementing cultural practices on them, even though they are included in a strategy D pasture. The large standard error of the mean associated with net revenue for the larch, lodgepole pine, and mountain grassland ecosystems in strategy D reflects the large variation observed in productivity and treatments implemented to achieve the strategy D.

Optimal strategies on Federal land did not change when beef prices varied by ± 25 percent, and all other prices and interest rate were held constant. Federal optimal strategies were not sensitive to changes in interest rate, beef prices, or management costs when only one was changed and the others held at the medium rate. When interest rate, management cost, and beef price were allowed to vary simultaneously, only the lowest net return alternative (high interest rate, high management costs, and low beef price) resulted in changes in optimal strategies among ecosystems. At this high-cost option, ponderosa pine and juniper ecosystem optimal strategies changed to C. This reflects the high costs and lower return associated with thinning and debris disposal (strategy D options) in ponderosa pine, and juniper removal and seeding in the juniper ecosystem. Net revenue remains greater in the other ecosystems by not changing from the optimal strategies at mid-levels of price, interest, and management cost. As the value of benefits become smaller and the costs associated with management and practices become greater, the shift away from D as the optimal strategy occurs first in ponderosa pine and then in juniper. This shift implies that benefits relative to costs in these ecosystems were lower than in the other ecosystems.

The average across all ecosystems for optimal strategies were $7.66/acre on Federal lands and $17.07/acre on private land. This twofold difference must be interpreted with caution because this analysis did not consider fixed costs. Fixed costs associated with use of private land are considerably greater than fixed costs on Federal land. Although requirements to hold permits on Federal land carry with them base property and livestock ownership requirements, the relative amount of fixed costs associated with Federal land is likely less. Managing both private and federal lands at optimal strategies resulted in positive net returns above variable costs. The relative advantage of one over the other cannot be concluded from this study.

Conclusions

Based on marketable beef, the optimal strategy for managing private land is to maximize commodity production (strategy E). This strategy was found to be optimal over a wide range of interest rates, management costs, and beef prices. Optimal management strategies on Federal land were intensive management (strategy D) for all ecosystems except the mountain meadow, where extensive management (strategy C) was optimal. Analysis of optimal strategies over a range of price, cost, and interest assumptions showed that optimal strategies for Federal land shifted to extensive management (strategy C) on ponderosa pine and juniper ecosystems when costs were high and beef prices were low.

Range management strategies as applied in the EVAL study were comprised of a mix of practices that had been individually subjected to a benefit cost analysis. Each strategy was applied to achieve the highest return possible under that strategy. Practices were implemented only on those sites where the potential production was sufficient to cover the cost or to achieve a goal of management, such as early forage for spring turnout. In many instances, juniper and sagebrush treatments were applied to abandoned cropland sites that had been invaded by these species. These productive sites responded well to treatments and resulted in positive net benefits. Results indicate that pastures intensively managed, using benefit cost analysis as one of the selection criteria for practices, will result in greater returns above variable cost than less intensively managed pastures. These costs and benefits represent average precipitation years; years of below or above average precipitation may show different optimal strategies. It should also be remembered that fixed costs are not included in this analysis.

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Holechek, J.L. 1980. The effects of vegetation type and grazing system on the performance, diet, and intake of yearling cattle. Corvallis, OR: Oregon State University. 247 p. Ph.D. dissertation.

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Pope, Arden C.; Wagstaff, Fred J. 1987. An economic evaluation of the Oak Creek Range Management Area, Utah. Gen. Tech. Rep. INT-224. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 14 p.

Quigley, Thomas M.; Gibbs, Kenneth; Sanderson, H. Reed. 1986. Rancher response to changes in Federal permitted livestock numbers in eastern Oregon. Rangelands. 8(6):276-278.

Sanderson, H. R.; Quigley, T.M.; Spink, L.R. 1988a. Defining, implementing, and evaluating grazing management strategies. Journal of Soil and Water Conservation. 43(4): 345-348.

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9 Publications From the Oregon Range Evaluation Project

Arthur R. Tiedemann

Bedell, T.E. 1984. Dependency on federal grazing in eastern Oregon. Rangelands. 6: 152-155.

See abstract for Bedell and Stringham 1984.

Bedell, T.E.; Stringham, T. 1984. Forage sources for eastern Oregon cattle ranches with Federal grazing permits. In: 1984 progress report-research in rangeland management. Spec. Rep. 715. Corvallis, OR: Oregon State University, Agricultural Experiment Station: 7-14.

Authors provide a breakdown of forage sources (percent) for ranches that have Federal grazing permits in 13 Oregon counties. Sources are further characterized by month for central, southeast, and northeast groups of Oregon counties.

Bolognani, D.A. 1981. Simulated storm runoff characteristics between natural and altered ecosystems in the Oregon Range Validation area. Corvallis, OR: Oregon State University. 58 p. M.S. thesis.

During summer 1980, an infiltration/sedimentation study was conducted on the EVAL project work area. A Rocky Mountain infiltrometer was used to simulate a high-intensity rainfall event lasting 28 minutes with samples collected at 3 minutes and at 5-minute intervals thereafter. Mean infiltration rates and average-potential sediment losses were determined on 19 treated resource units consisting of various combinations of productivity and condition classes. Improvements included seeding, tree thinning, herbicide spraying, mechanical brush control, and some combinations of two or more practices. Natural or untreated resource units of similar soil type and vegetation were sampled as controls. On four of nine seeded mountain grassland ecosystems, the control had significantly higher infiltration rates for each interval in the 28-minute period. On two other seeded mountain grassland ecosystems, no significant differences in infiltration rates occurred during the 3-to-8 minute intervals. Afterwards, the control had significantly higher infiltration rates. On the sagebrush ecosystems, where sagebrush was mechanically removed and the areas seeded, the treated area had significantly lower infiltration rates and potential sediment loss than the control. The control for a thinned, mixed-conifer ecosystem in fair condition had both significantly higher infiltration and potential sediment loss than the treated area for a 3-to-8 minute infiltration rate, after which no significant differences occurred. For a thinned and seeded mixed-conifer site in good condition, where seeding was not successful, infiltration rates were higher for the treated area than the control area for the entire 28-minute simulated storm; however, no significant difference in average potential sediment loss occurred. Within a thinned, western larch ecosystem, the control had significantly higher infiltration rates and potential sediment loss than pinegrass, artificially seeded, and bare-ground areas.

Boyle, K.J. 1981. Modifications of static input-output models used to reflect sectoral change. Corvallis, OR: Oregon State University. 165 p. M.S. thesis.

Although input-output models are commonly used as an economic tool, these models become outdated. The most common source of obsolescence is reflected in the structural coefficients; for example, purchasing patterns of sectors within an economy may change. Several procedures can be used to update models to account for these changes. The location of new industry (sector) within the modeled economy also results in the need to update a model; then, the model must be expanded to incorporate the new sector. The author developed an ex-ante method for incorporating a new sector into an input-output model. The method is applied by incorporating a new sector (coal-fired power-plant) into the Morrow County, Oregon, input-output model. Implications of the existence of excess capacity in the Morrow County economy were evaluated. The ex-ante method appeared to lead to questionable results when projected increases in sales exceed a sector's excess capability. Two of the basic assumptions of an input-output analysis may be violated: constant structural coefficients and perfectly elastic supply. The economy may not be able to adjust perfectly and instantaneously to the projected interindustry transactions of the new sector. The ex-ante method, used implicitly, assumed a demand for the new sector's product. This assumption may be reasonable when a new sector has already made a decision to relocate, but it may not be reasonable without such a decision.

The method therefore makes no assumptions about the feasibility of the industrial location decision.

Buckhouse, J.C. 1980. Watershed considerations in land resource planning. In: 1980 progress report, beef cattle and range resources. Spec. Rep. 583. Corvallis, OR: Oregon State University, Agricultural Experiment Station: 1-2.

Describes water balance characteristics that may be altered by rangeland management from the perspective of the EVAL project.

Buckhouse, J.C. 1984. Infiltration and erosion: identifying potential hazards in the rangelands of Oregon. In: 1984 Pacific Northwest range management shortcourse; 1984 Jan. 25-27; Pendleton, OR. Corvallis: Oregon State University: 31-34.

Identifies major factors associated with erosion hazard on rangelands. The author concludes that great differences in erosion and infiltration potential exist among broad ecological classifications; habitat typing is helpful in identifying potential hydrologic hazards; and as biomass and soil protection improve, erosion hazards are reduced. The soil loss from a given site seems to depend on the degree of disturbance, success of revegetation in restoring biomass productivity, and time since a given practice was implemented.

Buckhouse, J.C.; Bolognani, D.A. 1982. Hydrologic response following rangeland improvement practices in eastern Oregon. In: 1982 progress report—research in rangeland management. Spec. Rep. 663. Corvallis, OR: Oregon State University, Agricultural Experiment Station: 10-12.

See abstract of Bolognani 1981.

Buckhouse, J.C.; Gaither, R.E. 1982. Potential sediment production within vegetative communities in Oregon's Blue Mountains. Journal of Soil and Water Conservation. 37: 120-122.

A Rocky Mountain infiltrometer that simulated convectional rainstorms of 10 cm (4 in) in 28 minutes was used to generate potential sediment production losses from 10 natural ecosystems in Oregon's Blue Mountains. Potential sediment losses in meadow and forested ecosystems proved statistically similar, ranging from 15 to 217 kg/ha (13 to 194 lb/acre). In dry grassland ecosystems, potential sediment production was similar to that in most forested ecosystems with the exception of western larch. Potential sediment production in the western larch ecosystem also differed from potential sediment production in the meadow ecosystem. The grassland ecosystem produced a potential sediment loss of 431 kg/ha (384 lb/acre). Sagebrush and western juniper ecosystems had potential sediment losses exceeding those in all other ecosystems—1284 and 1572 kg/ha (1145 and 1402 lb/acre). As ecological condition class or productivity class changed within ecosystems, statistically significant changes in potential sediment production occurred.

Buckhouse, J.C.; Mattison, J.L. 1980. Sediment potentials and high intensity storms on rangelands. In: Research in rangeland managment. Spec. Rep. 586, Corvallis, OR: Oregon State University, Agricultural Experiment Station: 16-19.

Cimon, N.; Quigley, T. 1986. Evolution of a geographic information system: integration into the Oregon Range Evaluation computing facility. In: Proceedings of a Geographic Information System Workshop; 1986 April 1-4: Atlanta, GA. Falls Church, VA: American Society for Photogrammetry and Remote Sensing: 99-109.

The trend toward decreasing cost and increasing power in small computers has had a direct effect on the scope of natural resource data management that can be undertaken and on the level at which data can be analyzed. Researchers can now gain direct and immediate feedback on their efforts by using tools such as Geographic Information Systems (GIS). GIS hardware and software requirements of the EVAL project evolved over time and were integrated into available computing resources. The original computer system was upgraded, as was the GIS software. Additional processing power permitted concurrent digitizing and data analyses. Map review was distributed to networked microcomputers. Further development would allow rapid and transparent communication between these systems and a newly acquired minicomputer.

Coe, P.K.; Quigley T.M. 1986. Application of a geographic information system for the Oregon Range Evaluation project. In: proceedings of a Geographic Information System Workshop; 1986 April 1-4: Atlanta, GA. Falls Church, VA: American Society for Photogrammetry and Remote Sensing: 88-98.

A geographic information system (GeoBased Systems, Inc.'s, polygon-based "STRINGS" (TM) software) was implemented in 1980 to produce a graphic and tabular data base for the EVAL study area. Interactive digitizing and editing allowed the digitizer control over the entire mapping process. Four data sets were overlaid to produce a data base used in a simulation model. The software integrates the features of automated drafting systems with sophisticated analytical capabilities. The overlay analysis subprogram requires excessive processing time for large data files. The STRINGS (TM) file structure provided a good base for a comprehensive mapping system and met the needs of the EVAL project.

Etchamendy, P. 1979. Coordinated resource management plans—their preparation and use in the validation project. In: Range management short course, Coordinated resource mangement planning in the Pacific Northwest on private and public lands; 1979 March 20-22: Pullman, WA. Pullman, WA: Washington State University, Cooperative Extension Service: 40-47. In cooperation with: Oregon State University; University of Idaho.

Author describes in detail the elements of and the process for developing a coordinated resource management plan.

Farrell, W. 1979. Goals and objectives of the Grant County resource committee. In: Range management short course, Coordinated resource mangement planning in the Pacific Northwest on private and public lands, 1979 March 20-22: Pullman, WA. Pullman, WA: Washington State University, Cooperative Extension Service: 36-39. In cooperation with: Oregon State University; University of Idaho.

The author describes the involvement of the Grant County resource committee in planning for the management of the forest and range resources of the county. They are involved in (1) identifying and evaluating the effects of existing and experimental resource management activities; (2) cooperatively developing a unified planning system for managing county resources; and (3) implementing management practices that develop county resources while conserving the resource base.

Gaither, R.E. 1980. Storm runoff characteristics of various plant communities within the Oregon Range Validation area. Corvallis, OR: Oregon State University. 153 p. M.S. thesis.

Infiltration rates were measured with a Rocky Mountain infiltrometer for each of the 10 ecosystems that comprised the major vegetative habitats in the EVAL Project. Within each ecosystem, infiltration rates were expressed as a function of productivity and condition classes. Mean infiltration rates for ecosystems ranged from 6.6 cm/h for ponderosa pine to 8.8 cm/h for western larch. A trend toward increasing infiltration rates corresponded to increasingly mesic sites. Alpine, Douglas-fir, mountain meadow, and western larch had the highest vegetative cover, occupied the most mesic sites, and exhibited the greatest infiltration rates. Differences of infiltration rates within ecosystems as a consequence of differences in productivity or condition classes were also observed. Forested sites were more dependent on condition class (pole or timber-sized trees) than productivity class, with higher infiltration rates on pole-sized stands than on timber-sized stands. This difference was apparently because of higher tree densities associated with pole thickets. Nonforested sites were responsive to both productivity and condition classes. Higher infiltration rates were exhibited on sites with higher productivity or better condition classes. Sediment production ranged from 1572 kg/ha in the western juniper ecosystem to 15 kg/ha in the western larch ecosystem. Results of a stepwise regression analysis indicated that vegetative cover, litter, and erosion pavement were more closely correlated with potential sediment production than with infiltration rates.

