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Integrated Management of Southwestern Oregon's Rangeland Resources

Agricultural Experiment Station
Oregon State University

OREGON STATE UNIVERSITY

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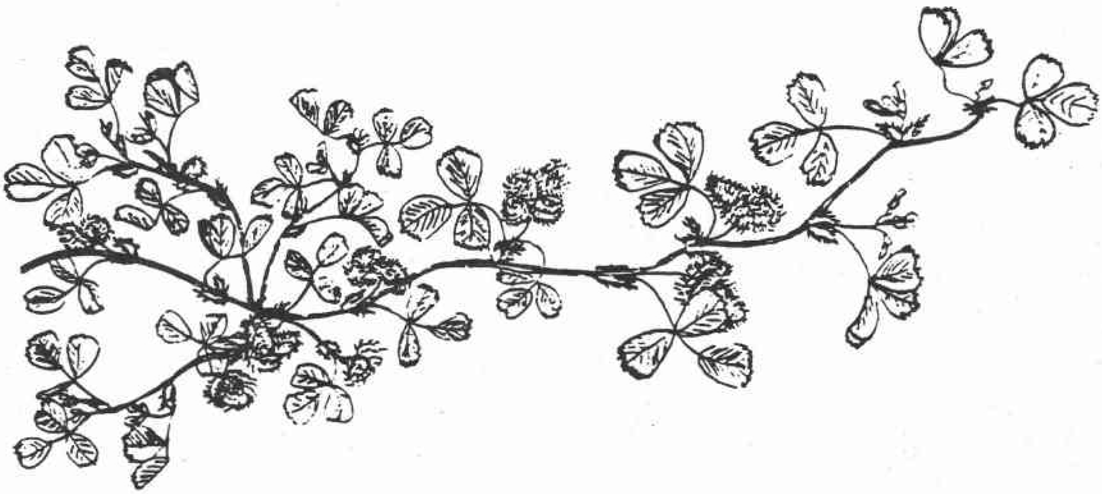
INTEGRATED MANAGEMENT OF SOUTHWESTERN OREGON'S RANGELAND RESOURCES



November 1990

OREGON STATE UNIVERSITY, DEPARTMENT OF RANGELAND RESOURCES

EASTERN OREGON AGRICULTURAL RESEARCH CENTER

USDA AGRICULTURAL RESEARCH SERVICE

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AGROFORESTY SYSTEMS IN WESTERN OREGON

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Interest in agroforestry, the joint production of trees together with other agricultural plants and/or animals, is rapidly increasing in both the developing and the developed countries of the world. Burgeoning demand for food, fuelwood, commercial tree products, and cash income has resulted in deforestation and the conversion of natural forestland to other uses at ever accelerating rates. People, especially in developing countries, are evaluating agroforestry systems as a means to provide sustainable natural resource supplies while preserving forest lands.

Agroforestry is also seen as a mechanism to reduce erosion and soil nutrient exhaustion on converted forest lands, to reintroduce trees to former forest and woodlands, thus reducing the impetus to destroy the remaining natural forests and woodlands. With ever-diminishing timber supplies, the developed countries such as the United States and Europe face remarkably similar problems as those now playing themselves out in the developing world.

Agroforestry is not a new technology. It has been practiced in all parts of the world where trees and crops grow together. The staggering variety and the widespread presence of these "native" systems in areas ranging from the humid tropics to cold temperate climates, from subsistence agriculturalists to large commercial producers, clearly demonstrates the inherent attractiveness of agroforestry approaches.

The basic concept of agroforestry is to combine forest or horticultural trees together with crops and/or livestock in such a way that each component not only produces usable products (productive functions), but also contributes to conservation of land resources or directly facilitates production of other components (service functions). Livestock/timber systems, for example, produce forest and animal products. Forest trees provide shade for livestock, while livestock serve to control weeds and to recycle nutrients through their feces and urine. It is the presence of these service functions which makes well-designed and managed agroforestry systems more productive than are sets of their individual components.

The proper frame of reference for the productivity of agroforestry systems is the entire system rather than the individual component. For example, established trees are often strong competitors with ground vegetation for site resources. It is unrealistic to expect grass yields under conifer trees to be as high as that of open pasture or rangeland. Lower forage production may be more than compensated for by reduced heat or cold stress on livestock together with the concurrent production of timber products. The timber/livestock combination may be more biologically or economically productive than livestock grazing alone. Service functions are often a by-product of production (e.g. sheep eat and thereby control tansy ragwort, a toxic weed to cattle). Other benefits may also be obtained at relatively low cost (e.g. nitrogen-fixing plants produce nitrogen so that costly nitrogen fertilizers are not needed). Agroforestry systems tend to be low-input systems which require little in the way of fertilizer, pesticide, or other off-farm inputs.

Agriculture and commercial forest products are Oregon's two largest industries. Within agriculture, livestock production has the highest farmgate sales value of any commodity. In light of the great economic importance of Oregon's livestock and timber industries and our long tradition of producing livestock and forest products, it is not surprising that most agroforests in Oregon are timber/livestock (silvopastoral) or timber/pasture/livestock (agrosilvopastoral) rather than tree/crop (agrosilviculture) combinations.

The Oregon Agricultural Experiment Station, in cooperation with the U.S. Forest Service-Siuslaw National Forest, established a research project "Alternative agroforestry systems for western Oregon" in 1980. This project developed appropriate agroforestry technology that would produce livestock products while controlling brush and improving deer and elk habitat in coastal Oregon timber plantations. Livestock performance, dietary habits, and grazing impacts of sheep upon both Douglas-fir trees and understory vegetation were intensively monitored for bands of 600-800 open-herded sheep which grazed a series of clearcuts each year. Sheep spent several days in each clearcut, then moved on in a predetermined route. The results of this work are detailed in a series of recent articles (see additional readings list).

The general findings of this work were that: (1) sheep weight gains were less than those generally achievable on improved pastures, but were adequate to support commercial sheep production; (2) few sheep were lost to predators; (3) if sheep were adequately controlled and grazing of young plantations was avoided in the spring when new succulent young conifer growth was present, sheep controlled brush with relatively little browsing damage to conifer trees; (4) Douglas-fir tree height growth was increased by approximately 5% and diameter growth by approximately 6% by grazing; (5) and grazing improved feed resources available to deer and elk by stimulating resprouting of grasses and forbs so that younger, more nutritious forage was present in the summer-fall. Grazing also stimulated earlier commencement of forage growth in the spring.

Work continues on this study. Vegetation is being monitored to assess the longer-term effects of livestock grazing on development of the timber stand. A fundamental question that arose during the project was exactly what level of browsing constitutes "damage" to a conifer. A graduate student, Mr. Khalid Osman, is pursuing this question through a clipping study to see exactly how young Douglas-fir trees respond to known levels of foliage removal. His work is not yet complete, but the preliminary data we have and reports from researchers working on other conifers suggest that established young conifers are fairly tolerant of grazing.

The project was expanded in 1982 to include more intensive improved pasture/tree/livestock systems. Work was initiated in cooperation with researchers from the OSU Forest Science department on a medium potential forest site in McDonald Forest near Corvallis planted in 1979. The concept behind this study is that during the early portion (first 8-15 years) of a timber crop rotation, trees do not use all of the site resources. Extra resources which would normally tend to support brush and weeds may be channeled into a forage crop which would produce saleable animal products as a second cash crop. The combination of livestock with its early financial returns to investments, together with the much longer-term returns from commercial forest products, produces more even cash flow than would pure forestry. Treatments included forest plantations planted in a conventional 8x8 ft grid, planted in clusters of 5 trees each with 25 ft between clusters, and unplanted open pasture. Half of each plantation/pasture was seeded to subclover in fall 1982 and was grazed by sheep each spring and summer during 1983-1987. The other half of each plot remained unseeded and ungrazed.

Subclover was chosen as forage because we expected that it would not compete with trees for summer moisture. It would enrich the soil by fixing nitrogen and provide nutritious feed for sheep. Sheep provide defoliation required for subclover to prosper, control weeds, and convert organic nitrogen fixed by the clover into a soluble form (urine) available to trees.

Although average annual forage production during 1983-1987 was 5000 lbs/acre on agroforestry (subclover + trees + grazing) compared to only 2500 lbs/acre on forestry plantations, tree height and diameter growth were similar. Trees did not begin to reduce forage production below levels of open pasture until 1986. Agroforestry plantations produced only 74%, 62%, and 54% as much forage as did open pasture in 1987, 1988, and 1989, respectively.

Computer models based upon clipping plots every 3 ft along transects run from tree-to-tree suggest that tree planting pattern is as important as tree density in determining the degree of competition between trees and understory forage plants. For example, a 10-year-old plantation of 45 trees/acre planted in a grid has the same predicted forage production as 182 trees planted in rows of clusters.

Clearly, spatial distribution of trees offers a powerful tool to optimize joint tree/pasture production in timber plantations. Our findings about pattern also raise questions about the applicability of much mainstream silvicultural practices, which are dominated by homogenously planted trees to more intensively managed agroforests planted in other patterns.

The life of a timber plantation may be conceptually divided into four stages for agroforestry management purposes: (1) from planting until trees are successfully established (usually 1-2 years after planting), (2) when trees are established but use only a small portion of site resources (usually 2-7 years after planting), (3) when trees and forage compete for site resources because demands by both trees and forage together exceed available site resources (usually 7-15 years after planting), and (4) when trees control most site resources and most competition is between trees rather than between trees and understory plants. Grouping trees together into clusters or rows tends to significantly increase forage production in stage 3 only. Tree growth shows no effect of pattern yet, however, we would not expect this to become evident until stage 4.

Knowledge obtained from past practical experience and from available literature were incorporated into second-generation agroforestry plantations planted on a low potential forest site near Corvallis in 1988-90. Treatments included three replications of: (1) open pasture, (2) forest plantations of 230 trees/acre planted in a grid, and (3) agroforests with 230 trees/acre planted in single rows (8 ft between trees, 23 ft between rows) + subclover planted in 1988 + sheep grazing. Agroforest trees were planted in rows in order to reduce competition between trees/pastures, to facilitate handling of livestock, and to provide access for forage harvesting machinery should haying be desired. This design will support study of tree/pasture interactions as the timber stand develops. Agroforest productivity (forest products/forage/livestock) may be compared to its forestry (forest products) and pasture (forage/livestock) components to see if it we have met our goal of producing a system whose productivity exceeds the sum of its parts.

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FOREST GRAZING IN SOUTHWEST OREGON: PRINCIPLES OF LIVESTOCK MANAGEMENT AND RESULTS OF RESEARCH

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SUMMARY

Utilization of controlled livestock grazing to suppress vegetation competing with conifer seedlings is currently gaining favor as an alternative silvicultural prescription for coniferous forests of Oregon. Recent studies in southwest Oregon (Doescher et al. 1989; Alejandro-Castro 1987), western Oregon (Sharrow et al. 1989; Leininger et al. 1989), and northeastern Oregon (Krueger 1983) have shown that controlled livestock grazing can suppress herbaceous vegetation competing with young tree seedlings. Although additional research needs to be performed to heighten the compatibility of tree production and grazing, certain grazing management strategies are known that will enhance the use of livestock as a means to manipulate competing vegetation. The purpose of this paper is to introduce principles of livestock management useful in the development of forest grazing approaches. In addition, important research results from over six years of forest grazing research in southwest Oregon will be discussed.

Principles of Livestock Management in Forested Ecosystems

Historically, livestock grazing of forestlands has been criticized by the forest industry. This has been partly due to destruction of young conifer plantations by uncontrolled grazing. However, when livestock numbers, distribution and season of use are carefully controlled, damage to conifer seedlings is minimized (Alejandro-Castro 1987; Kosco and Bartolome 1983; Leininger 1983).

The following discussion describes factors that influence grazing behavior. An understanding of these relationships is necessary in order to minimize conflicts between grazing and wood production. It should be stressed that not all forested areas are suitable for grazing by livestock. Steep terrain and lack or absence of palatable forages, water, and salt may make the site unsuitable for livestock grazing.

Forage Availability and Grazing Animals

It is important to select livestock that fit the available forage resource of the area. Grazing animals tend to be predictable in the types of forages they consume (Heady

1964). Cattle are primarily grass eaters, but will consume browse and forbs when grasses are unavailable or become mature and coarse. Sheep will eat grasses when they are succulent, but are prone to browse shrubs to a greater degree than cattle. Although conifer seedlings are relatively unpalatable to grazing animals (Kosco and Bartolome 1983; Leininger 1983), elimination of forage species will generally result in greater browsing to trees. The use of cattle as a silvicultural tool is best suited to sites with an understory of palatable grasses. If the site is dominated by shrubs, it may be best to graze the area with sheep.

Season of Grazing

Livestock browsing of conifer seedlings is generally greatest on the current year's succulent growth (Leininger 1983). Sheep should graze forested areas during periods before or after bud break (Black and Vladimiroff 1963; Leininger 1983).

The timing of seasonal cattle grazing is critical for successful control of competing vegetation. Defoliation when plants are actively growing will impart the greatest reduction in vigor (Moser 1977). For cool-season grasses, the critical period for defoliation is during development of seedheads. For shrubs, browsing during periods of active twig elongation will most likely result in the greatest reduction in competitiveness of the plant. Appropriate timing of grazing will not only decrease above ground production, but will also reduce rooting depth and rooting mass. Timing of grazing to coincide with critical periods in the growth cycle of forage species will help reduce their competitiveness. Unfortunately, this timing may also coincide with bud break in conifer species. Having a forage more palatable than the tree seedling available for cattle will reduce browsing impacts to trees.