Gaither, R.E.; Buckhouse, J.C. 1981. Comparing a high intensity simulated rainfall to theoretically characteristic storms within the range validation study area. Oregon Academy of Sciences Proceedings 17: 10-15.

When sediment production and infiltration potentials for rangeland sites are determined, producing simulated rainfall of an intensity that results in surface runoff is best. Infiltration curves were established for each of 10 ecosystems within the Oregon Range Evaluation area by using a Rocky Mountain infiltrometer. Values of storm intensities common to the area were obtained from National Oceanic and Atmospheric Administration records and related to return periods of 2, 5, 10, 25, 50, and 100 years. Comparisons of infiltrometer results with available precipitation data indicated that no characteristic storms of the area would approach the constant infiltration rates established by infiltrometer measurements within the 10 ecosystems of

the study area. Despite this comparison, and based on observed flooding, storms occur within the area that exceed the infiltration rates for the ecosystems studied. Quantitative data for these storms have yet to be established.

Gaither, R.E.; Buckhouse, J.C. 1981. Hydrologic outputs from woodland, shrubland, and grassland ecosystems in relation to grazing management strategies: an annotated bibliography. Spec. Rep. 640. Corvallis, OR: Oregon State University, Agricultural Experiment Station. 26 p.

Summaries of results of studies on water yield, infiltration, sediment production, water quality, and revegetation conducted throughout the western United States are provided, with particular emphasis on influences of grazing management.

Gaither, R.E.; Buckhouse, J.C. 1983. Infiltration rates of various vegetative communities within the Blue Mountains of Oregon. Journal of Range Management. 36: 58-60.

Infiltration rates were measured with a Rocky Mountain infiltrometer for each of the 10 ecosystems that comprised the major vegetative habitats in EVAL project. Within each ecosystem, infiltration rates were expressed as a function of productivity and condition classes. Mean infiltration rates for ecosystems ranged from 6.6 cm/h for ponderosa pine to 8.8 cm/h for western larch. A trend toward increasing infiltration rates corresponded to increasingly mesic sites. Alpine, Douglas-fir, mountain meadow, and western larch had the highest vegetative cover, occupied the most mesic sites, and exhibited the greatest infiltration rates. Differences of infiltration rates within ecosystems as a consequence of differences in productivity or condition classes were also observed. Forested sites were more dependent on condition class (pole- or timber-sized trees) than productivity class, with higher infiltration rates on pole-sized stands than on timber-sized stands. This was apparently because of higher tree densities associated with pole thickets. Nonforested sites were responsive to both productivity and condition classes. Higher infiltration rates were exhibited on sites with higher productivity or better condition classes.

Gibbs, J.L.; Matheson, J.C. 1979. Interagency site descriptions—a beginning. In: Range management short course, Coordinated resource mangement planning in the Pacific Northwest on private and public lands; 1979 March 20-22: Pullman, WA. Pullman, WA: Washington State University, Cooperative Extension Service: 21-28. In cooperation with: Oregon State University; University of Idaho.

Different Federal and State agencies use their own classification system for inventorying land and resources. As a result, use of data and communication among agencies and the private sector is difficult or confusing. In the EVAL project, eight agencies or groups worked together. To improve communications, a single set of interagency site descriptions was developed and is being used by all parties for the coordinated resource planning effort. Forty-five USDA Forest Service plant community types and 41 Soil Conservation Service range site descriptions were combined to produce 49 interagency site descriptions. Eight were field tested and deemed acceptable for use, and resource inventory was initiated by using the interagency site descriptions.

Gillen, R.L. 1982. Grazing behavior and distribution of cattle on mountain rangelands. Corvallis, OR: Oregon State University. 177 p. Ph.D. thesis.

Several aspects of cattle grazing behavior and distribution were studied on mountain rangeland dominated by ponderosa pine, Douglas-fir, mixed conifer, and grand fir forest communities in the EVAL project area. The association between upland distribution, determined by forage use and by direct cattle observation, and several habitat factors was studied through correlation and regression analyses. The use of small riparian meadows by cattle was monitored by periodic usage sampling and time-lapse photography. Individual cattle were marked so that the occurrence of home range behavior could be studied. Riparian meadows were the most heavily used plant communities and averaged about 75 percent forage use over all sites and years. Usage was similar under continuous grazing and the early and late grazing periods of a two-pasture deferred-rotation system. Late grazing increased the frequency of cattle presence in riparian meadows as compared to early grazing. Large quantities of forage, a dependable source of water, and gentle topography combined to make riparian meadows the major influence on cattle distribution. Afternoon temperature and relative humidity were similar in riparian meadows and upland plant communities. Upland forage use averaged 8 to 12 percent and the highest estimated use on a single site was 36 percent.

When available, clearcut forest sites were the most highly preferred upland plant community, especially when introduced grasses had been seeded. Late grazing decreased use on the clearcut sites by one-third because of the advanced maturity of herbage. Cattle use appeared to shift to riparian meadows in this situation. A large percentage of cattle were observed within the ponderosa pine-Douglas-fir forest communities although these were not the preferred range areas. The grassland, mixed conifer forest, and grand fir forest communities were all lightly used by cattle. Slope gradient was the physical habitat factor most consistently associated with cattle distribution. Salt distribution appeared to be important. Water distribution did not limit grazing behavior. Cattle restricted their activities to home ranges averaging 343 ha. Home range size for purbred was similar to that used by crossbred cattle.

Gillen, R.L.; Krueger, W.C.; Miller, R.F. 1984. Cattle distribution on mountain rangeland in northeastern Oregon. Journal of Range Management. 37: 549-553.

See Gillen 1982.

Grimes, T.N. 1980. Correlations between rainbow trout (*Salmo gairdneri*) populations and stream environments in eastern Oregon streams. Corvallis, OR: Oregon State University. 112 p. M.S. thesis.

The rainbow trout populations and the physical characteristics of 11 headwater tributaries of the Middle Fork John Day River and the John Day River were studied during the summers of 1978-80. Fish were shocked with a DIRIGO backpack electroshocker and captured in dip nets. Population sizes were estimated by using the single mark-recapture technique. Elevation, temperature, stream gradient, and characteristics of flow were measured at each of 50 sites. Average late summer stream widths ranged from 0.65 to 3.6 m. Elevations ranged from 1170 to 1561 m. Stream gradients ranged from 0.1 to 6.4 percent. Average late summer flows ranged from 4 to 366 L/s. Numbers of age 0 trout per 15.2-m site length ranged from 0 to 57.8. Numbers of ages I and II trout ranged from 1.5 to 39.3. The average number of age 0 trout per 15.2-m site length in all streams was 34.5 in 1978, 14.7 in 1979, and 13.6 in 1980. For age I and II trout, numbers were 8.2, 18.0, and 10.7 per 15.2-m site length for 1978, 1979, and 1980, respectively. Correlation analyses revealed that age 0 and ages I and II trout were inhabiting different habitats within the same stream. Age 0 trout were in shallow water (riffles) over spawning-size substrate and were associated with aquatic vegetation. Ages I and II trout were found in deep, swift water and deep, high-quality pools.

Harris, T.D.; Pool, D. 1979. Oregon Range and Related Resources Validation Area project. GPO 796-953. Washington, DC: U.S. Government Printing Office. 15 p.

An overview of the EVAL project is provided, with a brief description of funding and cost-share arrangements, coordinated resource planning, management strategies, management practices, and monitoring to be done.

Higgins, D.A.; Maloney, S.B.; Tiedemann, A.R.; Quigley, T.M. 1988. Calibration of a water balance model for small watersheds in eastern Oregon. Water Resources Bulletin. 24: 347-360.

The BURP water-balance model was calibrated for 13 small (0.46 to 7.00 mi^2) forested watersheds in the Blue Mountains of eastern Oregon where snowmelt is the dominant source of runoff. BURP is the model name and not an acronym. Six of the 16 parameters in BURP were calibrated. The subsurface recession coefficient and three subsurface-water storage parameters were most sensitive for simulating monthly flow. Calibrated subsurface recession coefficients ranged from 0.988 to 0.998. The subsurface-water storage parameters were calibrated at between 20 and 120 percent of their initial values obtained from a category III soil survey. That reconnaissance survey was apparently too broad to accurately reflect the subsurface-water storage in small watersheds. Tests of model performance showed BURP can produce accurate simulations of monthly flow for mountainous, snow-dominated watersheds with shallow (< 4.0 ft) soils when calibrated with 2 to 4 years of stream flow data. A regression of observed versus simulated monthly flows with data from all watersheds combined showed that BURP accounted for 85 percent of the variability in observed flows (0.01 to 20.8 in) with a slope of 1.15 that is significantly different from 1.0 ($p = 0.05$). The model underpredicted high-flow months. Without prior calibration, subsurface-water storage parameters seemed to be the greatest source of error.

Higgins, D.A.; Maloney, S.B.; Tiedemann, A.R.; Quigley, T.M. [In press]. Storm runoff characteristics of grazed watersheds in eastern Oregon. Water Resources Bulletin.

Rainfall and runoff data from 485 storms during the summers of 1979-84 were evaluated to characterize storm runoff volumes (SF) and peak flows (QP) for 13 small watersheds in the Blue Mountains of eastern Oregon and to determine differences among grazing intensities and vegetation types. Storm hydrographs were separated by using watershed-specific baseflow rise rates of 0.002 to 0.013 $ft^3 \cdot sec^{-1} \cdot mi^{-2} \cdot h^{-1}$ (cfsm/h). Median SF and QP were 0.0014 and 0.43 cfsm, respectively, for all storms. Total storm rainfall (PPT) and initial flow (QI) were important stepwise regression variables in accounting for the variation in SF and peak flow above the initial flow (QPI); 30 and 60 min rainfall intensities and rainfall duration were relatively unimportant. Two classes of dominant vegetation types were evaluated: larch-Douglas-fir (9 watersheds) and "other" (four watersheds representing fir-spruce, lodgepole pine, mountain meadow, and ponderosa pine). Mean SF and QP did not differ ($p = 0.05$) among vegetation types, but significant differences were apparent in the relation of SF to PPT and QI, and QPI to PPT and QI. As PPT and QI increased, SF and QPI from larch-Douglas-fir watersheds increased at a lower rate than they did from watersheds dominated by the other forest vegetation. Four grazing intensities had no effect on storm runoff.

Higgins, D.A.; Tiedemann, A.R.; Quigley, T.M.; Marx, D.B. Streamflow characteristics of small watersheds in the Blue Mountains of Oregon. Manuscript on file: Forestry and Range Sciences Laboratory, La Grande, OR.

Streamflow data for water years 1979-84 were evaluated to identify streamflow characteristics for 13 small watersheds (0.46 to 7.0 mi^2) in the Blue Mountains of eastern Oregon and to determine differences among grazing intensities and vegetation types. The ranges for mean annual water yields, peak flows, and 7-day low flows for the 13 watersheds were 5.5 to 28.1 inches, 2.0 to 34.7 cfsm, and 0.006 to 0.165 cfsm, respectively. Two classes of vegetation were evaluated: western larch-Douglas-fir (nine watersheds) and other (four watersheds representing fir-spruce, lodgepole pine, ponderosa pine, and mountain meadow). Means for annual peak flows and slopes of the flow-duration curve were significantly different ($p = 0.05$) between the two vegetation classes; differences in mean annual water yield were marginally significant ($0.05<p<0.10$). After adjusting for precipitation, means for annual water yield, peak flows, and slopes of the flow-duration curve were significantly different among the two vegetation classes; differences in the means for annual 7-day low flows were marginally significant. The western larch-Douglas-fir group had somewhat lower water yields but overall tended to have more favorable streamflow characteristics including lower peak flows, higher low flows, and more evenly distributed flow regimes (flatter flow-duration curves). Four grazing management intensities had no effect on streamflow characteristics.

Isley, A. 1980. Coordinated resource planning. In: 1980 progress report, beef cattle and range resources. Spec. Rep. 583. Corvallis, OR: U.S. Department of Agriculture, Agricultural Research Service; Oregon State University, Agricultural Experiment Station: 74-77.

Procedures for developing a coordinated resource management plan are described. A general description of the components of the plan is included.

Johnson, T.G. 1979. A dynamic input-output model for regional impact analysis. Corvallis, OR: Oregon State University. 188 p. Ph.D. dissertation.

The basic Leontief dynamic approach is revised and extended in several key directions, including incorporating continuous lags in production, consumption and investment activities, constraints on the rates of disinvestment, and capacity constraints. The resulting conceptual model forms the basis of a continuous-time simulation model. The simulation model is cast in the GASP IV simulation language because of certain desirable features of the language. The simulator is made operational with two sets of data; the first is based on the 1958 U.S. economy and the second on the 1977 Grant County, Oregon, economy. Historical simulations of the U.S. economy for the period 1952-62 support sufficient confidence in the accuracy of the modeling approach to justify its use. Several simulations of the Grant County economy were performed to demonstrate the versatility of the simulator. Dynamic time paths and multipliers are generated and interpreted. Outputs from the model are related to the potential user's requirements. Results support the conclusion that the extended dynamic model successfully solves serious methodological problems faced by other economists. The model provides accurate, coherent, useful projections of economic systems at very low cost.

Kehmeier, P.N.; Quigley, T.M.; Taylor, R.G.; Bartlett, E.T. 1987. Demand for Forest Service grazing in Colorado. Journal of Range Management. 40(6): 560-564.

Linear programming ranch models were constructed for size of ranch and species of livestock operation within five regions of Colorado. Options to improve existing ranch resources and regional forage supply were included in each model. Parametric programming was used to derive shadow prices to approximate demand for USDA Forest Service (FS) grazing in Colorado. Demand was derived under three livestock price scenarios and two herd management assumptions. Forest Service grazing demand was highly sensitive to livestock price changes. Variable herd management maximized profits and capitalized on high livestock prices, by increasing herds, thereby increasing the price of FS forage for any given quantity. With herd size constant, ranches that could not cover variable costs ceased operation and demanded no FS forage. Higher livestock prices could not induce increased FS forage demand as with variable herd management. Regional differences in demand were also noted, reflecting different transportation costs and ranch productivity.

Maloney, S.B.; Higgins, D.A.; Marx, D.B.; Quigley, T.M.; [and others]. Stream temperatures in grazed watersheds of eastern Oregon. Manuscript on file: Forestry and Range Sciences Laboratory, La Grande, OR.

Stream temperatures were measured from 1979-84 on 12 forested watersheds near John Day, Oregon to determine the temperature characteristics of the watersheds and to assess the effects of four grazing management strategies. Maximum stream temperatures exceeded 24 ^{o}C, the short-term maximum for rainbow trout and chinook salmon, on four of the watersheds. Percentage of stream shade, mean stream elevation, travel time, and weekly flow, in that order, were the most important watershed characteristics for predicting stream temperature. Streams with greater than 75 percent stream shade maintained acceptable stream temperatures for rainbow trout and chinook salmon. Grazing strategies had no significant effect (increase or decrease) on stream temperature.

Maser, Z.; Maser C. 1987. Notes on mycophagy of the yellow-pine chipmunk (*Eutamias amoenus*) in northeastern Oregon. The Murrelet. 68: 24-27.

The yellow pine chipmunk is the second most widely distributed chipmunk in western North America. In central and eastern Oregon, its habitat ranges from the subalpine forests east of the crest of the Cascade Range, throughout the mixed conifer forests, ponderosa pine forests, and western juniper woodlands. The authors describe the percentage by volume and relative frequency of fungal taxa in stomach contents of 135 yellow-pine chipmunks trapped in a mixed conifer forest dominated by western larch, grand fir, Engelmann spruce, and lodgepole pine.

McInnis, M.L.; Quigley, T.M.; Vavra, M. 1986. Using computer simulation to estimate grazing capacity and beef production. In: 1986 progress report...research in rangeland management. Spec. Rep. 773. Corvallis, OR: Oregon State University, Agricultural Experiment Station; U.S. Department of Agriculture, Agricultural Research Service: 25-31.

Increased efficiency of red meat production is an important goal of livestock management that can be enhanced by properly applied rangeland improvement practices. The outcome of such improvements cannot always be accurately predicted, however. A method of estimating potential grazing capacity and beef production would be a welcome tool for ranchers and resource managers. Such a method would also be helpful in coordinating livestock management with other rangeland activities. Toward this end, a computer model has been developed to simulate animal unit months (AUM's) of grazing and pounds of beef production potentially available from specific sites in central Oregon. The paper outlines the model structure, information, and units needed for input, and operation of a preliminary version of the model.

Miller, L.F. 1980. Grant County Oregon: impacts of changes in log flows on a timber-dependent community. Corvallis, OR: Oregon State University. 151 p. M.S. thesis.

During 1978, sample data were collected on the gross sales and purchases of 109 Grant County businesses in 22 economic sectors. This information was used to construct a Leontief type input-output model for Grant County. Additional detailed information obtained from the USDA Forest Service and local lumber and wood products processing firms was used to construct a linear programming model. This modified transportation model optimizes the distribution of timber resources among wood-products firms in Grant County based on each firm's total revenues and variable costs. These costs apply to hauling, harvesting, processing, and inventory activities. To evaluate the effects of changes in price and quantity relations locally, outputs from the linear program were entered into the input-output model as exogenous sales (exports). Three examples of changes in the price and quantity of local timber resources were evaluated: (1) a 20-percent increase in stumpage values, (2) a 20-percent decrease in 1977 stumpage quantities, and (3) a combination of both. The examples demonstrate business income, wage income, and employment impacts on the community from changes in both stumpage prices and quantities that exceed the direct impacts on forest-products firms. Effects of changes in stumpage prices had a greater relative impact than changes in available stumpage. In general,

changes in both stumpage prices and in quantities showed output, wage, and employment effects four times as large as changes in stumpage quantities and three times as large as changes in stumpage price alone.

Obermiller, F.W. 1980. The local costs of public land use restrictions. In: 1980 progress report, beef cattle and range resources. Spec. Rep. 583. Corvallis, OR: Oregon State University, Agricultural Experiment Station; U.S. Department of Agriculture, Agricultural Research Service: 48-71.

The consequences of two proposed forested wilderness areas and reduced availability of forage in the Baker grazing district for the local economies of affected areas are described. Inclusion of Strawberry Mountain and the North Fork into the wilderness system would result in losses of $3 million to households in Grant and Umatilla Counties. The present value or local opportunity costs of foregone income exceeds $33 million. About one-half of the income lost to local households ($1.65 million) would result from reduced income from the logging industry. Proposed reductions of 9,827 AUM's from U.S. Department of the Interior, Bureau of Land Management grazing allotments would result in an annual loss of $751,460 from the local economy.

Obermiller, F.W.; Miller, L.F. 1983. Grant County Oregon: impacts of changes in log flows on a timber-dependent community. In: Haynes, R.W., tech. ed. Competition for National Forest timber: effects on timber-dependent communities. Gen. Tech. Rep. 148. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station: 12-20.

Effects of changing Forest Service sales practices on the Grant County economy are examined. Grant County is strongly dependent on the forest-products industry. It accounts for 35 percent of all employment, 24 percent of goods and services, and 48 percent of goods exported from the county. Changes in the stumpage market affect exports, which in turn influence local economic transactions.

Patterson, G.J. 1982. Threatened eastern Oregon life styles: ranchers, Indians, and loggers in Grant and Harney Counties. Bibliophilos. 1(2): 71-81.

Author describes the day-to-day operation of typical ranches in Grant County Oregon and provides some history on the historical movements of Paiute Indians in the area. The relation of the logging industry to housing markets is established in the paper. The author provides some insights into the political support and funding processes of the EVAL project.

Patterson, G.J. 1983. Cattle ranchers in eastern Oregon get a helping hand. Forestry Research West. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, [Rocky Mountain Forest and Range Experiment Station]; January: 8-10.

The EVAL project is described.

Patterson, J.G. 1983. Social and cultural influences on range improvement: the Oregon Range and Related Resources Evaluation project as a model. In: Clawson, W.J., ed. Range improvements—today and tomorrow. U.S. MAB-3 Grazing Lands Committee. Spec. Rep., [Place of publication unknown]: UNESCO's Man and the Biosphere Program: 8-15.

The origin, implementation, and evolution of the EVAL project are described.

Quigley, T.M. 1981. Estimating contribution of overstory vegetation to stream surface shade. Wildlife Society Bulletin. 9(1): 22-27.

Loss of shade in summer, particularly in arid regions, can have serious effects on water quality and fish habitat. The most serious potential effect is solar heating, which can produce lethal stream temperatures for cold-water fish. Improved methods to quantify stream shade can benefit management of fisheries and water quality. A technique is given for indirectly estimating the contribution of forest overstory to stream surface shade. Characteristics that must be known to estimate stream surface shade are width of stream, distance from vegetation to stream, orientation of stream, height of overstory, density of vegetation, crown measurement, location, date, and time. Examples of the use of the method are provided.

Quigley, T.M.; Gibbs, K.; Sanderson, H.R. 1986. Rancher response to changes in federally permitted livestock numbers in eastern Oregon. Rangelands. 8: 276-278.

The EVAL project provided an opportunity to examine actual changes in ranch operations after shifts in federally permitted forage use. Ranchers receiving increases in forage use were questioned about actual management changes and likely changes if a decrease were received. Ranchers receiving increases in permitted use increased herd size and acquired more hay. These ranchers, if faced with a theoretical decrease in permitted use, would decrease herd size and sell more or buy less hay. Ranchers hypothesizing on shifts in response to changes in permitted use said they would expand herd size in response to an increase. They would decrease herd size or lease more summer range if given a decrease in permitted use. It seemed that ranchers who actually received an increase in permitted use visualized more changes in the ranch operation should they face a decrease in Federal forage use than queried ranchers who did not receive an actual increase. Indirect effects associated with changes in herd size are important when impacts of shifts in federally permitted use are considered.

Quigley, T.M.; Sanderson, H.R. [In press] Analysis of fence construction costs. Rangelands.

Between 1976 and 1984, 127 fence projects were completed on more than 210 miles of private and public forest and range land. An analysis showed that 1986 costs ranged from $3,000 to $6,000 per mile for wire-fence construction. Fence construction costs in forested ecosystems were significantly greater than construction costs in nonforested ecosystems. Cost of wire-fence construction was significantly greater than the cost of reconstruction. Size of the fencing project had a significant effect on the cost of unskilled labor for wire-fence construction and in labor costs for fence removal. Careful planning before fences are constructed can result in substantial savings.

Quigley, T.M.; Skovlin, J.M.; Workman, J.P. 1984. An economic analysis of two systems and three levels of grazing on ponderosa pine-bunchgrass range. Journal of Range Management. 37(4): 309-312.

A long-term study of the effects of season-long and deferred-rotation grazing at different stocking rates examined cow and calf weight gains. Production functions were derived using stocking rate (AUM's/ha) as a variable input and average summer weight gain (kg/ha) as the output. These functions were optimized economically to determine profit-maximizing stocking rates. Optimum stocking rates for season-long grazing on ponderosa pine-bunchgrass range were found to be moderate or light over a wide range of feasible price ratios. Optimum stocking rates for deferred-rotation grazing did not exceed moderate at any feasible price ratio. The ratio of forage price ($/AUM) to the price of livestock ($/kg) must exceed 11 under deferred-rotation grazing and 18 under season-long grazing before light stocking becomes the optimum. Based on fall 1979 livestock and forage prices, the stocking rate for profit maximization was moderate (0.235 AUM/ha or 10.6 acres/AUM) for deferred-rotation and moderate (0.312 AUM/ha or 7.9 acres/AUM) for season-long grazing. Season-long grazing also produced a higher net return than did deferred-rotation. To remain at the profit-maximizing stocking rate while shifting from season-long grazing to deferred-rotation, a manager would have to reduce the stocking level at all price ratios.

Quigley, T.M.; Tanaka, J.A. 1988. The Federal grazing fee: a viewpoint. Rangelands. 10(3): 130-131.

The use of forage values in economic analyses is discussed. The differences between the private-land lease rate and the Federal grazing fee are described. The appropriate use of the Federal grazing fee is in accounting and for calculating returns to the Federal treasury. Before any decision is made affecting grazing on Federal land, an economic analysis should be made; the grazing fee is not the appropriate measure of grazing value for those analyses.

Quigley, T.M.; Tanaka, J.A. [In press]. The Federal grazing fee: a viewpoint. Renewable Resources Journal.

Reprint of the Rangelands article of the same title.

Quigley, T.M.; Taylor, R.G. 1983. Econometric estimation of range forage demand. In: Wagstaff, F.J. comp.: Proceedings, range economics symposium and workshop; 1982 August 31-September 2; Salt Lake City. UT. Gen. Tech. Rep. INT-149. Odgen, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 120-128.

Econometric analysis provides an alternative approach to estimating demand for forage. Econometric application requires specifying structural forms for the production relations, data aggregation, and separation distinctions, and the possible estimation of multiproduct functions. The relations that result may use relatively few variables compared to optimization studies, and data-collection techniques may be simplified.

Quigley, T.M.; Taylor, R.G.; Cawley, R.M. 1988. Public resource pricing: an analysis of range policy. Resour. Bull. PNW-RB-158. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 38 p.

Pricing represents an important step in allocating scarce resources. Markets, which set the price policy, are not restricted by a simple buyer-seller relation. The Federal grazing-fee policy is at the forefront of controversy surrounding the pricing of all uses of public lands. The pricing process of grazing fees has been cyclical. With few exceptions, the cycle, which takes 8 to 14 years, includes (1) initial study, (2) fee implementation or proposal, (3) lawsuit, (4) congressional hearings, and (5) fee compromise. The tradeoff between strict market pricing and political market pricing is efficiency and equity. Government agencies, Congress, and the ranching industry have conflicting interests that affect strict equity-efficiency decisions. If policy results in income transfer for resource use or access, a quasi-right is established and controversy is assured in future pricing.

Quigley, T.M.; Thomas, J.W. [In press]. Range management and grazing fees on the National Forests—a time of transition. Rangelands.

Multiple-use management of resources on the National Forests requires a mix of expertise that may be adversely affected if three interrelated problems are not solved. First, the budgeting process of the Forest Service is functional-oriented and tends to result in personnel not crossing traditional lines of responsibility. The second problem is the perception that "range management" is equated with livestock and is somehow "subsidized." The third problem is that increased emphasis on holistic vegetation management is occurring at the same time that personnel trained in conservation and management of nontimber resources are receiving less financial support. These problems together are leading the Forest Service to the loss of staff who have training in ecology and vegetation management, which could jeopardize the agency's ability to meet broader goals of holistic range management. A possible first step is to bring the grazing fee into a market-pricing system and do so with no adverse impact on existing permittee wealth.

Sanderson, H.R.; Meganck, R.A.; Gibbs, K.C. 1986. Range management and scenic beauty as perceived by dispersed recreationists. Journal of Range Management. 39: 464-469.

Land management agencies have developed considerable interest in the visual impacts of intensive range management practices. This study was designed to determine the impact of increasing intensities of range management strategies on dispersed recreationists and their concepts of scenic beauty. Dispersed recreationists were asked to rate selected range management practices for a variety of ecosystems on the EVAL study area during summer 1978. Features significantly related to the reactions of 241 dispersed recreationists to increasing intensities of range management activities were primary recreational activity; place of residence; understanding the purpose of National Forest management; and number of prior visits. Respondents reacted favorably to the range management activities examined. A majority, however, indicated that their use of recreational areas would be altered if management intensity increased or became more apparent.

Sanderson, H.R.; Quigley, T.M. 1979. Range validation areas as perceived by the forest and range environmental study (FRES). In: Range management short course, Coordinated resource mangement planning in the Pacific Northwest on private and public lands; 1979 March 20-22: Pullman, WA. Pullman, WA: Washington State University, Cooperative Extension Service: 48-54. In cooperation with: Oregon State University; University of Idaho.

A brief description is provided of the EVAL area, purpose of establishment, what is to be accomplished, and who is involved. Strategies, management practices, resource outputs, and resource units of the EVAL project are also presented.

Sanderson, H.R.; Quigley, T.M. 1984. EVAL—a coordinated and comprehensive approach to range management. In: 1984 Pacific Northwest range management shortcourse; 1984; January 25-27 Pendleton, OR. Corvallis: Oregon State University: 84-85.

The development and implementation of the EVAL project are described.

Sanderson, H.R.; Quigley, T.M.; Spink, L.R. 1988. Defining, implementing, and evaluating grazing management strategies. Journal of Soil and Water Conservation. 43(4): 345-348.