Integration of cattle grazing with forest management requires careful consideration of the periods of growth of each plant species. Our experiences in southwest Oregon have indicated that cattle may successfully graze forest plantations even during periods of active bud burst when highly palatable forages have been established on the site. Through seeding of palatable species (such as perennial ryegrass [Lolium perenne]) and orchardgrass [Dactylis glomerata]), conifer development may be enhanced because:

1. They serve as an attractant, with cattle and wildlife preferring to graze these plants rather than conifer seedlings.

2. They minimize the growth and development of undesirable shrub and herbaceous species.

Intensity of Use

Controlled cattle grazing under light and moderate grazing intensities does not appear to adversely affect conifer regeneration (Kosco and Bartolome 1983). The amount of time cattle are grazing must be carefully regulated to prevent depletion of forage resources and shifting of cattle food preferences to trees. When livestock are carefully controlled, research has indicated a significant increase in height and/or diameter growth of trees under grazed versus not grazed conditions (Hedrick and Keniston 1966; Krueger 1983; Leininger 1983; Doescher et al. 1989). It is important to recognize that grazing of competing vegetation must be severe enough to reduce plant vigor. From our experience in southwest Oregon, repeated grazing of seeded orchardgrass to a stubble height of about 7-12 cm (2.7-4.7 in) during the grazing season will reduce the competitiveness of this plant.

Forest Grazing Research in Southwest Oregon

Since 1984, studies have been conducted in southwest Oregon to determine the feasibility of using cattle to graze competing vegetation during the first year of plantation establishment. The studies were part of a cooperative program between Oregon State University, The Bureau of Land Management, and local livestock producers.

A controlled grazing prescription was developed to maximize suppression of competing vegetation and promote growth and survival of both Douglas-fir and ponderosa pine seedlings. The grazing management strategies employed in this research have the following four key components:

1. Grazing the plantation early in the season so that ample soil moisture is available for the tree seedlings. It is important not to graze when soils are saturated so as to avoid compaction, but to put animals on the plantation when competing vegetation is first starting active growth.

2. Grazing the plantation at a stage of plant phenology when the palatability differences between conifer seedlings and herbaceous forages are maximized. Typically, for grasses this is in the stage of development prior to the exertion of the flowering stems.

3. Grazing must be intensive enough to reduce the demand for soil water and nutrients by the herbaceous vegetation. Intensive grazing of forages will reduce the amount of leaf area and reduce the extent of root development in grazed plants. This will increase the availability of soil moisture and nutrients to tree seedlings.

4. Grazing regrowth may be necessary to achieve good suppression of competing vegetation. Because growing conditions in late spring and early summer often are favorable for regrowth, repeated grazing of herbaceous forages will maximize reductions in their competitiveness with tree seedlings.

Important Research Findings

Three separate research studies assessing the feasibility of controlled cattle grazing to promote conifer growth and establishment have been conducted since 1984. Because of space and time limitations, we will not provide detailed results from each study. Rather, we will present the consistent findings between all three studies, and also report on some unique results from the most recent of the three studies conducted.

In general, early-season grazing increases availability of soil moisture and enhances growth of tree seedlings. Figure 1 shows pre-dawn water relation values during 1986 for Douglas-fir on the Salt Creek study site between grazed versus ungrazed treatments. The area had been grazed in 1984, 1985, and 1986. Trees on grazed plots had less moisture stress early in the growing season than did trees growing on the ungrazed plots. After June 27, no statistically different results were found between the two treatments. Table 1 shows tree growth response on the same site at the end of 1986. Both ponderosa pine and Douglas-fir seedlings exhibited enhanced growth in areas grazed by cattle than in areas left ungrazed.

Table 1. Mean growth measurements of ponderosa pine and Douglas-fir in 1986 for grazed (G) and ungrazed (UG) treatments at the Salt Creek Study Site.

	Ponderosa Pine		Douglas-fir	
	Treatment			
Seedling Characteristics	G	UG	G	UG
Diameter (cm)	3.3a[1]	2.6b	2.1a	1.6b
Height (cm)	94.4a	82.1b	74.6a	69.5a
Volume (cm^3)	388.0a	213.5b	137.5a	71.0b
Non-Nodal Buds (nos.)	-----	-----		6.1a4.5b
Sample Size	45	45	46	40

[1] Different letters within each row denote significant differences ($p < .05$) between seedlings in the G and UG competitive environments.

In addition, some unique results have been found on the Sugar Pine Flat Study site. Begun in 1986, this research further examined vegetational response to controlled cattle grazing and addressed root system dynamics as well as aboveground vegetation response. In this study, four treatments were applied to ponderosa pine and Douglas-fir seedlings on a 35-acre clearcut. These four treatments were: (1) paper mulching of Douglas-fir seedlings, (2) cattle grazing of natural establishing vegetation, (3) cattle grazing of seeded forages (orchardgrass and perennial ryegrass), and (4) no grazing of seeded vegetation. Detailed records of survival, tree growth, cattle browsing, and root system growth (as measured by the root periscope) were kept. Important conclusions to date found on this study site include the following:

1. Late-spring frost was found to be more important in decreasing survival of Douglas-fir seedlings than was competition from herbaceous vegetation. Ponderosa pine survival appeared not to be affected by either frost or herbaceous competition.

2. Survival of Douglas-fir seedlings was lowest on the seeded grazed treatment (Figure 2), probably a result of the interaction between: (a) severe late-spring frosts in 1987 and 1988; (b) cattle-caused stem scarring and browsing; and (c) drought stress. We speculate the grazing lowered the insulative canopy of seeded forages and therefore increased the probability of freezing injury to Douglas-fir.

3. Survival of ponderosa pine seedlings was high on all treatments (Figure 3). Most mortality occurred during the first growing season and later from porcupine girdling. Extreme browsing by cattle in August 1987 did not adversely affect the survival of this species in the seeded grazed treatment; however, subsequent growth was impacted adversely (Figure 4).

4. Repeated defoliation of orchardgrass, the dominant seeded forage, during active growth periods in the spring and early summer significantly reduced the number of roots in the soil to a depth of 0.7 m (Figure 5). This decrease in number of roots on grazed sites contributes to improved soil moisture availability for conifer seedlings.

CONCLUSIONS

Controlled cattle grazing beginning the first year of plantation establishment can result in enhanced growth of conifer seedlings. Factors that are crucial to controlled cattle grazing and subsequent enhanced growth of conifer seedlings are becoming better understood through this research.

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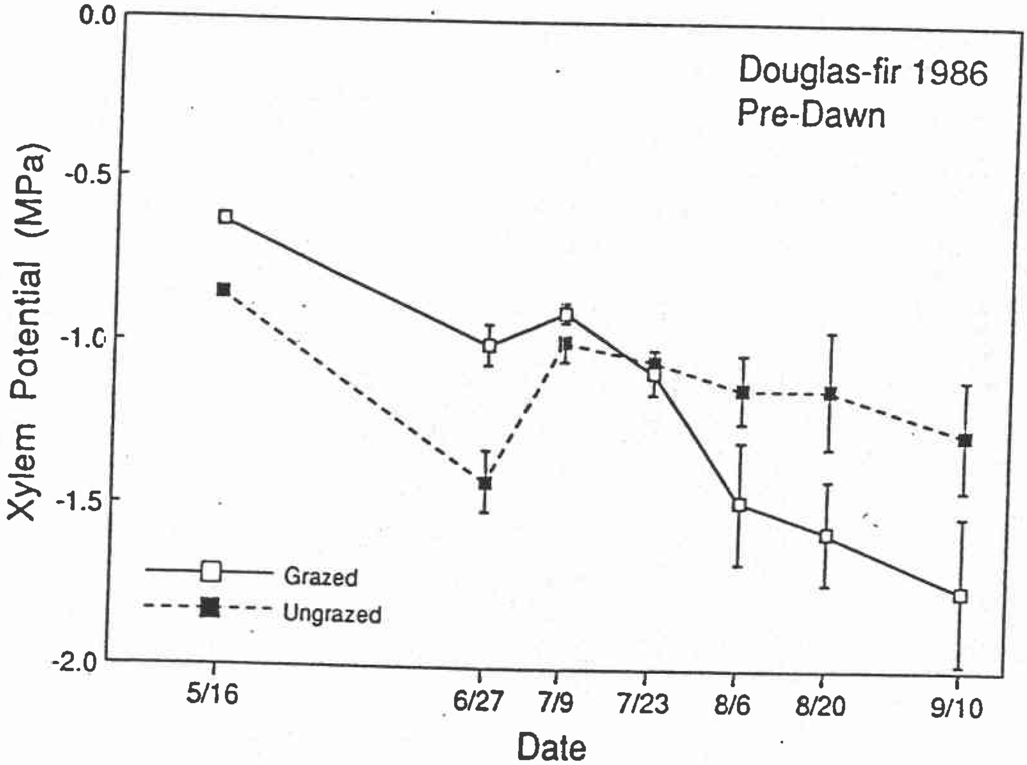

Figure 1. Predawn xylem potential (-MPa) of Douglas-fir in 1986 at the Salt Creek study site. Standard error bars are shown about each mean. The more negative the value is, the greater is the degree of moisture stress.

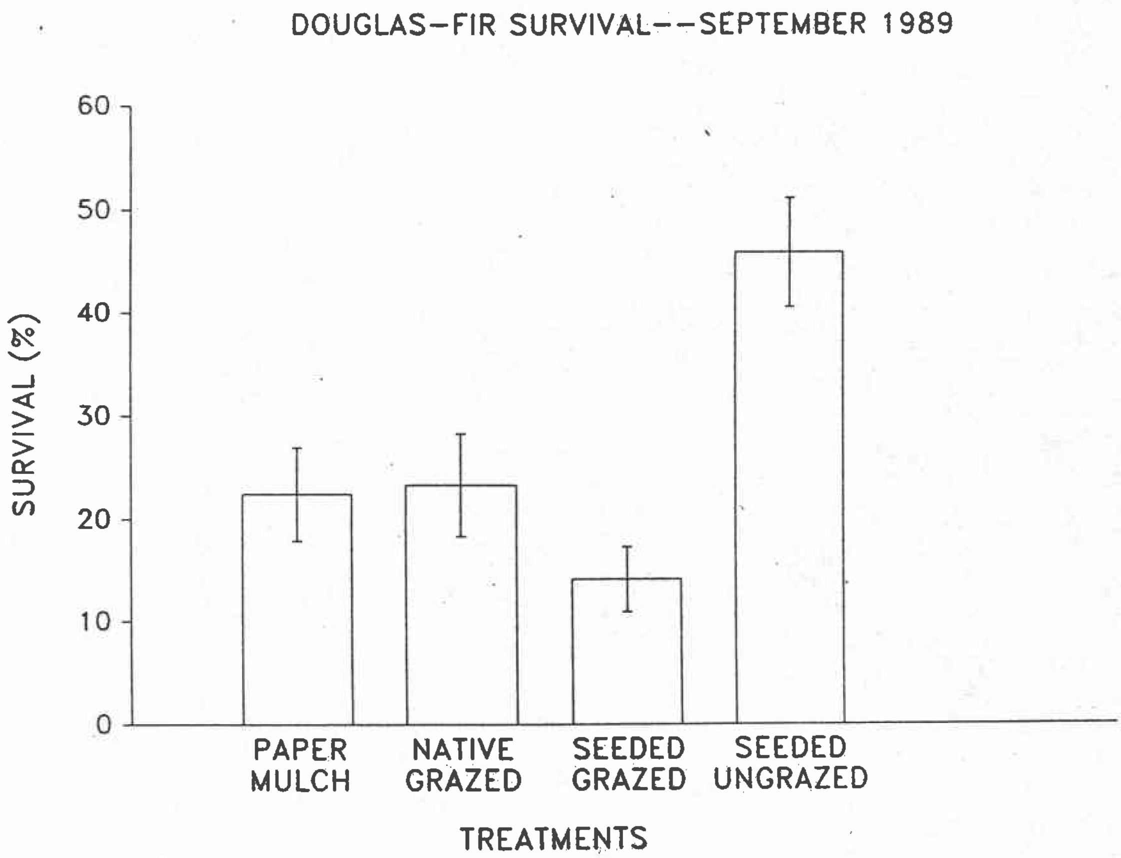

Figure 2. Douglas-fir survival ($\bar{x} \pm$ SE, %) on the Sugar Pine Flat research area in southwest Oregon, September 1989; n = 15 for each treatment.

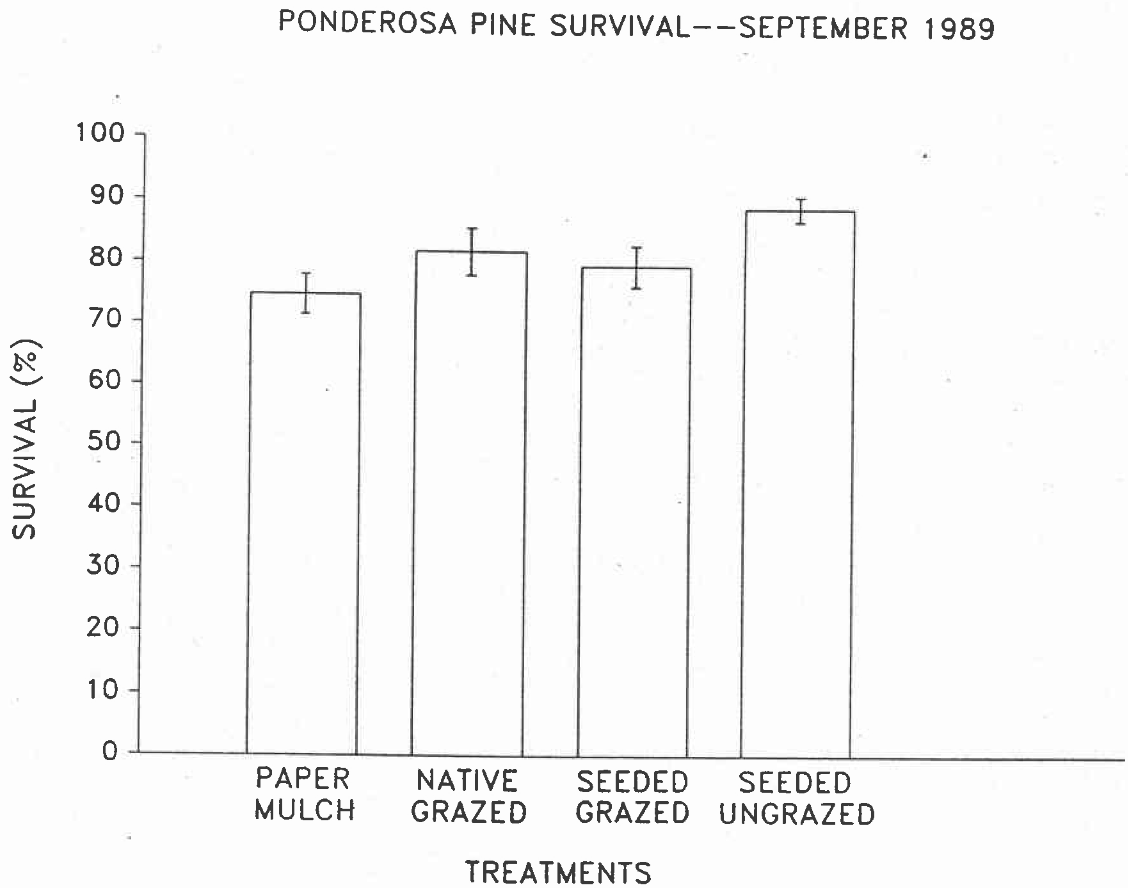

Figure 3. Ponderosa pine survival ($\bar{x} \pm$ SE, %) on the Sugar Pine Flat research area in southwest Oregon, September 1989; n = 15 for each treatment.