Six grazing management strategies were defined for application on the EVAL project: environmental management without livestock; environmental management with livestock; extensive management of environment and livestock; intensive management of environment and livestock with cultural practices; maximize commodity production while maintaining soil and water resources; and resource degradation. The first five represent increasing grazing management. The last strategy is exploitive and not recognized as a management goal. Coordinated resource planning within the EVAL framework resulted in each private and public pasture being assigned a management goal or strategy. Management practices required to implement the strategy were undertaken. The resource managers most familiar with the pastures and practices implemented were assembled as a team to evaluate the degree to which a management goal was attained in a pasture. Three subcategories within each strategy explained the degree of strategy attainment. Four additional subcategories described the impact of silvicultural activities on Federal lands from the standpoint of changes in forage production.

Sanderson, H.R.; Quigley, T.M.; Spink, L.R. 1988. Development and implementation of the Oregon Range Evaluation project. Rangelands. 10: 17-23.

The objective of the EVAL project was to determine the most cost-effective way to increase herbage and browse for livestock and to determine the effects of increasing intensities of grazing management (strategies) on water quantity and quality and consequences for the local economy. The EVAL project applied six levels of range management strategies on 338,000 acres of private and public lands in central eastern Oregon. The impact on range and related resources was examined. The USDA Forest Service was the lead agency with 7 cooperating Federal and State agencies and 22 private landowners. The results provide economic and environmental information to direct range management activities.

Sanderson, H.R.; Quigley, T.M.; Swan, E.E.; Spink, L.R. Specifications for structural range improvements. Gen. Tech. Rep. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Manuscript on file: Forestry and Range Sciences Laboratory, La Grande, OR.

Construction specifications and illustrations are provided for several types of barbed-wire and pole fences, gates, cattleguards, stiles, spring developments, water troughs, stock ponds, trick tanks, and livestock access trails.

Shultz, D. 1979. Oregon State Department of Forestry's role in coordinated resource planning. In: Range management short course, Coordinated resource mangement planning in the Pacific Northwest on private and public lands; 1979 March 20-22; Pullman, WA. Pullman, WA: Washington State University, Cooperative Extension Service: 55-60. In Cooperation with: Oregon State University; University of Idaho.

The elements of responsiblity of the Oregon Department of Forestry in the EVAL coordinated resource planning process are described. The procedure for developing that portion of the plan is also provided.

Skirvin, A.A. 1981. Effect of time of day and time of season on the number of observations and density estimates of breeding birds. Studies in Avian Biology. 6: 271-274.

In 1978 and 1979, a study was conducted to assess hourly and weekly changes in the numbers of detections and density estimates of birds during the breeding period. Bird detections, obtained from variable circular plot censuses, tended to decline from the first hour after sunrise to the fourth hour. Seasonally, peak numbers of birds occurred in June for 1978 and mid-May to mid-June 1979. Generally, detection of resident species was highest in May; detection of migrants peaked in June. Although statistically significant changes were found in number of detections among biweekly periods, patterns of observed changes over time differed considerably among species. To obtain data representative of the structure of a breeding-bird community, censuses should be conducted through most of the breeding season. Abundance estimates would be severely underestimated if censusing were restricted to periods of peak detection.

Southworth, J. 1977. One county and multimanagement. Rangeman's Journal. 4(6): 174-175.

The rationale for and early development of the EVAL project are described.

Stringham, T. 1984. Importance of publicly owned rangeland to the Oregon cattle industry. In: 1984 Pacific Northwest range management shortcourse; 1984 January 25-27; Pendleton, OR. Corvallis: Oregon State University: 45-58.

In Oregon, about 1.5 million animal unit months (AUM's) are authorized for livestock grazing by the U.S. Department of the Interior, Bureau of Land Management (BLM), and the USDA Forest Service (FS). In the 10 counties covered by this survey, a total of 272,636 AUM's were represented. Of this total, BLM permits accounted for 187,171 AUM's, or 21 percent of the AUM's authorized for Oregon. Forest Service permits accounted for 62,281 AUM's or 11 percent of the total FS authorized AUM's for Oregon. The remaining 23,184 AUM's were attributed to State lands and State and other lands. The number of brood cows reported by the 154 ranches surveyed totaled 64,857 head. Detailed information on the total percentage of the herd's roughage needs met by various forage sources are presented in tables for each county surveyed. Tabular information on number of ranches surveyed per county, average county herd size, average permitted paid AUM's, exchange of use, average culling weights, average replacement weights, cost of hay raised, cost of hay bought, and average percentage of hay raised is presented for each county surveyed.

Svejcar, T. 1982. Seasonal and diurnal changes in the water relations of elk sedge (*Carex geyeri*) and pinegrass (*Calamagrostis rubescens*). Corvallis, OR: Oregon State University. 124 p. Ph.D. dissertation.

Co-occurring plants of elk sedge and pinegrass were compared for diurnal fluctuations in xylem potential, abaxial diffusive resistance, and adaxial diffusive resistance. In addition, both species were measured for hygrometric osmotic potential, osmotic potential at full turgor, osmotic potential at zero turgor, bound water fraction, and elastic modulus. Soil moisture and diurnal fluctuation in ambient temperature and vapor density difference between leaf and air were also measured. Elk sedge appears physiologically better adapted to cope with drought than pinegrass based on the following factors: more negative xylem potentials, more negative osmotic potentials, higher bound water fraction, more rigid cell walls, and maintenance of low diffusive resistance to more negative xylem potentials.

Svejcar, T.; Vavra, M. 1985. The influence of several range improvements on estimated carrying capacity and potential beef production. Journal of Range Management. 38: 395-399.

A simple calculation is proposed for estimating carrying capacity of range sites based on seasonal forage quality and standing crop. The model estimates animal unit days a pasture can support. Potential beef production of a particular site was estimated by multiplying animal unit days by an average daily gain as indicated from forage quality. Improved and unimproved portions of four plant communities (grassland, mixed confier, lodgepole pine, and mountain meadow) were compared for carrying capacity and potential beef production. Improvement generally resulted in large increases in both carrying capacity and potential beef production; however, only in grassland did range improvement extend the period when weight gains could be expected. Calculations indicated that energy generally became limiting before crude protein. Forage quality was insufficient to maintain weight gains of growing animals after midsummer. Advantages and limitations of the calculations are presented.

Svejcar, T.; Vavra, M. 1985. Seasonal forage production and quality on four native and improved plant communities in eastern Oregon. Tech. Bull. 149. Corvallis, OR: Oregon State University, Agricultural Experiment Station. 24 p.

Seasonal trends in forage quality and production were studied on improved and unimproved portions of four plant communities in eastern Oregon. The range improvements consisted of seeding, thinning, or both. Improvement doubled forage production on the lodgepole pine site (thinned but not seeded), trippled production on the mountain grassland and mountain meadow sites (both seeded), and resulted in a sixfold increase in forage production on the mixed conifer site (thinned and seeded). Only for mountain grassland, however, did range improvement lengthen the period when forage provided adequate nutrition for the growth of yearling cattle; the improved nutrition can be attributed primarily to the inclusion of a legume (alfalfa) in the seeding mixture. On the forested sites, thinning tended to cause forage to mature earlier and to decline in quality faster than on unthinned controls.

Tanaka, J.A.; Quigley, T.M. Range improvement guides for private and public rangelands. Paper has been submitted to a journal for consideration. Manuscript on file: Forestry and Range Sciences Laboratory, La Grande, OR.

Investments in range improvement practices can be a major capital expense in managing rangelands for livestock production. The EVAL project was designed to study cost effective ways to develop public and private rangelands with different management strategies. Individual range improvement practices were identified by pasture. Average units of practices were calculated based on pastures observed in the project area. The results can be used in the planning phase for developing management strategies on public and private rangelands similar to those found in the project area. The actual mix of improvement practices put on the ground cannot be specified at this level, but the mix of expected improvement practices for a typical pasture can be evaluated. Expected investment costs at different management intensities can be used in an economic feasibility analysis.

Tiedemann, A.R.; Higgins, D.A.; Quigley, T.M. [and others]. 1987. Responses of fecal coliform in streamwater to four grazing strategies. Journal of Range Management. 40: 322-329.

Concentrations and instantaneous loadings (output, number^{-1}·day^{-1}· km^{-2}) of fecal coliform (FC) indicator bacteria were measured from 1979 through 1984 in streamflows from 13 forested watersheds under the following range management strategies: (A) no grazing; (B) grazing without management for livestock distribution; (C) grazing with management to obtain livestock distribution; and (D) grazing with management to obtain livestock distribution and cultural practices to increase forage. Both FC concentrations (number/100 ml) and instantaneous loadings (number^{-1}·day^{-1}·km^{-2}) differed significantly among strategies, seasons, and water years. Differences among strategies for mean concentrations were $A<C = B<D$. For instantaneous loadings, significant differences were $A<C$, B or D; and $C<D$. FC concentrations were the same for winter and for snowmelt runoff seasons, but concentrations of both were significantly lower than during the summer period. Loadings were different for each season with winter $<$ summer $<$ snowmelt runoff. A definite relation was established between the presence of cattle on the pastures and FC concentrations. Elevated FC counts in strategy D watersheds and loadings in excess of 108 organisms^{-1}·day^{-1}·km^{-2} in winter provide evidence that organisms live into and through winter in animal feces, sediment, and soil. Results provide evidence that livestock removal may not provide an immediate solution to elevated fecal coliforms in streamwater.

Tiedemann, A.R.; Higgins, D.A.; Quigley, T.M. [and others]. 1988. Bacterial water quality responses to four grazing strategies—comparisons with Oregon standards. Journal of Environmental Quality. 17: 492-498.

Concentrations of fecal coliform (FC) and fecal streptococcus (FS) were measured weekly during summer 1984 in streamwater of 13 wildland watersheds managed under four range management strategies. The strategies were (A) no grazing; (B) grazing without management for livestock distribution; (C) grazing with management for livestock distribution; and (D) grazing with management for livestock distribution and with cultural practices to increase forage. Counts of FC were compared to Oregon water quality standards. Data for FS were used for determining the ratio of FC to FS to assess origin of FC organisms. Counts of FC were significantly lower under strategies A and C than under strategy D, but no significant differences were apparent among other strategy comparisons. Two strategy D watersheds violated the Oregon water quality 30-day $\log_{10}$ standard of no more than 200 FC/100 mL; one watershed was in violation for the major part of the sampling period. Ratios of FC to FS indicated that wildlife was the major source of FC bacteria in strategies A, B, and C watersheds. Cattle were the primary source of FC bacteria on strategy D watersheds.

Tiedemann, A.R.; Higgins, D.A.; Quigley, T.M.; Sanderson, H.R. [In press]. Stream chemistry responses to four range management strategies in eastern Oregon. Gen. Tech. Rep. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Responses of stream chemistry parameters, nitrate-N (NO_3-N), phosphate (PO_4), calcium (Ca), magnesium (Mg), potassium (K), sodium (Na) and hydrogen ion activity (pH) were measured on 13 wildland watersheds managed at four different grazing strategies. Range management strategies tested were (A) no grazing; (B) grazing without control of livestock distribution (8.2 ha/AUM); (C) grazing with control of livestock distribution (7.7 ha/AUM); and (D) grazing with control of livestock distribution and cultural treatments to improve forage production (2.8 ha/AUM). Nitrate-N, PO_4, Ca, Mg, K, and Na were all significantly ($p<0.001$) related to average daily streamflow as a covariate in the analysis of variance. None of the stream chemistry characteristics measured were influenced by increasing intensity of grazing management.

Vavra, M. 1983. Managing grazing and animal response to forestland grazing. In: Forestland grazing, proceedings of a symposium; 1983 February 23-25; Spokane, WA. Pullman, WA. Cooperative Extension Service, Washington State University: 43-51.

Cattle grazing a grassland-forest rotation strategy gained 11.3 kg more than cattle allowed season-long use of forest and grassland plant communities. Meadow pastures can also be successfully incorporated into a plant community rotation grazing program. A cow-calf operation can be grazed on different plant communities so that weight gains are better than if cattle had free choice to all communities season long. Potential cattle use on native plant communities was compared to the same communities that had been treated to enhance forage production. Plowing and seeding rangeland, precommercial thinning of lodgepole pine, logging and grass seeding in mixed conifer stands, and plowing and seeding mountain meadow sites increased the potential beef production/per hectare.

Vavra, M.; Svejcar, T. 1983. Improved cattle production on forestlands. In: 1983 progress report...research in beef cattle nutrition and management. Spec. Rep. 678. Corvallis, OR: Oregon State University, Agricultural Experiment Station: 19-29.

Forage production, beef production per acre, metabolizable energy per acre, and crude protein per acre were compared on improved versus unimproved pasture. Areas studied included mountain grassland, lodgepole pine, mixed conifer, and mountain meadow.

Whitaker, J.O., Jr.; Cross, S.P.; Maser, C. 1983. Food of vagrant shrews (*Sorex vagrans*) from Grant County Oregon, as related to livestock grazing pressures. Northwest Science. 57: 107-111.

Vagrant shrews were trapped at three closely situated mountain meadow sites in the Blue Mountains of eastern Oregon. The three sites had different recent grazing management histories and provided conditions for comparing the effects of grazing on invertebrate fauna as reflected by shrew feeding habits. Major foods of the vagrant shrew in a relatively nongrazed portion of a mountain meadow were earthworms, spiders, crickets, caterpillars, moths, slugs, snails, and June beetles and their larvae. In two similar areas subjected to light grazing (no specific acres/AUM given) and heavy grazing (1.0 acres/AUM), flightless forms (except caterpillars) were much less used; they were replaced primarily by caterpillars and flying insects. The hypothesized cause for these changes was that grazing trampled and compressed the soil, thereby decreasing the populations of some food items. Penetrometer measurements that showed an increase in resistance to soil penetration with increasing intensity of grazing supported the hypothesis.

Whitaker, J.O., Jr.; Cross, S.P.; Skovlin, J.M.; Maser, C. Food habits of the spotted frog (*Rana pretiosa*) from managed sites in Grant County, Oregon. Northwest Science. 57: 147-154.

A great variety of insect food, including distasteful types, was eaten by the spotted frog, indicating that it is an opportunistic feeder. Frogs from four variously managed sites displayed different dietary habits, indicating that land management practices may have caused changes in the abundance or composition of local insect populations.

Whitaker, J.O., Jr.; Maser, C.; Cross, S.P. 1981. Food habits of eastern Oregon bats, based on stomach and scat analyses. Northwest Science. 55: 281-292.