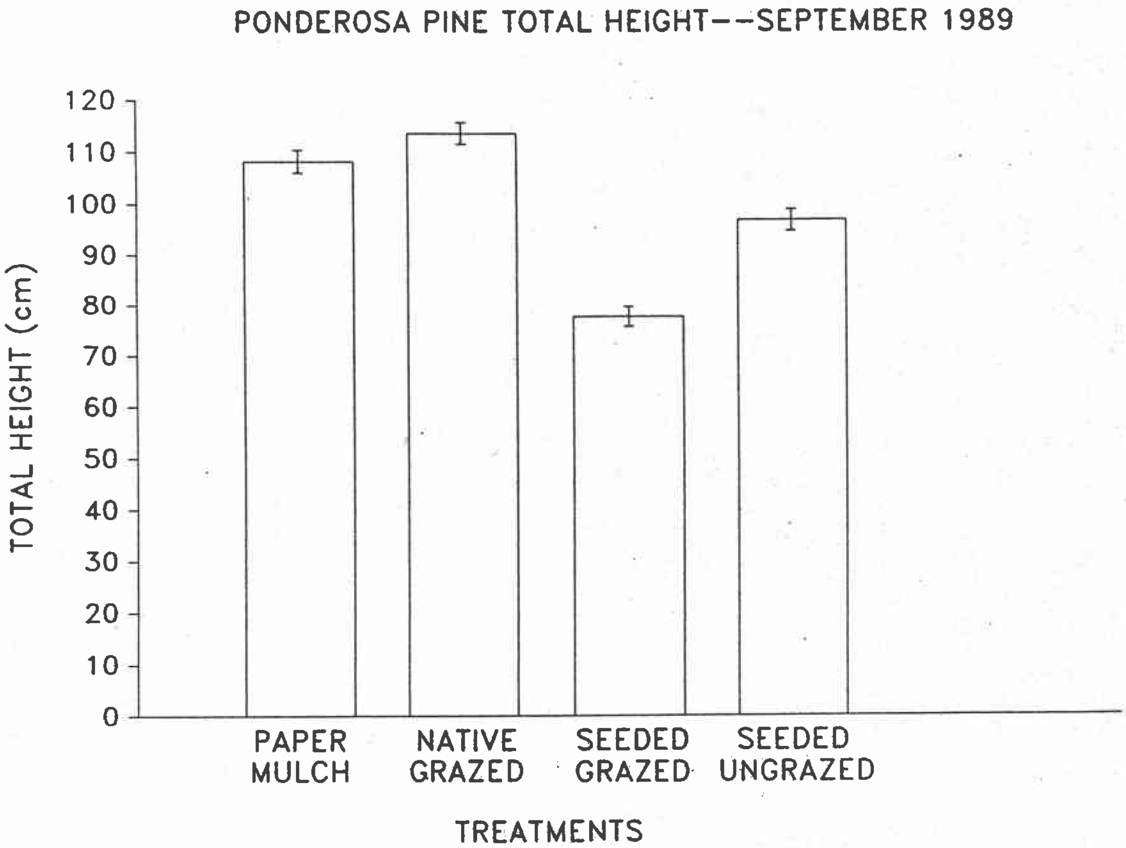

Figure 4. Ponderosa pine total height ($\bar{x} \pm$ SE, cm) for the Sugar Pine Flat research area in southwest Oregon, September 1989; n varied from 142 to 174 across treatments.

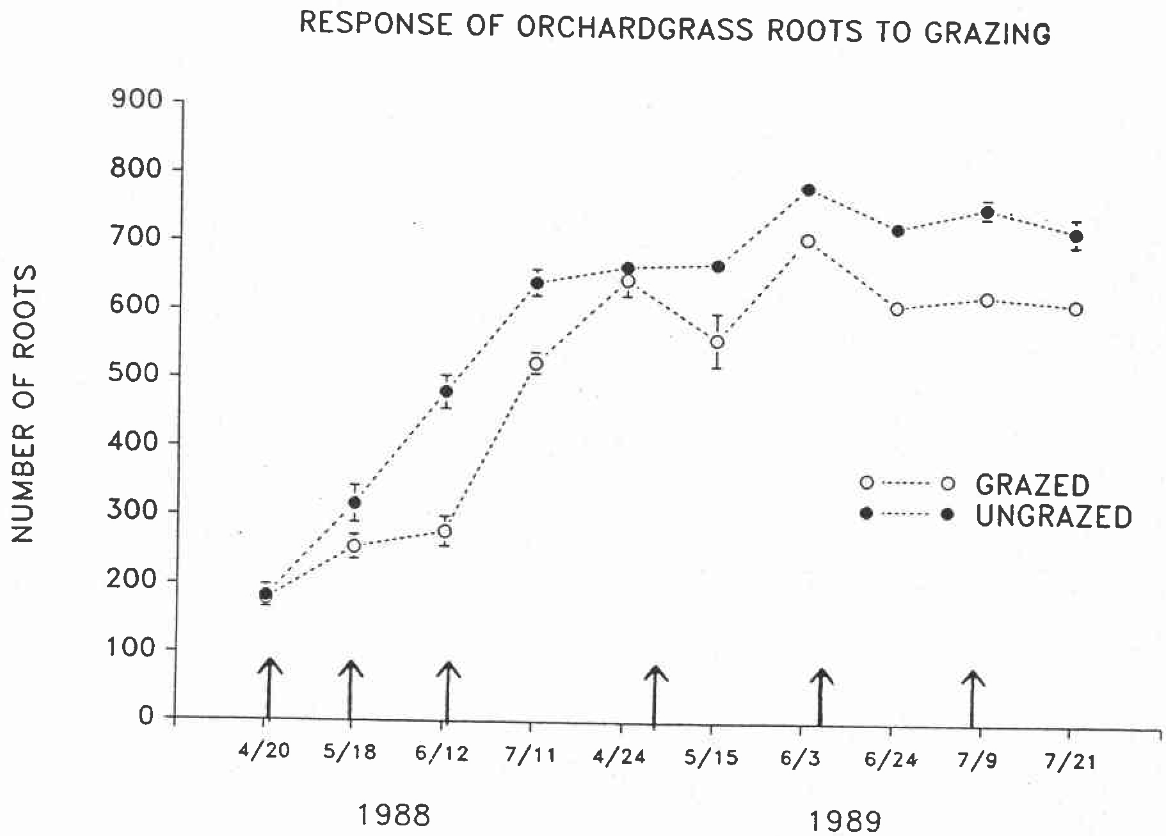

Figure 5. Number of roots ($\bar{x} \pm$ SE) counted with the root periscope/mini-rhizotron technique to a depth of 0.7 m for grazed and ungrazed orchardgrass on the Sugar Pine Flat research area in southwest Oregon during the 1988 and 1989 growing seasons. For 1988, n = 9 (ungrazed) and 12 (grazed); for 1989, n = 6 (ungrazed) and 5 (grazed). Upright arrows along x-axis represent grazing events.

FOREST GRAZING IN SOUTHERN OREGON: A FORESTER'S PERSPECTIVE

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A forester's perspective on forest grazing depends on the landowner/land manager's objectives and constraints. A small woodland owner will probably have a different view than a large private timber company, whose perspective is likely to be different from a state or Federal land manager. Ecological issues, profit motives, budgetary constraints, administrative considerations, legal guidelines and policies, and the impact of societal values vary by landowner. Public land managers have historically provided forest grazing opportunities under the multiple-use concept, often with little regard for other forest values beyond forage availability, palatability, and carrying capacity for livestock. Private foresters have usually scorned forest grazing on fee lands as administratively expensive and without redeeming ecological benefit to growing timber crops, except where "good will" with neighbors is valuable. In such cases, industrial landowners have often been leaders in the development of forest grazing strategies to use livestock as silvicultural tools.

Historically, the professional foresters' view of livestock in the woods has been primarily negative, especially in the context of uncontrolled grazing in large allotments under the multiple-use philosophy. However, research and operational experience in the last decade have demonstrated that carefully designed and implemented grazing prescriptions can help meet, or at least minimize conflict with, an assortment of different land management objectives (Krueger 1986). Rapidly changing public attitudes regarding the management of forestlands may further influence the perception of forest grazing. Traditional management tools such as prescribed fire and pesticides are increasingly constrained and, as a result, many foresters are seeking alternative vegetation control measures such as prescriptive livestock grazing (Doescher et al. 1987). On the other hand, issues such as protecting natural ecosystem stability and biodiversity may impair the freedom of domestic livestock in the woods.

The greatest conflict between livestock and foresters typically occurs during the reforestation stage. Without careful control, livestock grazing has resulted in a legacy of disaster in many young plantations. The common solution has been to delay grazing of such areas until trees are out of reach of browsing or have sufficient stem and crown to withstand some defoliation or rubbing. However, by that time, succession is beginning to move ahead and the opportunity to utilize some of the most nutritious transitory forage may have been missed.

In southwest Oregon, the environmental factor limiting successful reforestation on most sites is lack of moisture as a result of hot, dry summers and abundant, well-adapted competing vegetation (Hobbs et al. 1983). Lack of water can lead to lower seedling survival initially, and to growth and survival losses later on after establishment. In most cases though, research has shown that if competing vegetation can be controlled, stored soil moisture is adequate for both seedling survival and growth (Stewart et al. 1984). When livestock grazing is applied as a silvicultural tool, it must often be applied in the first growing season after planting and early enough in the year to reduce water use by competing plants that are phenologically active before the conifers (Doescher et al. 1987). This puts livestock in the plantation when seedlings are small enough to be severely damaged by browsing and trampling, as well as early enough in the growing season to expose tender new shoots and loose bark to livestock. However, if survival benefits are to be gained, early and heavy grazing appears necessary. This is especially true where herbaceous plants are the primary competition, as grasses and forbs cause most mortality in 1- to 3-year-old plantations (McDonald 1986). This also provides an opportunity to reduce the vigor of or perhaps kill germinating shrub seedlings before a root system is established. Closely controlled grazing programs have successfully limited development of competing vegetation and improved conifer seedling water relations, but few data are available that document immediate growth enhancement in very young plantations (Doescher et al. 1989). However, repeated grazing in herbaceous-dominated communities may lead to longer-term conifer growth benefits (Hedrick and Keniston 1966).

Grazing in stands where shrubs have become established can be used to promote either growth or continued survival. There are situations on droughty sites where browsing of shrubfields for release may also reduce mortality losses. For example, during the recent drought cycle, some stands of apparently established 5- to 10-year-old conifers, with canopies above the shrub cover, suffered heavy losses. In areas where the lower shrub layer had been controlled by vegetation management, mortality was usually much less.

When established shrubs are grazed to promote conifer growth (i.e. release), grazing can often be conducted later in the growing season as long as future leaf area can be reduced. Shrub cover reductions have been documented for typical plant communities in southern Oregon and northern California, but improved growth of conifers has been less obvious in the short term (McDonald and Fiddler 1988, Allen and Bartolome 1989). It appears that 6 - 8 years of annual browsing may be necessary before trends in enhanced growth are apparent, and perhaps 10 years of browsing before statistically significant differences are found (McDonald 1990, personal communication). However, once such differences begin to occur, it is likely the diverging growth patterns will continue into the future, with trees in repeatedly browsed plantations perhaps growing substantially better over time.

For prescriptive grazing to be accepted by foresters, the livestock must be viewed as a silvicultural tool, with the management objective of controlling competing vegetation taking top priority. This is not a business as usual situation, and the goal is not to simply provide forage for stock, but rather for stock to help achieve very specific objectives. In some cases this may mean a less than desirable situation for the stockman, in terms of logistics, animal gains, and so forth. Terms of such arrangements must be carefully thought out and the stockman fairly compensated so that long-term operating relationships may be fostered. Economies of scale (eg. 1 acre vs. 10,000 acres), ownership patterns (eg. checkerboard vs. large continuous blocks), and importantly, time perspective (eg. short vs. long term) are other issues influencing foresters' perspectives on forest grazing. For example, the very large contiguous Weyerhaeuser Company ownership in southern Oregon and large associated harvest units permits logistically simple forest grazing plans. On the other hand, the checkerboard ownership pattern of the Bureau of Land Management in the Cascades, with much smaller (10 - 60 acre) harvest units and more scattered concentrations of high quality forage presents a much greater administrative challenge for the agency. Checkerboard ownership is also a logistical challenge for the stockman, as animals must often be transported greater distances between grazing units.

The effect of forest grazing on other forest values is another issue. Concerns over forest and ecosystem health, ecological stability, and biodiversity, as well as higher priorities for aesthetics, are receiving much attention. Impacts of grazing on forest values can be associated with either prescriptive or multiple-use programs. The aesthetics issue might be minimized by strategic location of sacrifice zones, where livestock congregate for bedding, water, or salt.

Other issues may need a closer look. For example, one of the key components of a prescriptive grazing program is provision for palatable forage, either natural or through seeding of exotic forage species (Doescher et al. 1989). Such seeding programs can help minimize damage to conifers, but can also have significant impact on the local ecosystem. Seeding of non-native species can alter successional dynamics, affecting both the plant and animal components of the community. Heavy stands of grass can prevent normal development of shrubs that provide critical structure and forage for certain species of wildlife (McDonald and Oliver 1984). Conversion to grass-dominated forage may result in a population explosion of pocket gophers or other rodents that negatively affect a planned reforestation effort (Crouch 1979). Some ecologists would argue that early successional development in southwest Oregon plant communities has been substantially altered in the last century by the introduction of exotic herbaceous plants that affect soil biology and species composition after disturbance (Newton 1981). Alternatively, not all forage seeding impacts are negative. There can often be benefits to deer and elk populations, on a site-specific-basis.

So, how do we develop rational, defensible forest grazing programs that are likely to be as palatable as possible? To us, the best approach is to carefully set objectives and then develop an ecologically defensible operational approach to implement these objectives. Most southwest Oregon forests are the product of natural disturbance, and disturbance is typically required for the long-term health of the forests. Forest grazing may be able to provide some elements of various disturbance regimes.

We suggest assessment of the plant community associated with each forest grazing opportunity with respect to:

1. Plant species abundance and community structure.
2. Management history of the site.
3. Successional dynamics of the community.
4. Potential community responses to disturbance.
5. Management options that are available.
6. Availability of financial and technical resources.
7. Stand and landscape level impacts.

Such an analysis may ultimately provide an ecologically defensible rationale for either prescriptive or multiple-use grazing. It also makes sense from a manager's point of view because it can incorporate operational feasibilities, costs, and administrative issues with ecological principles.

CONCLUSIONS

Southwest Oregon forests are compositionally and structurally diverse and are managed for a variety of values. Forest grazing over the years has impacted these ecosystems, with some impacts viewed negatively by foresters and ecologists. Improved information on the ecological implications of grazing, changing availability of other silvicultural tools, and changing views on prescribing grazing to meet defined management objectives may lead to improved credibility of this practice in the future, particularly on public lands. However, while the current information base documents the ability of controlled grazing programs to meet a variety of vegetation management objectives, improvements in conifer survival and particularly growth have been difficult to document, and may take 5 to 10 years of annual grazing to appear. Prescriptive forest grazing should not be viewed as a panacea that will replace all existing vegetation management tools, but rather as one that should be considered with others on a site-specific basis. Any proposed forest grazing program should be evaluated within an analytical framework that identifies tradeoffs in ecosystem structure and function.

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PRESCRIBED GRAZING AND SILVOPASTORAL AGROFORESTRY: AN ECONOMIC PROBLEM ANALYSIS

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THE FRAMEWORK FOR ECONOMIC ANALYSIS

Forest grazing, plantation grazing, agroforestry, silvopastoralism, prescribed grazing: these five related concepts all suggest that somehow and in some cases there are advantages associated with the combination of animal husbandry and silviculture. Those advantages may, in the instances of agroforestry, silvopastoralism, forest grazing, and plantation grazing, take the form of multiple use, or as some economists would call it joint production processes and multiple enterprises.

The underlying idea behind these terms is that the simultaneous production of both wood and livestock products (multiple use) can result in more net benefit (or net return) to a given management unit (land area) than can single use management and the production of either wood products, or livestock products, but not both. Prescribed grazing is a little more specific and may not necessarily imply the production of wood products. Here, livestock are used as a vegetation management tool to achieve a nonlivestock objective or benefit, such as improved wildlife habitat or increased production of commercial timber.

All five concepts have the same underlying theme, however. There are circumstances under which livestock and wood (or other) production objectives may be complementary rather than competitive. Those complementary objectives, from the standpoint of economics, are the subject of this paper. The costs, benefits, and tradeoffs to private users and to the public at large, are identified, summarized, and interpreted. The major finding is that prescribed grazing is economically feasible from the public, but not necessarily from the private livestock operator's, perspective. In contrast, silvopastoralism as a specialized type of agroforestry, by definition a form of multiple use, makes economic sense.

Types of Management Strategies and Practices

To better understand differences in complementary objectives involving joint production of livestock and wood products, operational definitions of the five related concepts are needed. For the purposes of this paper, agroforestry is a management strategy under which at least one agricultural and one silvicultural activity are simultaneously practiced on the same parcel of (forested) land. If the agricultural activity is livestock grazing we are dealing with a silvopastoral management strategy that can be called silvopastoral agroforestry.[1] Other agroforestry management strategies include understory production of some food or fiber crop other than livestock, or alternating strips of crops or forages between tree hedgerows (as in tropical and subtropical "alley cropping").

In the United States, silvopastoralism takes one of two forms. In the timbered area grazed by livestock is a woodlot or forest in which the trees are allowed, at least in part, to naturally regenerate, we are dealing with a category of agroforestry called forest grazing. If artificial regeneration is used to develop and subsequently maintain the tree crop, we are dealing with a slightly different category of agroforestry called plantation grazing.

Prescribed grazing is better conceptualized as a management practice rather than a management strategy. Here, domestic livestock are used as a means to achieve some resource management end <u>other</u> than the production of red meat or other livestock products.[2] Hence, prescribed grazing is a management tool analogous to prescribed burning.

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[1] In the United States, the two primary classes of domestic livestock used in both prescribed grazing and silvopastoral agroforestry are beef cattle and sheep. Other species, including goats and llamas, are often used in agroforestry activities in developing countries. Since the latter two livestock species are browsing animals that may include a substantial portion of woody vegetation such as shrubs and brush in their preferred diets, they may under some conditions have potential in prescribed grazing and/or programs in the United States. The term "and/or" is intentional since in some circumstances domestic livestock grazing on forests and woodlands may serve both prescribed and joint production purposes.

[2] Although they are widely used in the range and forest science literature, none of these terms are operationally defined in the Range Management Glossary (third edition) published by the Society for Range Management. The definitions used here are based on the context in which the terms are used in the professional literature referenced in this paper. A further distinction may be drawn between **prescribed grazing** and **prescription grazing**. The latter term refers to a well designed and site specific livestock grazing system that may be totally unrelated to tree production. Marsh (1990, p. 101) offers the following definition of prescription grazing: "Prescription grazing is a single, or a series of, specific, purposeful grazing(s) by livestock, on any identified grazing management unit, according to prescribed controllable elements, in order to achieve two or more of a combination of pre-defined goals expressed in terms of the land, the animals, and the economics of the operation." According to this definition, if one of the defined goals is in fact tree production, Marsh's definition of prescription grazing would coincide with intensively managed silvopastoralism as that term is used in the present paper.

Basic Approaches to Economic Analysis

The reason why it is important to distinguish between prescribed grazing and silvopastoral agroforestry is that the type and depth of the required economic analysis depends on whether domestic livestock grazing is used as a means toward some other end, or whether livestock production is an end in itself. In essence, the economic analysis of prescribed grazing is easier than the economic analysis of silvopastoral agroforestry.

Prescribed Grazing and Cost Effectiveness Analysis. In prescribed grazing, domestic livestock are simply one of several vegetation manipulation instruments available to the resource manager (Tesch and Korpela, 1990). Other practices can be used to achieve the same end, and it is assumed that the manager will select a management tool that will allow him or her to achieve the desired level of control over undesirable vegetation. The alternative vegetation manipulation practices potentially available to the manager include herbicides, mulching, fire, and manual (including mechanical) removal of undesirable vegetation—as well as tightly controlled grazing by domestic livestock. The economic question to be answered is whether or not, and under what circumstances or conditions, prescribed grazing is cost effective relative to these alternative practices.[3]

Silvopastoral Agroforestry and Economic Feasibility Analysis. In both silvopastoral agroforestry and prescribed grazing there are benefits as well as costs associated with the livestock grazing activity. However, the types and values of benefits are much more relevant in the economic evaluation of the silvopastoral management strategy. This is so because in silvopastoral agroforestry the production of red meat or other livestock products is an end itself—along with the production of wood products. Hence, in the case of silvopastoralism, the nature or identity of both costs and benefits must be known before the bottom line can be answered: "Does grazing pay?" The fundamental question, of course, is "Does agroforestry pay?" when the agricultural enterprise in question is domestic livestock grazing.

A key, and related, question in the economic evaluation of silvopastoral agroforestry is "For whom does grazing pay?" One useful way of answering this question is to group the benefits and costs of domestic livestock grazing in silvopastoral agroforestry (and in

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[3] The term "cost effectiveness" as used here is taken from Randall (1987, pp. 277-278): "Cost effectiveness analysis seeks to identify the least-cost way in which to achieve a given objective, without asking whether there is any economic justification for achieving that objective...If benefits may be quantified, but not in economic terms, though costs are economically quantifiable, the cost effectiveness criterion provides guidance as to the least-cost method of obtaining the specified benefits."

prescribed grazing when there is reason to be interested in associated benefits) into two sets—public benefits and costs (the values of gains, losses, and net benefits accruing to society at large) and private benefits and costs (the revenues, costs, and net returns accruing to the private resource owner).

The distinction between public and private values stemming from livestock grazing on wooded and other lands is significant because the feasibility of grazing in the prescribed and joint production contexts depends, in part, on who captures the benefits in their various forms, and who pays the costs. It is possible for silvopastoral agroforestry to be privately feasible but publicly infeasible, and vice versa. The same holds for prescribed grazing. These possibilities exist because there may be both commodity and amenity benefits and costs associated with prescribed grazing and agroforestry. While commodity benefits and costs usually accrue to private individuals (livestock operators and forest/woodlot owners), amenity benefits and costs generally accrue to the public at large rather than to the private resource owner or user.

<u>Relevant Analytic Techniques and Economic Concepts</u>. In economics, two conceptually similar but in practice quite different approaches are used to address the private versus public feasibility questions. From the private perspective, the livestock and/or woodland owner is interested in the financial feasibility of forest or plantation grazing. The relevant economic techniques are budgeting (enterprise budgets, partial and capital budgets, cash-flow budgets) and whole farm or ranch plans (Torell and Tanaka, 1990). Observed or expected market prices and interest rates are used to assess the financial feasibility of livestock grazing on forests or tree plantations with appropriate allowances for risk.

From the public perspective (meaning society at large), the American taxpayer whose interests are represented by the federal land management agency and the public land manager, the economic efficiency of forest or plantation grazing is of greater interest. Here, the relevant techniques are used to estimate the expected net benefit of public agroforestry. These techniques include benefit-cost, risk-benefit, and net present value analysis. The data used in the analysis represent values obtained under optimal economic conditions. In economic efficiency analysis, all types of benefits and costs are efficiently valued—where efficient values usually differ from observed or expected market prices. If the economic efficiency analysis is dynamic (meaning that benefits and costs are incurred over time), social discount rates reflecting the opportunity cost of deferred consumption to society at large are used instead of observed or expected market interest rates.

The jargon used in economic efficiency analysis may seem esoteric, but the underlying logic is the same as in the more familiar financial feasibility analysis. Values are used instead of prices, and the scope of the measured values is extended to types of benefits and costs that society, but not necessarily individual resource owners, experience.

THE COSTS OF LIVESTOCK GRAZING ON FORESTS AND WOODLANDS

As has been said, in the economic analysis of either prescribed grazing or silvopastoral agroforestry, costs must be estimated. These costs may be either private (prices and interest rates) or public (values and discount rates). Private costs are relevant if the commercial woodland is privately owned, while public costs are relevant if we are dealing with domestic livestock grazing on a public (national or state) forest. Both sets of costs can be further subdivided into costs accruing to livestock owners and costs accruing to forest resource users.

The Private Costs of Livestock Grazing on Forests and Woodlands

On privately owned woodlands that are not currently grazed by domestic livestock, the livestock operator may be either the woodland owner or a tenant. In either case, the same questions are raised: "How much higher (or maybe lower) will be my costs if I graze my stock on these wooded areas rather than on the cleared pastures or open ranges that I already use?" "Will my stock stay healthy and gain weight while in the woods or forest?" It is the difference in forage utilization costs (the first question) and animal performance (the second question) as transformed into revenues from the sale of livestock products that are relevant to the private livestock operator.

The private woodland owner also will be concerned with costs, but in this instance the costs of harm or damage to trees done by livestock. In a parallel fashion to the structure of livestock costs, tree costs will be assessed on the basis either of the cost of repairing the damage done to the trees, or the amount of revenue ultimately foregone because the quality or quantity of stumpage was reduced due to the effects of livestock grazing.

<u>Livestock Costs</u>. Since in almost all circumstances the livestock will graze in the woods for only part of the year, private forage utilization costs should be categorized in the same manner as public permit or allotment forage utilization costs. A categorization scheme often followed in the analysis of forage utilization costs breaks these costs into the following groups: (1) turn-out, (2) gathering and take-off, (3) management, including checking and herding, (4) maintenance of improvements on the parcel, (5) salting, supplemental feeding, and medication including veterinary expenses, (6) meetings and communications, (7) fees and rents, and (8) other costs including stock round up due to vandalism and gates being left open, monitoring range or pasture condition, etc. Each of

these cost items may have cash and noncash components. The costs usually are reported on a cow animal unit month (AUM) basis.[4]

Estimates of average per AUM costs for each item and for different ownerships and regions may be obtained from a number of sources, including Lambert and Obermiller (1983). If they are known, the operator should use his or her existing costs for pastures and ranges that would be used in lieu of the wooded parcel. The difference between these existing costs and expected costs on the alternate wooded parcel, by item and in total, provide the basis from which the expected change in forage utilization costs incurred by substituting the wooded parcel for the existing range or pasture is estimated.