The diets of 12 species of bats were analyzed through examination of 413 stomachs and 536 scats. Results from scat analysis were compared to those from stomach analysis, and some differences were discerned. For example, lepidopterans were somewhat overrepresented and homopterans were somewhat underrepresented in scats; however, scat analysis was deemed acceptable and fairly indicative of the food intake of the following species of bats: *Myotis lucifugus*, *M. yumanensis*, *M. evotis*, *M. volans*, *M. californicus*, *M. leibi*, *Antrozous pallidus*, *Eptesicus fuscus*,

Lasionycteris noctivagans, *Pipistrellus hesperus*, and *Plecotus townsendi*. Dietary information (volume and frequency of occurrence) from stomach and scat content by order and family of insect and by class and order of arachnids is provided for each species of bat. The range, dwelling location, and feeding locations of all species of bats studied are briefly described.

Whitaker, J.O., Jr.; Maser, C.; Cross, S.P. 1981. Foods of Oregon silver-haired bats, *Lasionycteris noctivagans*. Northwest Science. 55: 75-77.

The silver-haired bat in Oregon feeds on a variety of insects. Major items are Lepidoptera, Homoptera (primarily Cercopidae), Hemiptera, Hymenoptera (primarily Formicidae), Coleoptera, and Neuroptera (Hemerobiidae).

Wilburn, R. 1979. The private landowner's role in the validation project. In: Range management short course, Coordinated resource mangement planning in the Pacific Northwest on private and public lands; 1979 March 20-22; Pullman, WA. Pullman, WA: Washington State University, Cooperative Extension Service: 61-64. In cooperation with: Oregon State University; University of Idaho.

Objectives of EVAL on one private ranch, elements of coordinated resource plan, range improvement practices installed, and preliminary results are outlined.

Wilburn, R. 1980. The Oregon range validation project from a rancher's viewpoint. In: 1980 progress report, beef cattle and range resources. Spec. Rep. 583. Corvallis, OR: Oregon State University, Agricultural Experiment Station: 2-24.

The development of the EVAL project is described from the personal perspective of a rancher. The process of coordinated resource planning and measurements taken as central elements to developing the plan are given. Some early benefits of the program to the ranching operation are also described.

Williams, K. 1983. Forest grazing: a rancher's viewpoint profit and loss. In: Forest-land grazing, proceedings of a symposium, 1983, February 23-25; Spokane, WA. Pullman, WA: Cooperative Extension Service, Washington State University: 59-62.

The author describes AUM and economic outputs associated with grazing forest areas managed by thinning and reseeding.

10 Conclusions and Critique

Arthur R. Tiedemann

The 11-year Oregon Range Evaluation project, which involved 7 Federal and State agencies, and 21 private landowners, resulted in the expenditure of nearly $12 million. With any program of this magnitude, accomplishing objectives assumes paramount importance.

From the perspective of developing new information on managing interior Northwest rangelands, the effort is unparalleled. Coordinated Resource Management Plans (CRMP's) were developed for 21 participating private ranches; the plans provided for five increasing intensities of management strategies for 140 pastures. These plans also included 19 associated United States Department of Agriculture Forest Service grazing allotments with 36 pastures that were managed at four increasing intensities. Management strategies, applied to individual pastures, ranged from no livestock grazing (strategy A) to intensive management that optimized resource production on Federal lands and maximized production on private lands. The information generated from evaluations of all the resource responses and economics has resulted in more than 100 publications.

Accomplishment of Objectives

When the project was began, 18 resource, cultural, and economic parameters were to be evaluated. By March 1982, funding allocated to the project was insufficient to support evaluation of 18 parameters at an intensity to meet the rigors of the scientific process. The number of parameters to be evaluated was revised to consider only 6: herbage production; water yield; water quality; storm runoff; practice cost accounting; and economics.

Objective 1: To identify and apply appropriate range management practices that can be expected to enhance herbage production.

The rationale for selecting areas to be treated and practices to be implemented relied heavily on an assessment of the opportunities for accomplishing specific objectives for individual pastures. The result was that cultural treatments designed to increase herbage production, such as tree thinning, juniper and sagebrush control, seeding, and fertilizing were applied only to areas assessed to have high enough potential site productivity for a reasonable chance of achieving the resource output goals outlined in the CRMP. In other studies where large areas of land have been treated without regard to productivity potential, the average benefits have largely been overshadowed by costs.

Success in accomplishing this objective is indicated by the fact that the more than 1000 range improvement practices installed on 347,000 acres of private and Federal land resulted in an increase in stocking on most of the ecosystems studied. All of these practices were evaluated for their costs, changes in AUM productivity, effects on herbage production, water quantity, water quality, and storm runoff responses, and economic relations.

Objective 2: To evaluate the costs associated with each practice and in combination with the practices applied to each pasture to achieve the range management strategies designated for each pasture.

Cost accounting for the Oregon Range Evaluation project was the most extensive and intensive ever accomplished for range management practices. Information was developed for 24 individual practices on Federal and private land and for 10 major ecosystems. The CRMP and the long-term agreements developed with the private landowners provided a vehicle to closely monitor costs. Actual costs of labor (skilled and unskilled), equipment, and materials used in construction were carefully monitored for the installation of every range improvement practice. Typical practices evaluated included various types of fence construction (and reconstruction), water developments, juniper and sagebrush control, seeding, precommercial thinning, debris disposal, water spreading, check dams, drainage systems, and rodent control. Costs (in 1986 dollars) were evaluated for private and Federal land, size of project, and ecosystem. For example, the average total cost for fence construction ranged from $2839/mile in the juniper ecosystem to $5462 in the western larch ecosystem. In addition to costs, a handbook of 100 range improvement construction specifications was developed and published (see Sanderson and others, Chapter 9).

Objective 3: To evaluate the direct effects of grazing strategies on herbage and browse production and determine changes in AUM outputs.

Herbage production was measured for 10 major forest and range ecosystems containing 51 different resource units. A resource unit was a combination of four rates of productivity and three condition classes within an ecosystem. The results provide information on herbage productivity (average annual) that can be expected for each productivity and condition class within each ecosystem. Results also indicate the change in productivity that can be expected to occur when treatments—such as juniper and sagebrush control, forest thinning, seeding, and fertilizing—are imposed. Herbage production responses to five different intensities of management are also provided for future planning by range managers and ranch owners.

Objective 4: To assess effects of four increasing intensities of management strategies on water resources.

The 13 watersheds instrumented for this study provided baseline information on water yield, timing of runoff, storm runoff, sediment of turbidity, stream temperature, bacterial quality, and chemical quality. This study appears to be the first characterization for watersheds dominated by western larch, Douglas-fir, spruce-fir, and lodgepole pine on the eastern side of the Cascade Range.

The watershed selection process played a major role in the eventual results from these studies. The goal was to determine effects of management on water resources, but the most intensively managed watersheds (strategy D) contained large meadow ecosystems where cultural practices such a seeding and fertilizing could be implemented. Conversely, some of the other watersheds either had no meadows or long narrow meadows. Use histories also differed among watersheds. In addition to probable differences in past grazing use, railroad logging and mining occurred on some watersheds. Therefore, for most parameters, discerning management effects was impossible because of the way watersheds were selected and because of the influence of about 100 years of prior use.

Bacterial quality proved to be a sensitive measure of the intensity of management and the ease with which cattle had access to the stream. The strategy D (most intensive management on Federal land) watersheds had the highest fecal coliform counts, which were determined to be higher than Oregon standards allow for the major part of the summer on one of these watersheds. High counts of fecal coliforms were attributed directly to livestock.

No detectable relation between increasing intensity of management and amount and timing of water yield was found. Results of studies of peak discharge and low flows provide information for forest managers to plan culvert installations, in-stream flow needs, and timing of yields for irrigation planning. Comparisons of total runoff with precipitation indicates what proportion of the moisture received is used for evapotranspiration for watersheds dominated by a variety of ecosystems. The BURP water-balance model was calibrated for the 13 study watersheds, providing a tool for the wildland resource managers to predict streamflow from similar watersheds. Studies of storm runoff from discrete precipitation events showed that this form of runoff is a minor part of the total flow.

One important finding of the storm runoff studies was that the maximum base flow rise rate on these watersheds is about one order of magnitude less than that observed on watersheds of the Eastern United States. Measurements of stream temperature during the summer showed that for those watersheds with a large meadow ecosystem and little stream cover, maximum temperatures were in excess of thermal tolerance limits of steelhead trout. These high stream temperatures, however, were not necessarily ascribed to the grazing systems implemented during the EVAL program but to past grazing use over a period of nearly 100 years, which was responsible for the removal of stream cover and caving of stream banks.

Objective 5: To evaluate the effect of management strategies on carrying capacity in animal unit months (AUM's) for ecosystems within pastures.

Estimates of grazing capacities in response to increasing intensities of management were provided through actual-use records and evaluations by a team of professionals comprised of range planners, managers, scientists, and ranchers. Grazing capacities were generally higher on private land than on Federal land. The difference for strategy C was as much as 5-fold. The anticipation that less land would be required per AUM as management intensity increased was generally observed. The team of professionals also provided an evaluation of a simulation model developed to allocate AUM's among ecosystems within a pasture. A geographic information system (GIS) was developed to provide maps of ecosystems, slope, and distance to water for each pasture. These maps were overlayed to generate a new map with unique polygons of similar classification and descriptive tabular data. This information, along with peak standing crop, proper-use factors, and season of grazing use, formed the basis for input into the simulation model. The model had two primary outputs: potential AUM's of grazing capacity and pounds of beef production. This model will have long-term utility to the ranching practitioner.

Objective 6: To determine economically optimal grazing strategies.

This objective represents the "bottom line" of the EVAL project. EVAL used range improvement practices to implement range management strategies for each pasture. Results provide a general planning guide to assist rangeland managers in determining the expected mix of practices and investment costs of managing at various intensities. Investment costs per AUM were highest for the management strategy to maximize commodity production (strategy E) on private land. Costs werse highest for strategy D on Federal land. Costs were lowest for extensive management (strategy C) on both private and Federal land. No investment costs were attributed to range management in strategies A and B. Optimal strategy was determined for each ecosystem by determining the greatest return above variable cost. Costs were annualized at interest rates of 4, 7, and 10 percent.

Benefits and costs were expressed in 1978 dollars for comparison. Management costs averaged $3.67 on private land and $9.79 on Federal land. Based on marketable beef, the optimal strategy for managing private land was to maximize commodity production (strategy E). This intensity of management was optimal over a wide range of interest rates, management costs, and beef prices. At medium interest rates, management costs, and beef prices, strategy D was optimal for all ecosystems on Federal land except for mountain meadow, where strategy C was optimal. Results indicated that pastures intensively managed, using benefit-cost analysis as one of the selection criteria for practices, will result in greater returns above variable costs than less intensively managed pastures.

Critique

This critique is a compilation of responses from inquiries made to ranchers, range managers, and scientists associated with the project. An internal review (March 24, 1977) also provided valuable insights.

The EVAL project was a joint Federal, State, and private venture that is unprecedented in the history of rangeland research and management in the United States. All of the respondents concluded that the spirit of cooperation was a major strength of the program. Without the cooperation and dedication of all the participants, accomplishing the objectives would have been impossible. The CRMP process, which was developed as a result of EVAL, is the model for management and land use planning activities for private ranchers in the interior Northwest. As the success of the process in EVAL becomes widely known, the application will also become more widespread. Some of the range improvement practices implemented with cost sharing during EVAL are now being applied by some ranchers totally at their own expense. Precommercial thinning is one such practice. The EVAL standard of thinning to 21-foot spacing is also now the recommended spacing for eastern Oregon.

Ranchers generally believe they benefited both economically and from improved management associated with the intensified application of range improvement practices. This benefit was evidenced by the interest shown by banks and other lending institutions in the long-term agreements and improvements taken on the ranch property. A greater awareness of the need to improve riparian habitat has also emerged, partly as a result of the EVAL effort. Some ranchers are participating in programs designed to protect and improve riparian zones.

One of the major criticisms of the project was the limited time available to plan the project. Several of the respondents and persons participating in the 1977 critique exercise recommended that 1 to 2 years should have been devoted to an inventory of the available resources and planning program procedures before the project was implemented. More time was needed to develop the scientific approach and study plans, understand local politics, line up cooperators, develop an operations plan with cost estimates, and assure that adequate funding was available and secure. The CRMP process was less efficient initially because of the lack of adequate vegetation and soil resource maps. Once these maps became available, the CRMP process proved to be successful in planning and implementing management practices.

Financial structuring and timing presented another challenge to the project. Success of projects such as EVAL depend on stable funding for the duration of the project. Funding during the first 5 years was stable at about $1.4 million for all agencies. Having a lump sum to be used over the entire period of the study or having smaller amounts in the first 1 or 2 years would have been far more efficient. A larger proportion of the funding during implementing and data-collecting years would have helped. In the 1977 critique and in the recent survey, some respondents shared the view that some of the agencies had insufficient administrative funds to use for the project and had to divert money from other programs.

The funding issue raises a point of central focus—the need for long-term commitment at the highest levels in the Federal agencies and Congress to be sure that adequate funds are available for the life of the project. In 1982, funding was severely restricted and 12 of the project parameters being evaluated had to be dropped. One of the agencies, the Bureau of Land Management, was not funded to do any work on the project and as a consequence no substantive improvements were accomplished on that sector of Federal land.

Because funding for the project came from the three branches of the Forest Service, cooperation and commitment were essential to successfully fund and implement the project. Dedication to the assigned task of completing the project was not equal within the three branches, however. Also, consistent commitment to accomplishing the goals of the project was not found in the chain of command in each agency. This problem might be avoided in the future by giving one branch lead responsibility.

One factor limiting participation of the private landowners was their financial ability to take part in the cost-sharing program for range improvements. As a result, part of the spectrum of the ranching community may have been excluded. This exclusion could have been remedied by a low-interest loan program.

The transfer of information from scientists conducting research and monitoring to the ranchers and range practitioners on the progress of the project was not as timely as it could have been. This delay may have been partly because of the time required to administer the program, with emphasis in the early years on planning and implementation. The result was that insufficient attention was paid to reporting during those years. A more balanced approach with reporting concurrent with planning and implementation would have been better.

The long-term agreements specified the responsibilities of each of the participants. Some of the rancher participants, however, did not implement the range improvements on schedule (and some improvements were never implemented). No mechanism existed within these agreements to assure commitment to the goals of the project, which resulted in a loss of valuable information. Ranchers could have been required to repay funds expended on projects not completed, thereby providing incentive for completing them. Repayment and diversion of funds from ranchers who did not implement practices could have been used to fund replacement sites. Future agreements should have penalties for failure to perform on the part of all participants.

From the scientific perspective, the project did not lend itself to a rigorous research treatment. Some resource units were inadequately represented. Some treatments applied were not well enough replicated to draw firm conclusions. Limited funding and a short planning period resulted in watershed selecting without each type of watershed being included in each strategy. This lack, coupled with previous grazing-use history, made distinguishing the effects of EVAL management strategies on water resource parameters difficult.

The project was conceived of as a "range" show. In reality, it was both multidisciplinary and multiresource in concept and execution. The range tag had some far-reaching ramifications. It forced the smallest and perhaps least well-funded resource activity in the National Forest System to come up with support personnel and funding. Other resource areas of the Forest Service were, at least initially, suspicious and either unsupportive or antagonistic toward the effort. These factors resulted in a political and economic support base that required attention from all management levels of the Forest Service to maintain support and funding. Future projects of this nature should be identified and funded based on a multidisciplinary and multiresource approach.

Research information gathered and reported as part of this project represents only a portion of the total benefit. The study demonstrated that Federal and State agencies can cooperate with private ranchers in a common goal to improve resource management. The technique of CRMP, as modified through the EVAL project, works to enhance management on both private and Federal lands. The inclusion of a benefit-cost analysis as one of the selection criteria for management practices yields more profitable management. On-the-ground improvements and the demonstration of increased profitability with increased range management intensity in the ecosystems of the interior Northwest have been demonstrated to spill over to lands not included in the EVAL project—with lasting effects.

Acknowledgments

To name everyone who invested time and energy on EVAL would be impossible, but we can recognize the team members and those who made other significant contributions. Team members were Jake Callentine, Paul Edgerton, Ken Evans, Jerry Grevstad, Ernie Kehrberg, Jerry Martinez, Leland Matheson, Reed Sanderson, Jon Skovlin, Bill Troxel, and Dan Williams of the Forest Service; Lee Brooks and Dalton Montgomery of the Soil Conservation Service; Eileen Prock and Fred Ringer of the Agricultural Stabilization and Conservation Service; Errol Claire, Ralph Denney, and Ron Garner of the Oregon Department of Fish and Wildlife; Greg Cline, Mark Labhart, Bryan Nelson, and Dan Schultz of the Oregon Department of Forestry; Bill Farrell and Arleigh Isley of the Oregon State University Extension Service; Roger Hoverman and Andy Ryan of the Bureau of Land Management; Phil Kuhl and King Williams private land representatives. The support and guidance provided by Bob Rummel (Forest Service, Washington, D.C.) and Jack Ward Thomas (Forest Service Research, La Grande) were important in maintaining the integrity of the project. Significant contributions were made by Bud Ball, Carolyn Bohn, Kim Brown, Larry Burnstadt, Fred Chugg, Norm Cimon, Pete Etchamendy, Fred Hall, Dale Higgins, Tim Holly, Gary Inouye, Red Justice, Larry Miller, Charles Quimby, Steve Segovia, Bill Skinner, Spike Thompson, and Dick Wildman of the Forest Service; Jacy Gibbs, Roy Mann, Roy Manning, Dan Merkle, Julie Rodgers, Bud Town, and Joe Thompson of the Soil Conservation Service; Cilla Coe, Brian Mattax, and the late Ron Stowasser of Eastern Oregon State College; and Ben Ladd of the National Park Service.

We wish to recognize the 21 private land owners whose cooperation made this project possible: Bentley Ranches and manager Clint Gray; Henry Blagden; John Borgerson; Al Brown; Jack Cavender; Emmel Brothers; Paul Hewitt; Bonham and Mike Kerrins; Joe Lane; Dan Lufkin; Leland and Bud McGirr; Monument Grazing Association; Morgrass Grazing Assoication and manager Rusty Clark; Lola and Charlie O'Rorke; Willard Reeve; John Rex; Michael Smith; George Stubblefield; Vaughn Ranches and operator Jack Johns; and Richard Wilburn.

Finally, we wish to thank Senators Mark Hatfield and Bob Packwood, the late Congressman Al Ullman, and the Grant County Resource Council—especially the late Garland Meador—for their support in creating and maintaining the Oregon Range Evaluation Project.

Glossary

Annualized cost: The amount of money that would have to be paid annually, including interest, for a specified period to finance an investment.

Benefit-Cost analysis: An economic analysis technique that compares the net benefits of alternative practices, such as range improvement treatments.

Bentonite: A type of clay that swells when moistened, used to seal stock ponds.

Digitize: The process of entering map information into a computer for processing and analysis.

Fecal coliforms: Bacteria of the group *Escherichia coli* found in feces of humans and other warm-blooded animals.

Fecal streptococci: Streptococcal bacteria found in the feces of humans and other warm-blooded animals.

Geometric mean: Antilog of the mean of numbers converted to logarithms.

Input-output model: An economic analysis technique that uses information about the interdependencies in a local economy to predict changes in economic activity when demand for products and resources change.

Seedbed preparation: Mechanical or chemical treatment before seeding to enhance seedling establishments by reducing competition between the seeded species and existing vegetation.

> **Mechanical**—A method that uses mechanical devices such as a plow, disk, or harrow.
> **Chemical**—A method that uses a chemical spray to eliminate competing species.

Separable cost-remaining benefit: A technique to separate the costs associated with a project that has multiple objectives into categories for each objective.

Plants and Animals Mentioned in Text

Common name	Scientific name
Plants	
Alder, Sitka	*Alnus sinuata*
Douglas-fir	*Pseudotsuga menziesii*
Fir	*Abies* spp.
Juniper, western	*Juniperus occidentalis*
Larch, western	*Larix occidentalis*
Pine, lodgepole	*Pinus contorta*
Pine, ponderosa	*Pinus ponderosa*
Pinegrass	*Calamagrostis rubescens*
Sagebrush	*Artemisia* spp.
Sedge, elk	*Carex geyeri*
Spruce	*Picea* spp.
Amphibians	
Frog, spotted	*Rana pretiosa*

Birds	
Chukar	*Alectoris graeca*
Dove, morning	*Zenaidura macroura*
Eagle, bald	*Haliaetus leucocephalus*
Falcon, peregrine	*Falco peregrinus*
Grouse, blue	*Dendragapus obscurus*
Grouse, ruffed	*Bonasa umbellus*
Partridge, Hungarian	*Perdix perdix*
Pheasant	*Phasianus colchicus*
Plover, snowy	*Charadrius alexandrius*
Quail, California	*Lophortyx californicus*
Quail, mountain	*Oreortyx pictus*
Turkey	*Meleagris gallopavo*
Fish	
Salmon, chinook	*Oncorhynchus tshawytscha*
Steelhead	*Salmo gairdneri*
Trout, bull	*Salvelinus confluentus*
Trout, cutthroat	*Salmo clarki*
Trout, rainbow	*Salmo gairdneri*
Mammals	
Antelope, pronghorn	*Antilocapra americana*
Badger	*Taxidea taxus*
Bear, black	*Ursus americanus*
Beaver	*Castor canadensis*
Bobcat	*Lynx rufus*
Cougar	*Felis concolor*
Coyote	*Canis latrans*
Deer, mule	*Odocoileus hemionus*
Elk, Rocky Mountain	*Cervus elaphus*
Mink	*Mustela vison*
Muskrat	*Ondatra zibethica*
Raccoon	*Procyon lotor*
Sheep, bighorn	*Ovis canadensis*
Shrews, vagrant	*Sorex vagrans*
Skunks	*Mephitis sp. and Spilogale* sp.

A

Table 1—Land ownership in the Oregon Range Evaluation Project

Land ownership	Acres
Public:	
National Forest System	570,930
Bureau of Land Management	102,442
National Park Service	6,301
Oregon State lands	6,522
Private	859,325
Total	1,545,520

Table 2—Appropriated funds for the Oregon Range Evaluation Project by year

Fiscal	Agency[a]			
year	NFS	S&PF	PNW	Total
	Thousand dollars			
1976	650	450	300.0	1,400.0
1977	650	450	310.4	1,410.4
1978	650	450	325.6	1,425.6
1979	650	450	490.0	1,590.0
1980	650	450	368.5	1,468.5
1981	357	111	511.0	979.0
1982	203	91	492.0	786.0
1983	236	190	524.0	950.0
1984	270	153	524.0	947.0
1985	217	174	590.0	981.0
1986	68	14	358.0	440.0
Total	4,601	2,983	4,793.5	12,377.5

[a] NFS = National Forest System; S&PF = State and Private Forestry; PNW = Pacific Northwest Research Station.

Table 3—Forest Service reimbursement to agencies cooperating in the Oregon Range Evaluation Project by year

Fiscal year	Agency[a]					
	ASCS	ODF&W	ODF	OSUES	SCS	Total
			Dollars			
1976		2,172	3,867	1,515	26,525	34,079
1977	1,245	5,201	26,948	16,847	46,699	96,940
1978	2,170	10,420	24,666	22,502	69,409	129,167
1979	1,198	23,772	24,256	24,214	46,542	119,982
1980	3,981	27,722	44,978	21,729	74,000	172,410
1981	14,388		35,903	38,747	39,290	128,328
1982	10,773		33,214	13,772	37,534	95,293
1983			36,068	7,972	33,426	77,466
1984			7,046	6,295	20,298	33,639
1985				32,000	25,000	57,000
Total	33,755	69,287	236,947	185,593	418,723	944,304

[a] ASCS = Agricultural Stabilization and Conservation Service; ODF&W = Oregon Department of Fish and Wildlife; ODF = Oregon Department of Forestry; OSUES = Oregon State University Extension Service; SCS = Soil Conservation Service.

Table 4—Permanent, full-time employees assigned to the Oregon Range Evaluation Project by year

Fiscal year	National Forest System	Pacific Northwest Research Station	Other agencies	Total
1976	5	3	8	16
1977	6	4	8	18
1978	5	4	8	17
1979	4	5	8	17
1980	5	6	8	19
1981	6	7	7	20
1982	5	6	7	18
1983	4	7	6	17
1984	4	8	6	18
1985	4	6	8	18
1986	2	5	4	11

Table 5—Resources monitored during the Oregon Range Evaluation Project before and after March 1982

Values	Before March 1982[a]	After March 1982[b]
Quantitative:		
Forage production	•	•
Wood production	•	
Water flow	•	•
Storm runoff	•	•
Sediment	•	
Water quality	•	•[c]
Soil stability[d]		
Qualitative:		
Birds	•	
Small mammals	•	
Other vertebrates	•	
Big game[d]		
Fish	•	
Riparian habitat	•	
Dispersed recreation	•	
Scenic beauty	•	
Cultural heritage	•	
Economic:		
Employment	•	
Animal value		•[e]
Practice cost accounting	•	•

[a] Asterisks indicate at least base data were collected or contracted before September 30, 1981. Sometimes the quantitative values were adequately assessed.

[b] Asterisks indicate resource values were monitored after March 1982.

[c] Sediment is considered part of water quality.

[d] Soil stability and big game were assigned but not monitored.

[e] Employment and animal value were combined in the economic assessment output.

B

Table 1—Fence costs by type of fence and ecosystem

Type of fence and ecosystem	Fences: Number	Fences: Miles	Average costs per mile[a]: Labor: Skilled	Labor: Unskilled	Equipment	Material	Total
			1986 dollars				
Permanent wire-fence construction:							
Douglas-fir			977	1143	1217	1611	4951
Ponderosa pine			787	1416	1104	1140	4448
Larch			1111	1909	1533	906	5462
Sagebrush			445	1232	622	1214	3515
Juniper				1042		1664	2839
Mountain grassland				1123		1839	3131
Mountain meadow				720		1833	2867
Overall average	97	154	639	1235	838	1515	4226
Change in per-mile cost[b]				-148		189	
Let-down wire-fence construction:							
Douglas-fir			1302	1850	1086	1495	5733
Larch			1093	1258	997	1386	4734
Lodgepole pine				3091		1403	5217
Sagebrush				1456		2202	5208
Alpine				963	1087	1009	3615
Overall average	16	45	1039	1430	1012	1508	4989
Wire-fence reconstruction:							
Douglas-fir				1804			3290
Ponderosa pine			1181	2276	1120		4673
Larch			616		758		2029
Mountain grassland				637		1071	1919
Overall average	14	12	323	1339	316	645	2623
Fence removal:							
Douglas-fir			166	178	201		550
Ponderosa pine			148	228	331		704
Larch			139	249	219		609
Overall average	46	65	142	214	214	2	572
Change in per-mile cost[b]			-23	-38			-88

[a] Average costs shown for ecosystems and change in per-mile cost are regression coefficients that differ significantly from zero. Overall averages are simple means. Costs may not add to the total because nonsignificant regression coefficients are not reported. Costs were converted from 1978 to 1986 dollars by multiplying the 1978 values by 1.51 (ratio of 1986 to 1978 prices paid index for agricultural production items with nonfarm orgin).

[b] Change in per-mile fence construction costs for each additional mile of fence constructed. Negative values indicate reductions in average cost per mile; positive values indicate an increase in average cost per mile.

Table 2—Spring development costs by ecosystem

Ecosystem	Number of cases	Average costs per unit: Labor: Skilled	Unskilled	Equipment	Material	Total
		1986 dollars				
Douglas-fir	25	228	186	596	747	1757
Ponderosa pine	19	243	192	486	680	1601
Larch	11	269	204	601	687	1761
Lodgepole pine	2	441	427	894	791	2553
Sagebrush	11	62	287	323	390	1062
Juniper	18	124	219	482	571	1396
Mountain grassland	15	98	190	205	438	931
Mountain meadow	1	118	429	328	633	1508
Overall average[a]	102	183	213	473	613	1482

[a] Overall averages are weighted by the number of cases.

Table 3—Spring redevelopment costs by ecosystem

Ecosystem	Number of cases	Average costs per unit: Labor: Skilled	Unskilled	Equipment	Material	Total
		1986 dollars				
Douglas-fir	15	192	122	361	618	1293
Ponderosa pine	6	213	143	393	572	1321
Larch	5	488	288	1027	966	2769
Lodgepole pine	2	270	130	636	612	1648
Sagebrush	3	69	146	165	455	835
Juniper	4	304	356	411	741	1812
Mountain grassland	3	128	103	233	565	1029
Mountain meadow	1	337	316	690	2161	3504
Overall average[a]	39	239	177	453	690	1559

[a] Overall averages are weighted by the number of cases.