Because damage to trees, and particularly seedlings, is of great concern in both prescribed grazing and silvopastoral agroforestry, considerable emphasis is placed on controlling the intensity, distribution, and timing of livestock grazing in wooded areas to minimize the damage done to trees by domestic livestock (Ohlson, 1985; Leininger, 1983; Kosco and Bartolome, 1983). The result is substantially higher management and monitoring costs. Again due to management intensity requirements, salting costs may be higher in forest, plantation, and prescribed grazing. If the parcel is publicly owned, veterinary and medicine costs will be higher as well (Ohlson, 1985). Typically, water facilities may have to be developed, as may exclosure and possibly exterior fences, leading to higher maintenance and improvement costs. Higher levels of management intensity may lead to greater communications and meetings costs as well (Richmond, 1983).

Some, but probably not all, of these higher forage utilization costs in silvopastoral agroforestry and prescribed grazing may be offset by lower gathering and take-off costs (due to closer management while the livestock are in the wooded area), and by lower rents and fees (which in the instance of prescribed grazing are sometimes waived in recognition of the role of the livestock as suppressors of undesirable vegetation). It generally can be concluded that on a per AUM basis, forage utilization costs will be

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[4] An AUM is defined in "A Glossary of Terms Used in Range Management," published by the Society for Range Management as "The amount of dry forage required by one animal unit (one mature cow of approximately 1,000 pounds, either dry or with calf up to six months of age, or their equivalent, based on a standard amount of forage consumed) for one month based on a forage allowance of 26 pounds per day." An animal unit conversion factor is in turn defined as "A numerical figure expressing the forage requirements of a particular kind or class of animal relative to the requirement for an animal-unit." Since the cow is the reference animal in the definition of an animal unit, when addressing the dry matter forage requirements of different species of domestic livestock during a given interval of time, it is necessary to use the species name as an adjective, ie, cow AUM and sheep AUM. Otherwise, the equivalent dry matter requirements of the two or more species being discussed cannot be calculated.

higher in a silvopastoral agroforestry or prescribed grazing setting than in the singular livestock enterprise context.

Animal performance under these same circumstances sometimes (not always) is poorer than in open range and pasture situations. The two most commonly identified performance deficiencies are lower average daily gains (ADG), particularly for lambs and calves, and smaller lamb or calf crops. If breeding occurs while the ewes or cows are on the wooded parcel, ram or bull ratios may have to be increased, and perhaps doubled, even to achieve the somewhat smaller lamb or calf crop percentage (Ohlson, 1985; Leininger et al., 1989). Several writers have noted that death losses, particularly for sheep, may be twice as high in forested and wooded areas versus improved open pastures and ranges (Ohlson, 1985; Leininger et al., 1989; Obermiller and Lambert, 1984).

The values of cumulative foregone ADG over the forest grazing season, foregone lamb or calf crop, and additional breeding and death loss costs can be calculated, expressed on a per AUM basis, then added to the change in expected per AUM forage utilization costs. Multiplying through by the total number of AUMs to be taken from the forest or woods during the grazing season will result in an estimate of the change in grazing season long livestock costs. This result answers the questions originally posed: "How much higher (or lower) will be my livestock grazing costs if I graze my stock on wooded areas rather than on pastures or open ranges? How much livestock revenue will I gain or lose?"

Tree Costs and Benefits. It needs to be recognized that there is a clear tradeoff between expected costs to the quality or quantity of wood fiber produced under conditions of agroforestry or prescribed grazing and the intensity of livestock management on the wooded parcel. The more intensive the livestock management, the less damage and cost to the tree and related resources. With good management, the timber resource may even be benefitted by domestic livestock grazing in the understory (Doescher and Karl, 1990).

Several writers have shown that both the rate of growth in height and diameter of conifers may be increased through livestock grazing for a number of different reasons (Hedrick and Keniston, 1966). Competition for available soil moisture and nutrients by other plants (especially shrubs) may be reduced (Doescher et al., 1989). Available soil nitrogen and other nutrients may be augmented by the presence of the livestock via their excreta (Krueger, 1983 and 1985; Ohlson, 1985; Senter and Galbraith; Sharrow et al., 1989). These beneficial effects can be achieved, in part, by rapid movement of relatively large numbers of herded stock through the forested area, resulting in relatively uniform removal of as much as 90 percent of the current year's growth (CYG) in competing biomass. With intensive management, minimal damage due to browsing of the trees (especially to young conifers during the critical bud burst period) has been observed (Doescher and Karl, 1990; Ohlson, 1985).

To reiterate, these advantages will be realized only if the livestock, especially sheep, are closely managed (Allen and Bartolome, 1989). The result is no additional tree cost due to the presence of livestock, but higher livestock management costs. More intensive management of sheep or cattle usually is required when livestock grazing is allowed in either a prescribed or a silvopastoral setting, particularly on public forest lands. This suggests that the increased livestock management costs which result are, in the minds of the resource managers, less than the tree costs would be in the absence of intensive livestock management. Intensive livestock management costs are assumed to be less than the costs of tree replantings and/or foregone timber sales. Tree costs are, at least in part, "internalized" to the livestock enterprise.

The Public Costs of Livestock Grazing on Woodlands

On national and state-owned forests or other wooded areas, the owner (taxpayer) and the public resource manager will not be the livestock operator. Rather, the livestock operator will be a tenant (permittee) or a contractor whose livestock will remove forage and browse from the wooded area under the terms and conditions established by the land management agency. The public livestock grazing costs resulting from that permit, or contract, will be equal to the costs of administering the permit or the contractual agreement plus whatever fee waivers and direct payments are made by the agency to the permittee or contracted livestock operator in order to entice the livestock operator to use the forest or wooded area. These various public livestock grazing costs often are specified in a detailed written "Cooperative Grazing Agreement" between the Forest Service and the permittee (Forest Service, 1988), or a much more succinct "Purchase Order" between the Bureau of Land Management and the contracted livestock operator (Bureau of Land Management, 1984 and 1990).

From this perspective there really is very little difference between public livestock grazing costs on forests where permits are routinely issued to livestock operators who seek commercial gain through their use of the public land forage resources, versus the same costs on forests and other wooded areas used by livestock operators only when they are financially encouraged to do so by the land management agency. The reason why private livestock operators must be financially encouraged to graze their stock on the public forests or woodlands in some areas is that the private forage utilization costs in those areas exceed the private livestock revenues resulting from the grazing use. This can be due to the condition of the permit lands, the quantity or quality (or both) of available forage and browse, and/or the structure of the local livestock industry.

In some areas, particularly west of the Cascades, local livestock operators have not historically depended on the grazing use of national and state-owned forests. Given the generally higher forage utilization costs of forest and plantation grazing, it would be financially imprudent to graze stock on the public lands in the absence of a monetary inducement. In Eastern Oregon and other arid regions characterized by a preponderance of public lands and associated forage resources, year-round livestock operations are often feasible only if the livestock graze on public lands during part of the year. In both cases some form of grazing authorization is required, and in both cases the public land management agency incurs permit or contract administration costs.

Livestock and Tree Costs. Assuming, as in the private livestock grazing cost discussion, that tree costs are internalized in the terms and conditions of the authorizing grazing agreement, the public livestock grazing costs are reduced to the sum of (1) permit or contract administration costs, (2) fee waiver costs, and (3) other direct payments to the permittee or contracted livestock operator.

Recently, the Forest Service and the Bureau of Land Management completed their review and evaluation of the Public Rangeland Improvement Act (PRIA) grazing fee formula (Secretary of Agriculture and Secretary of the Interior, 1986). One of the components of their review was an evaluation of the per AUM costs of permit administration. The estimate was $2.40 per cow AUM (Subcommittee on National Parks and Public Lands, 1988). In the prescribed grazing and silvopastoral situations it is possible, maybe probable, that permit administration costs would be relatively higher simply because monitoring costs are higher. These additional costs are estimable (as an example, they could be $0.60 per cow AUM)[5], and could be added to the $2.40 per AUM average permit administration cost estimate with the result (in the present example $3.00 per cow AUM) being one component of the public livestock grazing cost value.

Fee waivers are a common component of the "Cooperative Grazing Agreement" or "Purchase Order." The formula based PRIA grazing fee system causes the fee paid by commercial livestock operators for the grazing use of public lands to rise and fall from year to year. If the fee over a permit term of, say, three years were to have an expected

[5] While the $0.60 per cow AUM additional monitoring cost is hypothetical, it is not without basis. The Forest Service has maintained that its administrative costs per cow AUM are higher (by $0.57 to $1.28 per cow AUM) than are the administrative costs of the Bureau of Land Management (Subcommittee on National Parks and Public Lands, 1988, p. 50). These higher costs are attributed in part to more intensive monitoring of domestic livestock grazing on National Forests. The $0.60 per cow AUM figure used in the example falls at the low end of this range in higher grazing administration costs on Forest Service lands.

annual average price of $2.00 per cow AUM[6], this value would be added to adjusted permit administration cost ($3.00 per cow AUM) bringing the total public livestock grazing cost estimate up to $5.00 per cow AUM in our example.

The final component of the public livestock grazing cost is direct payments to the permittee. In recognition of the significantly higher livestock management costs associated with prescribed grazing and silvopastoral agroforestry as the terms are being used in the present discussion, several "Cooperative Grazing Agreements" and "Purchase Orders" provide for a direct payment by the agency to the permittee or contracted livestock operator for the salary and expenses of a herdsman. Since the number of AUMs to be removed is calculable from the terms of the permit, this expense can be expressed on a per AUM basis, say $1.00 per cow AUM[7].

In this example, the average public livestock grazing costs now become $6.00 per AUM (for cattle), or $1.20 per sheep AUM (where five sheep AUMs equal one cow AUM).[8] As in the private grazing case, tree costs are internalized to the livestock grazing enterprise. Are there any other relevant public livestock grazing costs?

Other Public Costs. Other categories of relevant public costs would include (1) additional costs, if any, required to make livestock grazing possible in the forest or woodland setting and (2) costs to public resources other than trees. We can call these "grazing practicality" and "other resource" costs, respectively.

Some of the pertinent types of "grazing practicality" costs include the public costs of seeding to palatable grasses and legumes, without which the existing browse would be insufficient for the needs of the domestic livestock; fencing; water development; and the

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6 The Public Rangeland Improvement Act of 1978 (PRIA) established a formula-based federal grazing fee system applicable to most grazing permits and leases administered by both the Forest Service and the Bureau of Land Management. The grazing fee varies from year-to-year based on changes in various cost of production, livestock price, and private pasture rental rate indices. The current (1990) grazing fee under the PRIA formula is $1.81 per cow AUM, and was $1.86 per cow AUM in 1989.

7 The $1.00 per cow AUM figure is fictitious but not arbitrary. It would be equivalent to paying a herdsman $800 per month to assist in the management of a band of 4,000 sheep, or a herd of 800 cows.

8 The reason why it is necessary to identify the species of domestic livestock for which the AUM applies is explained in footnote 4. The conversion of one cow AUM to five sheep AUMs is standard in the rangeland management literature and is based on the equivalent dry matter and energy requirements of sheep and beef cattle using commonly accepted "animal unit conversion factors." As noted elsewhere, these various terms are defined in the third edition of the Society for Range Management's publication, "A Glossary of Terms Used in Range Management."

development or construction of other needed facilities including roads, trails, corrals, etc. With the exception of seeding, these additional costs may be incurred for the primary purpose of making domestic livestock grazing possible and practical.[9] These "grazing practicality" costs could be absorbed by the agency (in which case they would represent an additional public livestock grazing cost) or they could be passed along to the permittee or contractor under the terms of the "Cooperative Grazing Agreement" or "Purchase Order" (in which case they would represent additional private livestock grazing costs).

One would expect that these additional costs would vary from permit to permit, and thus would have to be assessed on a case by case basis. For expository purposes we can assign an arbitrary value to these (nonseeding) "grazing practicality" costs—say $1.50 per cow or $0.30 per sheep AUM.[10] This brings the average total public livestock grazing costs to $7.50 per cow AUM, or $1.50 per sheep AUM in our example.

The seeding cost, if any, is difficult to deal with because forage seedings generate multiple benefits, only one of which is improved domestic livestock grazing. Some writers have argued that forested, plantation, and prescribed grazing may not be effective unless palatable grasses and legumes are provided for the domestic livestock (Doescher et al., 1987; Krueger, 1983; Ohlson, 1985). In some cases, clearcuts in Western Oregon for example, native vegetation will contain little or no palatable grasses or legumes. In these cases, use by domestic livestock of the areas will be impractical since both sheep and cattle require more than just browse for their maintenance.[11] Thus, a public seeding cost must be incurred, and added to the public livestock grazing costs previously discussed.

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[9] In some cases, certain silvicultural practices such as slash disposal also may be implemented to in part benefit domestic livestock grazing. In such cases, part of the cost of the silvicultural practice should be attributed to the livestock enterprise, as in the instance of seeding.

[10] When the Bureau of Land Management adopted its current rangeland improvement policy (in 1981), responsibility for maintenance of improvements was shifted from the agency to the permittee, if the permittee's livestock accounted for half or more of the benefits of the improvement. The Bureau estimates that this policy change added $1.00 per cow AUM to the permittees' forage utilization costs, on average, in 1981 prices. Obermiller and Lambert (1984) found that equivalent permittee improvement costs on the Black Hills National Forest ranged from $0.60 to $1.02 in 1983 prices. With adjustments for subsequent inflation, these are the basis for the $1.50 per cow AUM illustration of "grazing practicality" costs used in the present example.

[11] Ohlson (1985) reports that browse accounts for 12 to 15 percent of sheep diets throughout the grazing season in the Oregon Coastal Range.

The problem is that such seeding costs generate additional benefits directly to wildlife, particularly elk and deer, and indirectly to fish and other water users due to erosion control and groundwater infiltration effects of surface cover (Currie and Gary, 1978; Johnson and Borman, 1990). Further, the soil retention and moisture effects of ground cover restoration accomplished through reseeding ultimately benefit the tree production enterprise. Hence, the net seeding cost, from a social perspective, is the initial seeding cost minus the values of direct and indirect benefits to uses other than domestic livestock. In some cases the net seeding costs may even be negative, meaning that the sum of the multiple benefits resulting from seeding exceed the cost of seeding.[12] Since net seeding costs may be either positive or negative, depending on the circumstances, no seeding cost is added to the "grazing practicality" costs in the hypothetical example presented here.

Besides these additional "grazing practicality" costs incurred in order to make the forested or wooded area attractive to domestic livestock, the presence of livestock may result in "other resource" costs—public costs in the form of harm or damage to resources other than trees. The forest, plantation, and prescribed grazing literature seldom addresses this issue, but environmental concerns about commercial livestock grazing on public lands in general are widespread (Tesch and Korpela, 1990). Overgrazing by domestic livestock on arid ranges is said to result in downward trends in condition and carrying capacity, loss of biological diversity, and severe damage to riparian areas (Godfrey and Pope, 1990; General Accounting Office, 1988). If these allegations are valid, and they are questioned by some (Quigley and Bartlett, 1990), there may be additional public livestock grazing costs beyond the grazing administration and grazing practicality costs. These "other resource" costs would be relatively more applicable in a silvopastoral, less applicable in a prescribed grazing, context.

One would expect that the astute public land manager would recognize that uncontrolled domestic livestock grazing on forests and other wooded areas could result in "other resource" costs. If so, the costs could be mitigated, and perhaps eliminated, through good management—meaning rigorous control over the intensity, distribution, and timing of grazing on plantations, forests, and other wooded areas. The need for such control is embodied in the phrasing of terms and conditions of "Cooperative Grazing Agreements." This means that, like tree costs in prescribed grazing, "other resource" costs are internalized to the private livestock enterprise which, given the benefits of control over undesirable vegetation, the agency may choose to defray.

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[12] From this perspective, seeding is a multiple use management practice. As such, a case can be made for calling seeding a "prescribed" management practice in the same sense as prescribed fire or prescribed grazing.

Hence, in the present example "other resource" costs are excluded from the set of relevant public livestock grazing costs in forest, plantation, and prescribed grazing systems. The additional public costs of domestic livestock grazing on woodlands and forests remains $7.50 per cow AUM, and $1.50 per sheep AUM.

The Cost Effectiveness of Livestock Grazing

So is livestock grazing in either a prescribed or a silvopastoral setting cost effective? For prescribed grazing, the answer depends on whether or not the cost of controlling undesirable vegetation using livestock as the means is less than the cost of the alternatives—fire, mulching, manual control, and herbicides—given the desired or target level of vegetation control. In silvopastoral agroforestry, the answer is contingent on whether or not the expected returns (or benefits) to livestock grazing exceed the expected costs.

Cost Effectiveness from the Private Perspective. From the private point of view, the cost effectiveness of grazing livestock in forests and wooded areas boils down to whether or not the costs of producing some given quantity and quality of livestock products are higher or lower, when the forage source is woodland plants versus open range or pasture forages. Most of the cost items discussed earlier may be higher for woodland and forest versus rangeland and cleared pasture grazing, even if the livestock operator receives direct payments and fee (or rent) remissions from the public land management agency (or private woodland owner).[13] Animal performance may be poorer vis-a-vis the pasture and rangeland alternatives. It can be concluded that only if the direct payments from the public agency to the permittee or contractor, or from the private woodland owner to the livestock operator, are greater than the increases in management costs associated with utilization of the forest forage resource will the prescribed grazing program be cost effective relative to other sources of forage available to the livestock operator during the same grazing season.

For the private livestock operator, "Does prescribed grazing pay?" Probably not, at least as long as all costs to the timber production enterprise (or other resource use to be enhanced through prescribed grazing) are internalized to the livestock enterprise; and

[13] In all reviewed "Cooperative Grazing Agreements" and "Purchase Orders," direct payments were made only for additional herdsmen and transportation expense items. Other sources of additional forage utilization costs as described earlier were not subject to reimbursement in these contractual agreements.

the livestock operator has other sources of pasture or range forage available during the same grazing season.[14]

<u>**Cost Effectiveness from the Public Perspective**</u>. From the public perspective, the issue is whether or not it is cheaper to use domestic livestock or other means to achieve target levels of control over undesirable (meaning tree competitive) forms of vegetation. Can fire, mulching, manual control, or herbicides do just as good a job but at less expense?

For many years, herbicides were the favored method of control of undesirable vegetation. To achieve an acceptable level of control over undesirable vegetation, per acre herbicide application costs have been estimated to range from $70.00 to $145.00 per year (Grelman, 1988; Krueger, 1985). The use of herbicides as vegetation manipulation tools on public lands was banned by a federal court order in 1984, however. The relative cost effectiveness of herbicides as a means of controlling undesirable vegetation on national and state-owned forests thus became a mute point. However, herbicides continue to be used on privately owned forests and woodlands, suggesting that where it is legally permissible, herbicides may be cost effective (or for technical reasons preferred) relative to domestic livestock as a means of control over tree-competing types of vegetation.

Prescribed fire, another means of controlling undesirable vegetation in forests and woodlands, is possibly more cost effective than herbicides. However, many (particularly public) land managers are reluctant to use prescribed fire as a management tool (Wester, 1990). This reluctance may be a form of risk aversion because of the extremely high (but under managed conditions unlikely) costs of catastrophic wildfires stemming from prescribed burns (Walstad, Radosevich, and Sandberg, 1990). As with herbicides, if prescribed fire gain wider acceptability, it too could be cost effective relative to domestic livestock as a mechanism for the control of undesirable vegetation.

But, especially on public forest lands, we can't spray and we often won't burn (Doescher, Tesch, and Drewien, 1987). That leaves covering the ground with an artificial mulch to suppress the growth of competing vegetation, or manually removing the vegetation before it becomes competitive with the tree seedlings. Evidence suggests that both practices are cost ineffective, in many instances, relative to removal of the offending plant growth by domestic livestock (Grelman, 1988).

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14 When the livestock operator is required to manage livestock to ensure that no damage is done to trees or other resources, the implicit assumption is made that the values of timber and other nonlivestock resources are higher than the value of the grazing livestock.

Implications

In conclusion, from the private livestock operator's perspective prescribed grazing on public forests probably is not financially feasible unless the operator receives some form of financial subsidy due to the imposed constraints, restrictions, and managerial requirements. As these restrictions are relaxed, as may be the case on some private forests and woodlots, forage utilization costs may decline the financial attractiveness of prescribed grazing to the livestock operator can be expected to increase (Monfore, 1983).

Given the presently acceptable alternatives, from the public forest manager's perspective prescribed grazing probably is cost effective in some situations (Klamath Resource Area; District Silviculturist). This suggests that the wider adoption of prescribed grazing as a means of controlling undesirable vegetation on public forests will be conditioned on increased direct payments by public land management agencies to permittees and contractors (Klamath Resource Area, 1989).

As these payments to the livestock operator increase, the cost effectiveness of livestock grazing as a control mechanism on public forests relative to other control mechanisms (mulching and manual grubbing) will decrease. At some point a balance will be met, and undesirable vegetation will be controlled through some combination, among different public forests, of mulching, manual control, and prescribed domestic livestock grazing. On private forests and woodlands, with fewer restrictions on livestock as well as fire and herbicides as vegetation control mechanisms, the final balance probably will exclude the more expensive (mulching and manual grubbing) vegetation control practices.

THE BENEFITS OF LIVESTOCK GRAZING ON COMMERCIAL WOODLANDS

Silvopastoral agroforestry is fundamentally different than prescribed grazing in that the commercial production of livestock products is given legitimacy. There is no need to internalize all external costs within the structure of the livestock operator's forage utilization costs. Rather, the underlying rationale is to maximize the difference between total benefits and total costs from the multiple uses of a land parcel. From the economic standpoint, silvopastoral agroforestry is multiple use, prescribed grazing is a land resource management practice. The costs are treated differently and the benefits, in agroforestry, are counted.

The Private Returns to Livestock Grazing on Woodlands

If the production and sale of livestock products is seen as a legitimate use of forested or wooded areas, emphasis is placed on the efficient use of available forage and browse by domestic livestock, rather than exclusively on control of undesirable vegetation and protection of the timber resource. The various types of forage utilization costs described earlier still exist, but the magnitude of those cost items change. More specifically, Lambert and Obermiller (1983) found that the nonfee/nonrent portions of per cow AUM forage utilization costs averaged about $6.00 per AUM on private pastures and rangelands in Oregon, while on National Forests the same costs averaged over $14.00 per AUM. The difference between these two costs, $8.00 per cow AUM, can be interpreted as the additional costs to the livestock operator incurred by grazing livestock on forested lands rather than on pastures and rangelands.

Some portion of the additional $8.00 per cow AUM in forage utilization cost is the additional management cost associated with the protection of the timber (and other nonlivestock) resource. That portion represents the potential additional private return to the livestock operator who seeks to maximize his return to the grazing use of the forest or wooded area.

From the private perspective, we need to know whether the private costs to the tree production enterprise resulting from the grazing use by livestock of the forest forage resource are greater or less than the additional private return potentially available to the livestock operator (if tree and other resource protection is not an overriding concern). Indirect evidence based largely on the experience of the Weyerhaeuser Company on its tree plantations in Southern Oregon suggests that increases in private tree enterprise costs experienced when cattle graze in tree plantations under less intensive (hence less costly) management regimes are minimal (Monfore, 1983). In fact, for the reasons discussed earlier, tree growth may be enhanced.

The Weyerhaeuser experience implies that livestock grazing on tree plantations generates additional revenue above and beyond that stemming from the sale of livestock products. The combined effects of livestock grazing—control over competing vegetation, enhanced palatability of browse and herbage to wildlife following the removal of livestock, fertilization, etc.—can lead to more, not less, wood fiber production per acre over the span of the rotation, even if the livestock are not intensively managed to protect the tree resource.

The Public Benefits of Livestock Grazing on Woodlands

An obvious benefit to domestic livestock grazing on public forests (in the silvopastoral agroforestry but not the prescribed grazing sense) is grazing fee receipts. As noted earlier, costs of administering the permit system on public lands may be higher than the level of the grazing fee itself, in which case the net public benefit to permitted livestock grazing as a distinct and separate enterprise may be negative.

As noted earlier, however, there is a considerable body of evidence to suggest that the external public benefits, or benefits to other public uses and users of the forest resource stemming from domestic livestock grazing and associated management and improvement practices, may more than offset the negative net benefit to domestic livestock grazing on public forests (Anderson et al., 1990; Sharrow, 1990). These external benefits include enhancement of tree growth for the reasons and by the authorities previously mentioned, increases in tree seedling survival rates due in part to rodent control, reduction in wildfire hazard due to control of understory biomass and litter (Krueger, 1985), improvement in water quality and stabilization of streamflow, enhancement of wildlife habitat (Ohlson; Rhodes and Sharrow, 1983; Rustad, 1988), protection against soil loss especially in reseeded clearcuts, and perhaps most important—public acceptance of livestock as a preferred (relative to herbicides and fire) means of control over undesirable vegetation.

Each of these, and conceivably other, public benefits to forest and plantation grazing is valued. The total external benefit from livestock grazing in a silvopastoral agroforestry management context will vary from time to time, place to place, and with the intensity of domestic livestock management. However, it is highly unlikely that the sum of these external benefits will be less than the negative net public benefit associated with administration of the permit program.

The hypothesis, "Silvopastoral agroforestry <u>does</u> pay!" has been subject to repeated testing. Nowhere in the literature is there any empirical economic evidence that would lead to a rejection of the hypothesis. Until such evidence is discovered, given the documented benefits, it would seem to be in society's best interest to encourage well managed commercial livestock production on our public and private forests and tree plantations.

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SOUTHWEST OREGON FOOTHILLS RESTORATION RESEARCH: PREVIOUS WORK AND PRESENT OUTLOOK

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Restoration of southern Oregon foothills rangelands has been a goal of ranchers and both federal and state agencies for a number of years. The OSU Extension Service, USDA Soil Conservation Service, and local ranchers have conducted numerous small and large scale seedings of plants with mixed results. Gene Hickman (USDA/SCS) has compiled an impressive listing of trial seedings and rated them as to their success throughout Jackson County. In addition, he has collected seed from promising perennial plant species and given them to the SCS regional plant materials center at Corvallis for expansion and testing. Ronald Mobley (OSU Extension Service) has likewise conducted and evaluated seedings in Jackson county.

Detailed biological and ecological examination of resident weeds, successful seeded species and the search for more beneficial plants that could be used to ameliorate the foothills are, unfortunately, beyond the scope of work of both extension service and SCS staff. Their work, however, provided a listing of plants with restoration potential and indicates the interest and concern of regional landowners and citizens for their pastures and the environment.

In order to ascertain true usefulness of plants for restoration, it is essential that we sort out the biological details of success and failure. The most pressing problem has been the identification of plants, both native and introduced, that can reliably be used to revegetate the foothills. Some plant species have established on some sites but not others and some (especially annuals) have tremendous variability in production from year to year.

Scientific investigations by the Department of Rangeland Resources with the cooperation of the Jackson County OSU Extension Service, Southern Oregon Experiment Station and Jackson County Soil Conservation Service began in 1984 when several plant screening experiments were initiated. These experiments have been followed for six years and have identified several adapted plant species. Berber orchardgrass (Dactylis glomerata var. Berber), Covar sheep fescue (Festuca ovina var. Covar), a local collection of Idaho Fescue (Festuca idahoensis), Palestine orchardgrass (Dactylis glomerata var. Palestine), and intermediate wheatgrass (Agropyron intermedium) have shown promise for revegetation (Borman 1989). These species, however, have not been successful every year or on all sites throughout the Rogue River Valley when broadcast seeded with minimal seedbed preparation. Therefore, the identification of species for revegetation needs to continue with trials that include local collections of California oatgrass (Danthonia californica), Idaho fescue, and other species. Introduced plants or those naturalized in the US should also continue to be examined, including additional varieties and subspecies of orchardgrass and intermediate wheatgrass.

The research described above was followed by a series of experiments to define growth parameters, phenological and physiological characteristics (including rain use efficiency), net aboveground primary productivity, and competitiveness of the most promising plant species. Concurrently, work was begun on seeding techniques and the use of herbicides while establishing perennial plants. The successes to date have been impressive.