Table 4—Stock pond construction costs by ecosystem

Ecosystem	Number of cases	Average costs per unit: Labor: Skilled	Unskilled	Equipment	Material	Total
		1986 dollars				
Douglas-fir	62	88	23	311	92	514
Ponderosa pine	29	100	15	385	92	592
Larch	31	62	11	239	62	374
Lodgepole pine	4	157	33	371	254	815
Sagebrush	18	109	3	412	47	571
Juniper	15	107	3	461	23	594
Mountain grassland	44	106	2	525	15	648
Mountain meadow	8	145	17	507	137	806
Overall average[a]	211	95	12	384	68	559

[a] Overall averages are weighted by the number of cases.

Table 5—Stock pond reconstruction costs by ecosystem

Ecosystem	Number of cases	Average costs per unit: Labor: Skilled	Unskilled	Equipment	Material	Total
		1986 dollars				
Douglas-fir	32	80	14	264	85	443
Ponderosa pine	13	71	53	222	236	582
Larch	12	192	151	412	100	855
Lodgepole pine	1	65	35	308	128	536
Sagebrush	10	98	6	290	76	470
Juniper	9	98	24	279	388	789
Mountain grassland	4	74	33	329	181	617
Mountain meadow	4	95	2	282	60	439
Overall average[a]	85	98	41	287	145	571

[a] Overall averages are weighted by the number of cases.

Table 6—Large water development costs

Development	Number of cases	Average costs per unit: Labor: Skilled	Unskilled	Equipment	Material	Total
		-----	-----	1986 dollars	-----	-----
Reservoir	2	716	344	3102	2756	6918
Well	1	251	544	766	4255	5816

Table 7—Brush removal and seeding treament costs in the sagebrush ecosystem by treatment

Treatment	Number of cases	Treated area	Average costs per mile[a]: Labor: Skilled	Unskilled	Equipment	Material	Total
		Acres	-----	-----	1986 dollars	-----	-----
Seeding treatment:							
Rangeland drill	4	246	6	0	12	39	57
Plow, disk, drill	11	758	17	0	48	23	88
Beat, drill	3	89	32	0	59	17	108
Spray, plow, drill	2	120	17	0	36	143	196
Burn, seed	3	181	8	17	27	44	96
Overall average[a]	23	1394	15	2	39	38	94
Brush removal:							
Plow sage	1	38	12	0	77	0	89
Beat sage	3	143	15	0	29	0	44
Aerial spray of sage	1	450	2	0	5	8	15
Ground spray of sage	1	65	24	0	79	18	121
Burn sage	4	390	2	5	5	0	12
Overall average[a]	10	1086	5	2	15	4	26

[a] Overall averages are weighted by the acres treated.

Table 8—Juniper control and seeding treatment costs in the juniper ecosystem by treatment

Treatment	Number of cases	Treated area	Average costs per unit: Labor: Skilled	Labor: Unskilled	Equipment	Material	Total
		Acres	1986 dollars				
Tree removal and seeding:							
Chainsaw, drill	1	25	29	0	30	24	83
Dozer, disk, drill	4	144	20	0	74	21	115
Plow, disk, drill	2	58	12	0	38	20	70
Overall average[a]	7	227	18	0	57	21	96
Tree removal:							
Dozer, machine pile	8	117	18	0	77	0	95
Chainsaw, machine pile	8	308	57	12	63	0	132
Chainsaw	2	597	17	0	11	0	28
Chainsaw, hand pile	5	264	27	8	26	5	65
Overall average[a]	23	1286	29	5	33	1	68

[a] Overall averages are weighted by the number of acres treated.

Table 9—Mountain grassland seeding costs by treatment

Treatment	Number of cases	Treated area	Average costs per unit: Labor: Skilled	Labor: Unskilled	Equipment	Material	Total
		Acres	1986 dollars				
Mechanical preparation, drill	22	992	17	2	65	29	113
Disk, broadcast seed	1	16	14	2	35	36	87
Plow, disk, drill	1	92	6	0	36	12	54
Overall average[a]	24	1100	17	2	62	29	110

[a] Overall average is weighted by the acres treated.

Table 10—Mountain meadow seeding costs by treatment

Treatment	Number of cases	Treated area	Average costs per unit: Labor: Skilled	Unskilled	Equipment	Material	Total
		Acres	1986 dollars				
Chemical preparation, drill	2	79	12	0	33	88	133
Rototill, drill	4	136	17	0	41	85	143
Disk, plow, drill	4	163	23	0	60	65	148
Rangeland drill	1	48	5	0	12	35	52
Plow, disk, harrow, broadcast seed	1	60	21	3	50	38	112
Overall average[a]	12	486	17	0	44	71	132

[a] Overall average is weighted by acres treated.

Table 11—Debris disposal treatment costs by treatment

Treatment	Number of cases	Treated area	Average costs per unit: Labor: Skilled	Unskilled	Equipment	Material	Total
		Acres	1986 dollars				
Debris disposal, seeding:							
Mechanical preparation, seeding	3	99	30	11	76	20	137
Broadcast seed	7	637	14	5	48	38	105
Burn piles, seed burnspot	3	91	2	9	6	72	89
Overall average[a]	13	827	15	6	47	40	108
Debris disposal, machine pile:							
Douglas-fir ecosystem	2	79	12	0	63	0	75
Ponderosa pine ecosystem	2	72	9	0	27	0	36
Larch ecosystem	1	41	9	0	36	0	45
Overall average[a]	5	192	11	0	45	0	56

[a] Overall average is weighted by the acres treated.

Table 12—Thinning and piling costs by treatment

			Average costs per unit				
			Labor				
Treatment	Number of cases	Treated area	Skilled	Unskilled	Equipment	Material	Total
		Acres	1986 dollars				
Thin, pile, debris disposal, and dribble seed:							
Douglas-fir ecosystem			47		98	21	166
Ponderosa pine ecosystem			48		85	17	150
Overall average	7	434	48	9	91	18	166
Thin, pile, and broadcast seed:							
Douglas-fir ecosystem			51	5	65	20	141
Ponderosa pine ecosystem			60	5	115	20	200
Overall average	15	780	56	6	103	18	183
Overall average for thin, pile, burn piles, and broadcast seed	7	280	82	20	125	23	250
Thin and pile, no seeding:							
Douglas-fir ecosystem			47		92		139
Ponderosa pine ecosystem			50	6	107	3	166
Overall average	8	504	48	3	97	2	150
Thinning, no piling, no seeding, Ponderosa pine ecosystem	2	14	42	0	24	0	66

Table 13—Fertilization and irrigation costs by treatment and owner

Treatment and owner[a]	Number of cases	Units treated	Unit of Measure	Average costs per unit: Labor: Skilled	Labor: Unskilled	Equipment	Material	Total
				1986 dollars				
Fertilization:								
FED	5	325	Acres	8	2	32	96	138
PRIV	2	147	Acres	1	0	3	46	50
Check dams, COMB	4	12	Each	101	15	218	151	485
Water spreading system, PRIV	2	392	Acres	113	11	581	34	739
Drainage system, PRIV	1	195	Acres	1	0	3	0	4

[a] FED=federal cases, PRIV=private cases, COMB=combined federal and private cases.

Table 14—Costs associated with weed control, fireline construction, rodent control, and construction of livestock access trails

Improvement type	Number of cases	Units treated	Unit of Measure	Average costs per unit: Labor: Skilled	Labor: Unskilled	Equipment	Material	Total
				1986 dollars				
Weed control	5	74	Acres	11	0	14	11	36
Fireline construction, sagebrush ecosystem	1	2	Miles	169	249	764	0	1182
Rodent control, mountain grassland ecosystem	4	341	Acres	3	0	6	3	12
Access trails, machine construction	2	.6	Miles	319	0	1462	0	1781
Hand construction	6	15	Miles	177	162	189	47	575

C

Table 1—Average annual herbage and browse production for forest ecosystems and strategies, Oregon Range Evaluation Project, 1977-84

Forest ecosystem	Strategies: X	A	B	C	D	E	Average, all strategies
	pounds per acre						
Fir-spruce	—	47	47	—	—	—	47
Larch	—	82	101	112	103	200	101
Douglas-fir	47	136	150	129	143	254	143
Lodgepole pine	—	—	—	165	114	—	146
Ponderosa pine	65	205	173	153	176	236	173
Average	53	106	129	132	139	243	129

Table 2—Average annual herbage and browse production for range ecosystems and strategies, Oregon Range Evaluation Project, 1977-84

Range ecosystem	Strategies: X	C	B	D	A	E	Average, all strategies
	pounds per acre						
Juniper	226	129	220	225	—	338	200
Mountain grassland	132	315	231	323	—	470	323
Sagebrush	567	308	301	516	372	492	399
Alpine	—	—	581	—	482	—	541
Mountain meadow	504	992	843	786	637	1167	925
Average	301	315	338	381	516	567	372

Table 3—Summary of annual grass production on resource units as a result of range management practices, Oregon Range Evaluation Project, 1977-84

Range management practice	Resource unit	Grass production	
		Treated	Untreated
		pounds per acre	
Precommerical thin	Douglas-fir, low, timber	111	72
	Ponderosa pine, low, poles	133	114
	Ponderosa pine, low, timber	154	78
Chemical spray	Sagebrush, moderately low, fair	439	271
Fire	Sagebrush, moderately low, fair	458	271
	Sagebrush, low, fair	165	61
Mechanical control	Juniper, high, poor	259	153
Seed	Sagebrush, moderately low, poor	475	205
	Mountain grassland, moderately low, fair	562	428
	Mountain grassland, moderately low, poor	865	673
	Mountain grassland, low, poor	367	58
	Mountain meadow, high, fair	1502	769
Fertilize	Mountain meadow, high, fair	1293	737
	Mountain meadow, high, poor	1210	652
	Mountain meadow, moderately high, fair	2152	1290
	Mountain meadow, moderately low, fair	906	495
	Mountain meadow, low, poor	54	430

Table 1—Annual water yield (inches) for 13 small watersheds in the Blue Mountains of Oregon, water years 1978-84

Watershed	Drainage Area mi²	Eco-systems[a]	Annual water yield by water year 1978	1979	1980	1981	1982	1983	1984	Mean
			inches							
Big	2.02	FS	21.1	27.5	22.7	24.8	37.4	34.8	—	28.1
Blackeye	.90	LA/PP	18.6	16.1	11.4	11.0	20.7	—	35.6	18.9
Caribou	2.43	PP	—[b]	10.5	5.7	4.5	—	12.8	17.3	10.2
East Donaldson	1.60	LA/DF	4.5	3.1	2.8	4.0	6.6	8.8	9.1	5.6
East Little Butte	1.16	LA/DF	—	—	—	6.0	12.6	12.5	14.5	11.4
Flood	7.00	LP	9.7	—	10.9	9.4	15.5	17.5	20.3	13.9
Keeney	4.90	MM	9.9	13.0	10.5	10.1	15.6	18.6	20.4	14.0
Lake	.46	LA/DF	—	—	—	—	9.7	9.8	10.5	10.0
Little Boulder	2.30	LA/DF	13.0	12.6	8.2	7.7	17.5	21.1	22.9	14.7
Ragged	3.38	LA/DF	6.5	9.1	4.2	4.4	10.1	11.9	13.9	8.6
Tinker	1.70	LA/DF	6.6	7.2	5.1	5.3	13.5	12.7	13.3	9.1
West Donaldson	1.50	LA/DF	3.6	—	2.5	3.7	5.9	8.7	8.4	5.5
West Little Butte	1.76	LA/DF	7.8	7.7	6.0	6.5	13.1	13.6	14.8	9.9
	Mean		10.1	11.9	8.2	8.1	14.9	15.2	16.8	12.3

[a] FS=fir-spruce; LA/PP=western larch/ponderosa pine; PP=ponderosa pine; LA/DF=western larch/Douglas-fir; LP=lodgepole pine; MM=mountain meadow.
[b] No data.

Table 2—Annual peak-flows (cfsm) for 13 small watersheds in the Blue Mountains of Oregon, water years 1978-84

Watershed	Drainage area mi²	Annual peak flow by water year 1978	1979	1980	1981	1982	1983	1984	Mean
		cfsm							
Big	2.02	20.1	29.0	16.2	25.1	55.3	52.6	41.7	34.3
Blackeye	.90	7.4	18.4	3.8	6.8	13.3	30.6	31.2	15.9
Caribou	2.43	—[a]	7.7	3.3	3.3	8.4	12.2	14.5	8.2
East Donaldson	1.60	2.7	2.0	1.0	1.6	2.7	4.9	3.2	2.6
East Little Butte	1.16	5.3	—	3.1	2.2	7.5	8.3	10.3	6.1
Flood	7.00	16.8	8.3	7.5	4.4	11.0	15.6	21.9	12.2
Keeney	4.90	28.9	28.8	25.0	14.1	22.1	23.1	47.1	27.0
Lake	.46	—	—	—	—	7.7	6.0	8.5	7.4
Little Boulder	2.30	7.6	8.8	4.3	4.5	12.5	17.7	16.6	10.3
Ragged	3.38	3.2	6.2	2.0	1.4	6.7	7.3	7.7	4.9
Tinker	1.70	6.3	7.9	3.4	2.2	8.5	7.6	11.1	6.7
West Donaldson	1.50	1.2	.8	.5	1.2	3.3	5.7	2.7	2.2
West Little Butte	1.76	4.9	5.1	2.4	2.3	5.6	8.3	8.7	5.3
	Mean	9.5	11.2	6.0	5.8	12.7	15.4	17.3	11.1

[a] No data.

Table 3—Annual 7-day low flows for 11 small watersheds in the Blue Mountains of Oregon, water years 1978-84

Watershed	Drainage Area mi^2	Annual 7-day low flows by low-flow water year (April 1-March 30)						
		1978-79	1979-80	1980-81	1981-82	1982-83	1983-84	Mean
		cfsm						
Big	2.02	0.126	0.119	0.116	0.108	0.219	0.155	0.141
Caribou	2.43	.009	.012	.013	.010	.028	.021	.016
East Donaldson	1.60	.070	.043	.054	.055	.096	.191	.085
Flood	7.00	.070	.053	.057	.047	.069	.069	.061
Keeney	4.90	.009	.002	.006	.008	.014	.005	.007
Lake	.46	—[a]	.019	.022	.016	.056	.039	.030
Little Boulder	2.30	.021	.107	.106	.067	.323	.154	.130
Ragged	3.38	.104	.013	.051	.047	.087	.112	.069
Tinker	1.70	.037	.034	.035	.024	.071	.073	.046
West Donaldson	1.49	.083	.066	.078	.076	.108	.152	.094
West Little Butte	1.76	.142	.147	.156	.171	.222	.214	.175
	Mean	.067	.056	.063	.057	.118	.108	.078

[a] No data.