Berber and Palestine orchardgrass are especially competitive in test plots near Phoenix and Ashland, Oregon. In order to establish these and other perennial grasses, annual weeds were controlled during the first growing season. In subsequent years these varieties of orchardgrass had dramatically suppressed the resident vegetation (after the stand became established). Direct seeding of orchardgrass varieties was successful in 1984 and established plants were able to set viable seed that has expanded the stand to areas beyond the original plot boundaries. At two other locations in the Rogue River Valley, seedings of this species have failed (Sam's Valley and northeast of Medford). In both failures, land was tilled but no other weed control techniques were employed. The establishment phase and reseeding techniques are therefore critical to the success of any restoration effort.

A local (Phoenix, OR) collection of Idaho fescue also has been tested. This accession produces well, has a phenological development that is in concert with climate and rainfall patterns and is robust. Additional screening and production testing should be done with this species.

The ecological tolerances of the plants tested are different. We have not yet examined resiliency to grazing and have only fully evaluated these plants at two locations in Jackson County, Oregon. In order to determine the full potential of these (and other) plants, we should test them across both wider geographic ranges and broader ecologic conditions. A research program is being initiated in the Department of Rangeland Resources that will define these parameters for four of the most promising plant species.

Economics of technical interventions are always of interest and concern. Thus far we have kept records on the cost of various actions, the productivity and benefits accrued from successful interventions and the risks involved with the procedures. Risk of failure is by far the most difficult aspect to accurately evaluate. The climatic regime for southwestern Oregon is classified as Mediterranean/Maritime, with its inherent variability. Timing of rainfall is critical for plants. Especially important are fall rains that occur while temperatures are still warm enough to permit growth and late spring rain when plants are producing carbohydrates necessary for seed and root reserves. Rainfall in both these seasons is unreliable.

Establishment and success of a seeding may likewise depend upon favorable growing conditions in these seasons. Thus far it appears that reseeding must be done in the fall (before October 15) to provide plants with sufficient time for development and that weed control can substantially hasten stand development. The most successful plants are those with relatively short development periods and pronounced summer dormanc, (i.e. Berber orchardgrass, Palestine orchardgrass and Idaho fescue).

An economic analysis should be done for each proposed reseeding taking into consideration site potential, cost of proposed activities, the value of benefits (which necessitates integration of benefits with other farm or ranch enterprises), chance of success, as well as other factors. As our knowledge of foothill ecosystems increases we are better able to accurately estimate benefits as well as risks. This will permit us to make clear, realistic assumptions and accurate economic predictions. It is hoped that in the near future this can be done.

In the subsequent papers in this volume we have outlined specific questions addressed, methods employed, and results of the research program to date. In addition, there are plot diagrams of a series of experiments that are in progress. Our experience leads us to believe that there is high potential for restoration of southern Oregon foothill rangelands.

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INITIAL SCREENING OF PLANT SPECIES USEFUL FOR RESTORATION OF SOUTHWESTERN OREGON FOOTHILL RANGELANDS

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ABSTRACT

Initial screening of plant species and varieties for use in restoring foothill rangelands of southwestern Oregon was begun in 1984 on two sites in Jackson County, Oregon. Additional tests were carried out in 1985. All plantings were evaluated in 1989 and rated and ranked on the basis of their survivability, vigor, and presence of reproductive culms. Several species appear to have potential for revegetating rangelands. The most promising perennial grasses studied are sheep fescue (Festuca ovina L. var. Covar), Berber and Palestine orchardgrass (Dactylis glomerata L. var. Berber and D. glomerata L. var. Palestine), and two varieties of intermediate wheatgrass (Agropyron intermedium (Host.) Beauv. var. Greenar and A. intermedium (Host.) Beauv. form Rush). Lana vetch (Vicia villosa Roth. var. Lana) also persisted and was vigorous in these row plots.

INTRODUCTION

Foothill rangelands of the interior valleys of southwestern Oregon and northern California have undergone major changes in their floristic composition since the arrival of Euro-americans (Franklin and Dyrness 1973). The original grasslands and savannas have been invaded by exotic species, most of which originated in the Mediterranean basin (Munz 1963). Many invading species such as Dogtail (Cynosurus echinatus L.) and Medusahead (Taeniatherium asperum (Sim.) Nevski) are of little value for wildlife and livestock or have such a short duration of acceptability to grazing animals that their use is limited. Yellow starthistle (Centaurea solstitialis L.), a relatively recent invader (Maddox et al 1985), could eventually spread to many semiarid rangelands (Callihan et al 1982). It is toxic to horses, and is used by other classes of livestock only when the plant is young (Thompsen et al. 1989). The spiny flowering head becomes a nuisance as the plant matures.

Because these alien weeds are objectionable, numerous attempts at range and pasture revegetation have been made by landowners. Results have been mixed and many seedings have failed. This study was designed to screen, test and evaluate an assortment of plants to determine their potential for restoration of rangelands to a more stable, productive plant community.

STUDY AREAS

Two sites were selected for evaluation of plant species. The Fern's Ranch study area is located 3 km east of Phoenix, Oregon on a hilltop that had historically been tilled and seeded to oats. This field had not been seeded since 1982. The elevation of the site is 430 m above sea level and the soil is Darrow silty clay loam. This soil is classified as a fine, montmorillonitic, mesic, Vertic Argixeroll derived from siltstones and shale bedrock. It has a high shrink/swell capacity. Aspect of the site is southwesterly and the slope is 3%. The Stanley Ranch site had never been tilled. Soil is classified as a fine-loamy, mixed, mesic Typic Xerochrept. It is west facing with a slope of 2%. The climate of both sites is classified as Mediterranean (cool, moist winters and hot, dry summers). Average annual precipitation is 500 mm of which approximately 80% falls between October 1 and May 1. Rainfall for the period of this study was below normal and averaged 390 mm/year on an agricultural year basis (September through August).

Resident vegetation on the Fern's Ranch Site is dominated by yellow starthistle with patches of medusahead, ripgut brome (Bromus diandrus Roth.) and wild oat (Avena fatua L.). Adjacent areas that have not been tilled are an Oregon white oak savanna dominated with Oregon white oak (Quercus garryana Dougl.), poison oak (Rhus diversiloba T. & G.), yellow starthistle, dogtail, medusahead, ripgut brome and buckhorn plantain (Plantago lanceolata L.). The Stanley Ranch site is also an oak savanna with similar species composition, but the soil remains saturated with water throughout much of the winter.

METHODS

The land was disked twice (Fern's Ranch) or rototilled (Stanley Ranch) to prepare a seedbed in the fall of 1984. Two 7.5 by 15 m subplots were delineated and five rows of each of the species listed in Table 1 were seeded in 1.5 by 7.5 m subsubplots. Plots were hand raked to cover the seed. Seeding was completed by 29 October 1984. The following year, two additional 7.5 by 15 m subplots were delineated and the species listed in Tables 2 and 3 were seeded in single rows, 30 cm apart. The 1985 seeding was completed on October 11. Weeds and invading plants were not controlled during the course of this study and the plots were not grazed by livestock.

All plots were evaluated in June of 1989 for density, vigor and the presence of reproductive culms or flowers. Continuity and uniformity of the established plants in the row were judged as absent, trace (Tr-5% of the row vegetated), occasional (6-33% vegetated), frequent (34-66% vegetated), or continuous (67-100% vegetated). Reproductive tillers were recorded as present or absent and the general vigor of the plants was ranked as poor, fair, good or excellent. Density was determined by counting the number of living plants in the row. Since the 1984 plots contained multiple rows, additional measurements included density, above-ground phytomass, and cover which were estimated in twenty randomly placed 25x25 cm quadrats.

RESULTS AND DISCUSSION

Rush wheatgrass (Agropyron intermedium (Host.) Beauv. form Rush) was the only seeded species of those planted in 1984 (Table 1) to persist for four years (until June 1989). It maintained a mean density of 12 plants per m^2 and produced 83.3 g of DM/m^2 at the Fern's Ranch site. Foliar cover was 20%. Both the density and vigor of this species was lower at the Stanley Ranch site, where only 7 plants survived until June of 1989.

None of the seeded species planted in 1985 (Table 2) at the Stanley Ranch survived; however, several of the perennial grass species at Fern's Ranch (Table 3) persisted and were vigorous in 1989. Covar sheep fescue (Festuca ovina L. var. Covar) had more living plants in both blocks than did other species. Rows in each subplot were continuous, reproductive culms were present, and the plants had excellent vigor. However, Covar sheep fescue is a low-statured grass and the production of above ground phytomass is low relative to Berber orchardgrass in this seeding. Covar sheep fescue was also found to be highly competitive to yellow starthistle in northeastern Oregon (Larson and McInnis 1989), indicating a wide geographical range of potential use in Oregon.

Berber orchardgrass (Dactylis glomerata L. var. Berber) was the only other perennial grass that formed a continuous row. Berber orchardgrass plants were larger and more erect than Covar sheep fescue and the leaf tissue appeared more succulent. Reproductive culms were present and plants were vigorous. A sister variety, Palestine orchardgrass (Dactylis glomerata L. var. Palestine), also had excellent vigor, but fewer plants germinated and survived four years and the continuity of the row was less pronounced (Table 3). Palestine orchardgrass plants are intrinsically larger and leafier than Berber orchardgrass plants.

Several perennial wheatgrasses also show promise. Greenar intermediate wheatgrass (A. intermedium (Host.) Beauv. var. Greenar), Rush wheatgrass and Secar bluebunch wheatgrass (A. spicatum (Pursh) Scribn. & Sm. var. Secar)(Table 3) all survived, and a row defined by their presence was discernable. These plants mature later in the year than do the orchardgrasses or sheep fescue and seedheads had not emerged by the end of June 1989. The summer of 1989 was relatively cool and wet and by mid August reproductive culms were present on these plants. However, late spring and early summer rainfall is unreliable and these plants may not produce seed on a regular basis. Site potentials for some of these plants have been examined by Borman (1989). He found that wheatgrasses can produce more aboveground phytomass than Berber and Palestine orchardgrasses, yet not prevent reinvasion of resident annual plants. He further suggests, since wheatgrasses extract moisture from greater depth than annual grasses, that competition between these groups may not be as intense as between orchardgrass and resident annual grasses.

Lana vetch (Vicia villosa Roth. var. Lana) was well represented in the plots in June of 1989. The plants had spread (as would be expected by their growth form), yet most of the plants were still in the line of the row. Plants were very vigorous and producing seed.

CONCLUSIONS

Several perennial grasses have potential for restoring southwestern Oregon and northern California foothill rangelands to a more productive, stable ecosystem on a site-specific basis. Several species have been able to establish from seed and persist for four years in row plots. The most vigorous grasses were Covar sheep fescue, Berber orchardgrass, Palestine orchardgrass, Greenar intermediate wheatgrass, Rush intermediate wheatgrass and Secar bluebunch wheatgrass. The legume Lana vetch may also persist in spite of competition from yellowstar thistle and resident annual grasses.

ACKNOWLEDGEMENTS

We would like to acknowledge the United States Soil Conservation Service, Corvallis Plant Materials Center, Pullman Plant Materials Center and Lockeford Plant Materials Center for providing seed of some of the plant species tested. Robert Ferns and Gordon Stanley provided the research sites. They also fenced the locations and assisted in plot construction. Funding was provided by the Oregon Agricultural Experiment Station.

Table 1. Plant species seeded at the Fern's Ranch site 3 km east of Phoenix, Oregon and at the Stanley Ranch sites northeast of Medford, Oregon on October 26, 1984.

Scientific Name	Common Name
Agropyron intermedium form Rush	Rush Wheatgrass
Elymus glaucus	Blue Wildrye - Early Maturing
Elymus glaucus	Blue Wildrye - Late Maturing
Festuca arundinacea var. Fawn	Fawn Fescue
Festuca arundinacea var. Safe	Safe Fescue
Festuca arundinacea var. Kenhy	Kenhy Fescue
Festuca arundinacea var. Barcel	Barcel Fescue
Lotus corniculatus arvensis	Dwarf English Trefoil
Lotus pedunculatus	Big Trefoil
Lupinus albicaulis	Sickle Pod Lupine

Table 2. Plant species seeded at the Stanley Ranch northeast of Medford, Oregon on October 2, 1985.

Scientific Name	Common Name
Agropyron elongatum var Alkar	Alkar Tall Wheatgrass
Agropyron intermedium var Greenar	Greenar Intermediate Wheatgrass
Dactylis glomerata var Wana	Wana Orchardgrass
Festuca arundinaceae var Tempo	Tempo Tall Fescue
Festuca idahoensis var Joseph	Joseph Idaho Fescue
Festuca occidentalis	Western Fescue T28786
Lolium perenne var Ariki	Ariki Perennial Ryegrass
Lolium perenne var Ellet	Ellet Perennial Ryegrass
Lolium perenne var Grimalda	Grimalda Perennial Ryegrass
Lolium perenne var Pennfine	Pennfine Perennial Ryegrass
Lolium rigidum	Wimmera Annual Ryegrass
Phalaris aquatica	Perla Grass

Table 3. Plant species seeded in replicated row plots on 11 October 1985 at the Fern's Ranch site near Phoenix Oregon. The plots were evaluated in June 1989.