E

Average annual wood fiber growth on 24 paired plots available for remeasurement in 1984.

Fenced	Not fenced
cubic feet per acre	
142.50	112.35
19.05	55.85
46.95	52.80
240.60	173.35
81.35	57.40
141.40	105.70
51.05	5.95
97.70	104.00
39.40	134.90
121.50	81.00
90.25	94.40
120.40	-21.00
118.65	72.35
81.55	75.80
62.75	120.10
89.00	94.35
43.35	64.30
99.50	148.40
104.05	120.90
99.65	73.10
90.70	90.50
97.40	48.95
29.05	32.75
47.00	35.85

F

Stocking densities on private and Federal land by strategy[a]

Strategies[b]	Douglas-fir	Ponderosa pine	Larch	Lodgepole pine	Sage	Juniper	Mountain grassland	Mountain meadow	Overall average
	Ecosystem								
Private land:									
Strategy C—									
Ave	3.82	3.77	NA	NA	4.54	5.73	5.11	1.06	4.53
SE	(.81)	(.44)	NA	NA	(.62)	(.45)	(.72)	(.19)	(.35)
n	4	8	NA	NA	11	12	26	6	67
Strategy D—									
Ave	4.10	3.09	NA	NA	3.54	5.49	4.50	1.34	4.04
SE	(1.37)	(.33)	NA	NA	(.60)	(.58)	(.57)	(.47)	(.28)
n	4	13	NA	NA	13	19	16	6	71
Strategy E—									
Ave	3.38	3.81	NA	NA	3.25	4.77	3.02	.74	3.24
SE	(.73)	(.48)	NA	NA	(.58)	(.48)	(.37)	(.15)	(.22)
n	9	18	NA	NA	27	25	46	16	141
Federal land:									
Strategy C—									
Ave	24.09	16.54	23.61	27.64	9.49	18.53	14.18	1.72	17.07
SE	(8.85)	(6.17)	(5.57)	(3.48)	(2.05)	(3.85)	(4.86)	(.29)	(2.34)
n	20	21	17	5	7	15	11	15	111
Strategy D—									
Ave	8.12	7.31	13.63	70.92	11.71	15.94	3.37	1.99	13.79
SE	(1.02)	(1.26)	(3.96)	(28.32)	(4.77)	(7.72)	(.50)	7.31)	(3.58)
n	9	8	7	4	3	4	2	9	46

[a] Stocking density in acres per AUM on private and federal land as determined through the AUM allocation process.
[b] Ave = average; SE = standard error of mean; n = sample size.

G

Table 1—Seasonal percentage of total forage consumed by cattle from Evaluation and non-Evaluation Project dependent ranches by herd size, Grant County, 1980

Herd size	Forage consumed												
and ranch type	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year long
	Percent												
0-99:													
Evaluation	4.7	4.6	4.3	3.9	3.9	4.0	3.6	3.6	4.1	4.3	4.7	4.6	4.2
Non-Evaluation	5.8	5.9	5.3	5.0	6.7	6.8	6.7	6.6	6.6	4.4	6.1	6.1	6.0
100-199:													
Evaluation	16.8	16.7	16.6	16.8	16.2	16.7	16.6	16.7	18.4	20.6	18.7	17.6	17.3
Non-Evaluation	16.9	15.1	14.4	13.7	17.4	14.9	15.5	15.5	16.5	15.6	16.7	18.9	15.9
200-449:													
Evaluation	27.0	26.5	26.4	26.9	26.3	26.9	25.6	25.5	28.3	25.3	23.6	25.6	26.2
Non-Evaluation	25.2	25.8	24.7	30.7	21.8	24.7	24.0	23.9	27.3	25.2	25.7	27.6	25.5
450-749:													
Evaluation	24.4	25.4	26.1	25.9	25.6	26.3	25.7	25.5	27.4	27.9	30.0	29.2	26.5
Non-Evaluation	20.5	21.0	24.7	19.9	19.1	20.3	19.6	19.8	21.5	29.0	24.4	19.7	21.6
Over 750:													
Evaluation	27.0	26.8	26.6	26.7	28.0	26.1	28.4	28.7	21.8	21.9	22.9	23.1	25.8
Non-Evaluation	31.6	32.2	30.9	30.7	35.0	33.2	34.1	34.1	28.1	25.8	27.0	27.8	30.9
Composite:													
Evaluation ranches	8.6	8.7	8.7	8.7	8.9	8.7	8.7	8.7	7.9	7.8	7.4	7.3	
Non-Evaluation ranches	8.6	8.5	8.8	8.9	8.2	8.1	8.4	8.4	7.8	8.4	7.9	7.8	

Table 2—Seasonal percentage of total forage from different sources consumed by cattle from Evaluation and non-Evaluation project dependent ranches, Grant County, 1980

Source and ranch type	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
	Forage consumed												
	Percent												
All deeded range:													
Evaluation	0	0	0	57.7	83.0	56.5	49.8	48.3	58.3	43.7	13.5	3.3	35.5
Non-Evaluation	1.0	1.6	1.6	31.4	76.6	35.5	31.0	30.3	35.3	31.2	32.3	6.0	25.9
BLM range:													
Evaluation				2.2	2.4	2.5	2.5	2.5	2.8	2.5	.5	.3	1.5
Non-Evaluation	1.0	1.0	1.0	8.5	10.8	6.2	3.7	3.6	1.3	5.2	2.1	1.1	3.8
Forest Service range:													
Evaluation						21.5	25.6	26.8	27.8	10.9	T		9.5
Non-Evaluation					1.4	35.5	40.1	41.1	36.2	16.8	2.1	1.0	14.4
State range:													
Evaluation					.6	.6	.6	.6	.7				.3
Non-Evaluation					0	0	0	0	0				0
Irrigated pasture:													
Evaluation				0	8.1	18.9	21.5	21.7	10.1	5.3	0	0	7.3
Non-Evaluation				.7	9.1	22.0	24.4	24.1	16.8	4.3	4.7	.4	8.9
Aftermath:													
Evaluation	3.6	1.3	1.3	2.8	.2	0	0	0	.3	37.5	72.4	19.6	10.8
Non-Evaluation	0	0	0	0	.9	.9	.9	.9	10.5	45.4	50.7	11.9	9.8
Hay:													
Evaluation	96.4	98.7	98.7	37.3	.4						13.5	76.7	35.2
Non-Evaluation	98.0	97.4	97.3	60.6	1.1						8.3	79.6	37.2

T = trace.

Table 3—Seasonal percent of range forage from different ownerships consumed by cattle from Evaluation and non-Evaluation dependent ranches, Grant County, 1980

	Range forage consumed							
	April	May	June	July	Aug.	Sept.	Oct.	Nov.
	Percentage							
Deeded range:								
Evaluation	96.3	96.5	72.0	63.4	61.8	65.1	76.5	96.4
Non-Evaluation	78.7	86.3	46.0	41.4	40.9	48.5	58.6	88.5
BLM:								
Evaluation	3.7	2.8	3.2	3.2	3.2	3.1	4.4	3.6
Non-Evaluation	21.3	12.1	8.0	4.9	4.9	1.9	9.8	5.7
Forest Service:								
Evaluation		0	27.4	32.6	34.3	31.0	19.1	0
Non-Evaluation		.6	46.0	53.6	55.5	49.7	31.6	5.7
State:								
Evaluation		.7	.8	.8	.8	.8		
Non-Evaluation		0	0	0	0	0		

Table 4—Costs, benefits, and return above variable costs on private land with interest rate at 7 percent, beef price at $54.32 per hundred weight, and management costs at $3.67 per AUM, by strategy

	Ecosystem						
Strategy[a]	Douglas-fir	Ponderosa pine	Sage	Juniper	Mountain grassland	Mountain meadow	Overall average
	1978 dollars/acre						
Strategy C:							
Sample size	4	8	11	12	26	6	67
Costs/acre							
Ave	3.21	3.08	2.76	3.02	2.51	9.49	3.38
SE	(.74)	(.35)	(.43)	(.84)	(.16)	(2.10)	(.35)
Benefits/acre—							
Ave	9.49	11.60	10.37	6.74	10.22	43.49	12.72
SE	(1.32)	(1.23)	(2.79)	(.53)	(1.04)	(8.27)	(1.51)
Returns above variable costs/acre—							
Ave	6.27	8.52	7.61	3.73	7.70	34.00	9.34
SE	(.82)	(.94)	(2.40)	(.89)	(.94)	(6.40)	(1.24)
Strategy D:							
Sample size	4	13	13	19	16	6	71
Costs/acre—							
Ave	2.68	5.03	4.71	3.46	4.01	17.55	5.25
SE	(.60)	(.88)	(.68)	(.41)	(.75)	(8.83)	(.87)
Benefits/acre—							
Ave	10.95	14.67	14.54	7.84	10.71	44.10	14.20
SE	(3.42)	(1.58)	(2.60)	(1.02)	(2.23)	(14.74)	(1.80)
Returns above variable costs/acre—							
Ave	8.28	9.64	9.83	4.39	6.70	26.55	8.96
SE	(2.90)	(1.56)	(2.05)	(.97)	(1.85)	(7.26)	(1.12)
Strategy E:							
Sample size	9	18	27	25	46	16	141
Costs/acre—							
Ave	6.73	4.66	7.64	4.78	6.94	17.54	7.59
SE	(1.98)	(.90)	(1.04)	(.97)	(.88)	(1.95)	(.57)
Benefits/acre—							
Ave	19.67	15.07	21.36	12.09	23.35	67.23	24.66
SE	(5.68)	(3.01)	(3.33)	(2.51)	(3.33)	(8.80)	(2.18)
Returns above variable costs/acre—							
Ave	12.94	10.41	13.72	7.31	16.41	49.68	17.07
SE	(3.73)	(2.18)	(2.52)	(1.64)	(2.58)	(7.16)	(1.67)

[a]Ave = average; SE = standard error of the mean.

Table 5—Costs, benefits, and return above variable costs on Federal land with interest rate at 7 percent, beef price at $54.32 per hundred weight, and management costs at $9.79 per AUM, by strategy

Strategy[a]	Ecosystem								
	Douglas-fir	Ponderosa pine	Larch	Lodgepole pine	Sage	Juniper	Mountain grassland	Mountain meadow	Overall average
	1978 dollars/acre								
Strategy C:									
Sample size	20	21	17	5	7	15	11	15	111
Costs/acre—									
Ave	1.42	1.82	1.15	0.45	2.82	1.27	2.29	11.42	2.92
SE	(.23)	(.23)	(.18)	(.07)	(.81)	(.15)	(.52)	(1.89)	(.42)
Benefits/acre—									
Ave	3.20	4.42	2.70	1.13	4.59	2.58	4.16	28.20	6.74
SE	(.51)	(.66)	(.47)	(.27)	(.78)	(.30)	(.68)	(4.38)	(1.01)
Returns above variable costs/acre—									
Ave	1.77	2.60	1.55	0.68	1.76	1.31	1.87	16.78	3.82
SE	(.33)	(.45)	(.35)	(.22)	(.58)	(.20)	(.44)	(2.74)	(.62)
Strategy D:									
Sample size	9	8	7	4	3	4	2	9	46
Costs/acre—									
Ave	2.38	2.60	4.55	0.95	1.94	2.27	2.08	8.91	3.85
SE	(.38)	(.51)	(3.58)	(.76)	(.08)	(.93)	(1.51)	(1.65)	(.73)
Benefits/acre—									
Ave	4.88	5.52	15.03	2.50	4.29	4.09	5.62	22.24	9.65
SE	(.60)	(1.11)	(12.81)	(2.10)	(.62)	(1.47)	(4.19)	(5.22)	(2.36)
Returns above variable costs/acre—									
Ave	2.50	2.92	10.48	1.56	2.35	1.83	3.55	13.33	5.80
SE	(.34)	(.66)	(9.23)	(1.35)	(.54)	(.59)	(2.69)	(3.69)	(1.65)

[a] Ave = average; SE = standard error of the mean.

Quigley, Thomas M.; Sanderson, H. Reed; Tiedemann, Arthur R. 1989. Managing interior Northwest rangelands: The Oregon Range Evaluation Project. Gen. Tech. Rep. PNW-GTR-238. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 207 p.

This report is a synthesis of results from an 11-year study of the effects of increasing intensities of range management strategies on herbage production, water resources, economics, and associated resources—such as wood fiber and recreation—in Grant County, Oregon. Four intensities of management were studied on Federal land (19 grazing allotments) ranging from no grazing to intensive management aimed at improving livestock distribution and forage production by applying cultural treatments. On private land (21 cooperating ranches), an additional strategy aimed at maximizing commodity production was tested. During the course of the project, more than 1000 range improvement practices were installed on 350,000 acres.

Baseline herbage production information was developed for 51 resource units that comprise 10 major ecosystems. Effects of increasing intensities of management on herbage production were determined. The resultant increase in carrying capacity was determined, and the allocation—by ecosystem—of animal unit months within pastures was determined. The most intensive strategy on both Federal and private land was generally the economically optimal strategy. Effects of increasing intensity of management on water resources was tested only on Federal land. Baseline information on water yield and timing, storm runoff, pollution indicator bacteria, dissolved chemicals, and temperature was generated. Changes in the measured water parameters in response to increasing intensity of management were measured. The only parameter that could be related directly to increasing intensity of management and increased cattle use was bacterial quality.

More than 100 publications and reports were developed. Predictive models for water yield, stream temperature, and animal unit months outputs were developed. A handbook on specifications for range improvement practices was produced, and costs of these practices were determined.

Results provide state-of-the-art information for managing rangelands in the interior West, with understanding of the economic consequences and effects on related resources.

Keywords: Range improvement, range management strategies, range economics, herbage production, forage production, range carrying capacity, animal unit month allocation, range watersheds, water yield, stream discharge, stream temperature, pollution indicator bacteria, fecal coliforms, fecal streptococcus, stream chemistry.

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