Scientific Name	Common Name	Mean Number of Plants in 7.5 m Row	Continuity of the Planting*	Vigor	Presence of Reproductive Structures
Agropyron elongatum var. Largo	Largo Tall Wheatgrass	0	Absent		
Agropyron intermedium var. Greenar	Greenar Intermediate Wheatgrass	14	Occasional	Good	Absent
Agropyron intermedium form Rush	Rush Intermediate Wheatgrass	8.5	Intermittant	Good	Present
Agropyron spicatum	Bluebunch Wheatgrass	2.5	Trace	Fair	Absent
Agropyron spicatum var. Secar	Secar Bluebunch Wheatgrass	12	Occasional	Good	Absent
Alopecurus pratensis	Meadow Foxtail	0	Absent		
Bromus erectus	Meadow Brome	0	Absent		
Bromus inermis var. Manchar	Manchar Smooth Brome	0	Absent		
Bromus mollis var. Blando	Blando Soft Chess	12	Trace	Good	Present
Dactylis glomerata var. Berber	Berber Orchardgrass	16.5	Continuous	Excellent	Present
Dactylis glomerata var. Paiute	Paiute Orchardgrass	0	Absent		
Dactylis glomerata var. Palestine	Palestine Orchardgrass	9	Occasional	Excellent	Present
Dactylis glomerata var. Wana	Wana Orchardgrass	0	Absent		
Elymus glaucus	Blue Wildrye T19633	0	Absent		
Elymus glaucus	Blue Wildrye T19638	0	Absent		
Elymus glaucus	Blue Wildrye T19643	0	Absent		
Elymus glaucus	Blue Wildrye T19655	0	Absent		
Elymus glaucus	Blue Wildrye T19678	0	Absent		
Elymus glaucus	Blue Wildrye T19690	0	Absent		
Festuca arundinacea var. Alkar	Alkar Tall Fescue	2	Trace	Fair	Absent
Festuca arundinacea var. Goar	Goar Tall Fescue	0	Absent		
Festuca arundinacea var. Tempo	Tempo Tall Fescue	0	Absent		
Festuca rubra stolonifera	Creeping Red Fescue	0	Absent		
Festuca idahoensis var. Joseph	Joseph Idaho Fescue	0	Absent		
Festuca idahoensis var. Nez Perce	Nez Perce Idaho Fescue	0	Absent		
Festuca occidentalis	Western Fescue T28784	0	Absent		
Festuca occidentalis	Western Fescue T28786	0	Absent		
Festuca occidentalis	Western Fescue T28822	0	Absent		
Festuca ovina	German Sheep Fescue	0	Absent		
Festuca ovina var. Covar	Covar Sheep Fescue	23.5	Continuous	Excellent	Present
Lolium perenne var. Ariki	Ariki Perennial Ryegrass	1	Trace	Poor	Present
Lolium perenne var. Ellet	Ellet Perennial Ryegrass	7	Occasional	Fair	Present
Lolium perenne var. Grimalda	Grimalda Perennial Ryegrass	5.5	Occasional	Fair	Present
Lolium perenne var. Pennfine	Pennfine Perennial Ryegrass	1.5	Trace	Poor	Present
Lolium rigidum var. Wimmera	Wimmera 62 Annual Ryegrass	1	Trace	Poor	Present
Oryzopsis hymenoides	Indian Ricegrass	0	Absent		
Phalaris aquatica	Perla Grass	0	Absent		
Phalaris tuberosa	Harding Grass	0	Absent		
Poa canbyi var. Canbar	Canbar Canby Bluegrass	0	Absent		
Poa compressa var. Ruben	Ruben's Canada Bluegrass	0	Absent		
Trifolium fragiferum	Strawberry Clover	0	Absent		
Vicia dasycarpa var. Lana	Lana Vetch	12.5	Intermittant	Excellent	Present

* Continuity was judged as Trace = 0-5% of the row filled with seeded plants, Occasional = 5-33% of the row filled, Intermittant = 33-66% of the row filled, Complete = 66-100% of the row filled.

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STANDING CROP AND POPULATION DYNAMICS OF SELECTED PLANT SPECIES GROWING ON SOUTHERN OREGON FOOTHILL RANGELANDS

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INTRODUCTION

The foothill rangelands of southwestern Oregon and Northern California comprise some of the most degraded ecosystems in the nation. The vast majority of the foothill and valley plant communities are composed of exotic plants that were accidentally introduced from the Mediterranean Basin and Eurasia. Plants such as yellow starthistle (Centaurea solstitialis L.), ripgut brome (Bromus diandrus Roth), medusahead (Taeniatherum asperum (Sim.) Nevski), and dogtail (Cynosurus echinatus L.) evolved under intense grazing pressure and in association with man. There are a number of reasons why these exotic plants have been successful in the interior valleys of southwestern Oregon. They generally have a superior defense against herbivory (in the form of toxins, spines or coarseness), rapid growth during favorable climatic and soil moisture conditions, and effective seed dispersal mechanisms.

Undoubtedly, anthropogenic factors such as overstocking in the early settlement period, movement of animal feeds and livestock, suppression of fire, transport of mud (and seed) on vehicles, and tillage contributed to spread of these exotics and the nearly universal replacement of native herbaceous plants on the foothills. Today, the native perennial plants that they replaced are found in isolated areas or in pockets within the annual grassland type.

Regardless of the reasons for exotic plant success or our past managerial mistakes in dealing with the foothills, we are confronted with a serious problem. The valleys and foothills of southern Oregon and northern California are dominated by noxious plant communities of limited value to livestock and wildlife. These plants discourage recreational use of foothills during much of the year. Spines from the seed heads of yellow starthistle, as well as seeds and awns from the annual grasses, preclude recreational use without leather boots because they readily penetrate clothing and canvas shoes.

Of greater importance is the increased fire hazard. Annual grasses and forbs dry so completely (often to 95% or more dry organic matter content) in the late spring or early summer that there is a build up of fine fuels, substantially increasing the risk of accidental fires. These factors take on added significance when we consider that the human population of the region is rapidly expanding. Many valleys have developed extensive residential areas composed of homes on small acreages. This increases the complexity of the urban/rural interface and substantially increases the cost of fire suppression and weed control. At present, the only way residents can change the plant community is by irrigation or application of herbicides. Irrigation is capital intensive and energy and resource expensive. Herbicides, aside from environmental danger, cannot insure improvement unless competitive, locally adapted, and desirable plants are established.

It is estimated that in Jackson County, Oregon alone there are 120,000 ha of foothill rangelands dominated by weedy annual grasses and/or yellow starthistle. From a rancher's perspective, this land is only marginally productive since it is used for 3 to 6 weeks of spring grazing by livestock. Typically, total peak standing crop of annuals on these rangelands is between 800 and 3000 kg Dry Matter/ha. The production depends upon the characteristics of the site and the amount and timing of annual precipitation. Half or more of this production is generally yellow starthistle. Usable production, therefore, is much lower, normally amounting to less than 400 kg Dry Matter/ha. Frequently ranchers obtain little or no grazing use of foothill rangelands at all because the production of usable forage is meager.

Restoration of the foothills to a perennial grassland system is not only a difficult task but one that has received relatively little attention until recently from researchers at Oregon State University. In order to be successful, we believe that the problem must be broken into its components and each problem attacked separately. The questions that we have attempted to answer with this research program are as follows:

1. Which perennial grasses can survive and reproduce in the climate found in the interior valleys of southwestern Oregon? This separates establishment problems from survivability of mature plants.
2. What is the potential productivity of these plants on several sites?
3. What are the expected growth patterns by season (using weather variables as predictors) for these grasses?

MATERIALS AND METHODS

Study Site

The study was conducted at two foothills sites in Jackson County in southwest Oregon. Site 1 (mid slope) is located 3 km east of Phoenix on the Ferns ranch, and Site 2 (toe slope) is located about 5 km northeast of Ashland on the Dauenhauer ranch. Soils at the two sites are Darrow silty clay loam and Carney clay, respectively. Sites 1 and 2 have southwest and west-southwest aspects, respectively; and slopes are 20-35% (mid slope) and 5-20% (toe slope), respectively. The area is characterized by a Mediterranean/Maritime climate pattern with cool, wet winters and hot, dry summers. Annual precipitation averages 500 mm at both sites, but distribution and quantity vary considerably from year to year. On average, approximately 82% of the precipitation falls between October 1 and April 30, 4.8% in May, 2.3% in June and 0.7% in July. The average January temperature is 38°F and the average July temperature is 23°C. Extreme temperatures range from -21°C to 46°C.

Plant Materials

Eleven species or varieties of species (Table 1) of cool-season, perennial grass were evaluated. Three of the species were natives growing in association with Oregon white oak (Quercus garryana) on sites similar to the study sites. The others were introduced species.

Plot Design

All plants were transplanted into plots during the fall and winter of 1986-87 and allowed to establish in the absence of competition during the 1986-87 growing season. Suppression of competition was accomplished by transplanting into plots covered with black Vispore.[1] The vispore, a black visqueen plastic sheet, had 62 holes per square centimeter to allow water and air passage. Following establishment during the first growing season, the plots were split by removing the vispore from half of each plot. The resident annuals were thus allowed to provide competition for the perennials on half of each plot while the perennials remained competition free on the other half. Plants

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[1] Disclaimer: This paper reports on research only. Mention of a specific proprietary product does not constitute a recommendation by Oregon State University and does not imply their approval to the exclusion of other suitable products.

growing without competitive interference provided an assessment of growth potentials on the sites. Plants growing with potential competitive interference provided an assessment of stand maintenance potentials of the various grasses on the sites.

Sampling

Sampling for establishment year peak standing crops was conducted during the summer of 1987. During the 1987-88 and 1988-89 growing seasons, sampling began following sufficient precipitation to initiate regrowth. The 1987-88 growing season began in December. Sampling was conducted once a month through March to evaluate winter growth, then biweekly for the duration of the growing season. It was terminated in the summer after maturity. The 1988-89 growing season began in November. Sampling was conducted once a month through mid-March to evaluate fall and winter growth, then biweekly through mid-April to evaluate early spring growth. Peak standing crop estimates were made during early summer 1989.

Experimental Design and Analysis

The experimental design allowed us to compare the two sites, make comparisons among the species, and evaluate the effects of potential competition from the resident annual plants on perennial grass growth and stand maintenance. For a technical description of the design and analyses utilized refer to Borman (1989).

RESULTS AND DISCUSSION

Perennial Grass Adaptation

In spite of competition, several perennial grasses have been able to persist and substantially reduce the production and density of yellow starthistle and annual grasses. Berber and Palestine orchardgrass and Idaho fescue have survived and produced well at the Ferns site. Weed cover and biomass have been reduced considerably in the two orchardgrass plots in particular. Through May 1990 there was virtually no weed production within the Berber and Palestine orchardgrass plots. The wheatgrasses are also persisting at Ferns, but they have not been as resistant to competition from resident annual weeds as the two orchardgrasses or Idaho fescue. Paiute orchardgrass, Rush wheatgrass, California oatgrass, tall fescue, Junegrass and perennial ryegrass have not persisted under competition.

Berber orchardgrass and Idaho fescue are the only two grasses to have survived and produced reasonably well at the Dauenhauer site. Competition from resident annual weeds has been much more severe at the Dauenhauer site relative to the Ferns site and, with the exception of Berber orchardgrass and Idaho fescue, has resulted in a much higher mortality rate at the Dauenhauer site.

Perennial grasses capable of initiating growth subsequent to sufficient fall precipitation and of continuing growth through the winter developed a competitive advantage vis-a-vis the resident annuals when compared to perennial grasses that initiated growth later. During the winter growth period, rates of growth on a per day basis were small. However, over several weeks an advantage in terms of accumulated biomass became established. In this study those grasses that initiated growth earliest and maintained growth through the winter have had the lowest mortality rates and the most uniform stands. In this study, timing of growth and pheological development occurred from earliest to latest in the following order:

Idaho fescue < Berber orchardgrass < Palestine orchardgrass
< intermediate wheatgrass < tall wheatgrass

Long-term production and stand maintenance potentials would be expected to follow the same order. For the most part, that order appears to hold with the exception that tall wheatgrass was more productive and suffered less mortality than intermediate wheatgrass in 1989 and appears to be maintaining its edge in 1990. The orchardgrasses have been more effective at suppressing annual plant reinvasion than has Idaho fescue, which may indicate a greater competitive ability by the orchardgrasses.

Production Potentials

As can be seen in Figures 1 - 6, production varies considerably from year to year and from site to site. Production was generally greater in 1988 than in 1989 at both sites. Production by perennial grasses was greater at the Dauenhauer site relative to the Ferns site in 1988, but in 1989 the situation had reversed. In 1989, competition from annual weeds severely reduced production by perennial grasses at the Dauenhauer site.

At the Ferns site, a perennial grass production potential of about 4000 kgDM/ha appears to be about what can be expected under good growing conditions. The wheatgrasses were able to produce at about that level in 1988 and Berber orchardgrass produced approximately 4,000 kgDM/ha in 1989.

At the Dauenhauer site, if weeds could be controlled, a perennial grass production potential of as high as 6000 kgDM/ha appears to be possible. Idaho fescue produced over 6300 kgDM/ha in 1988. However, in 1989 competition from annual weeds was much greater and production by perennial grasses was consequently much lower. Idaho fescue, which has been able to most effectively resist annual weed reinvasion, had the highest 1989 production (3000 kgDM/ha) among the perennial grasses at the Dauenhauer site. In general, the Dauenhauer site has greater production potential than the Ferns site, but that is true for annual plants as well as for perennial grasses; therefore, the potential for competition is also much greater at the Dauenhauer site. For perennial grass production potential to be realized, at the Dauenhauer site in particular, effective weed control will have to be achieved.

Period of Growth

Period of growth is a function of rainfall distribution. Growth begins in the fall or winter only after sufficient rainfall has occurred to break dormancy. In Fall 1987, growth did not begin until December. In Fall 1988, growth began in November. Most of the annual plants matured and set seed by May before soil moisture was depleted. Yellow starthistle took advantage of the residual soil moisture to continue growth into the summer. Perennial grass growth also continued into the summer as long as sufficient soil moisture was available to sustain growth. The 1987 growth season for perennial grasses lasted into August as a result of 34 mm rainfall in mid-July. During 1988, the last significant rainfall was received in early June. Tall wheatgrass, the latest maturing of the perennial grasses included in the study, matured by early July in 1988.

Periods of active growth appear to be very important with respect to the ability of established perennial grasses to maintain a stand. Some winter growth and continued growth until soil moisture depletion in the summer have contributed to the abilities of Idaho fescue and especially the orchardgrasses to suppress resident annual weeds, including yellow starthistle. Growth curves for selected species during 1988 are presented in Figures 7 - 10.

SUMMARY AND CONCLUSIONS

Stand maintenance potential can be fully assessed only after a number of years of evaluation. The ability of a species to maintain a stand will be a function more of the extreme stress years than of the average years or of those years with better than normal precipitation distribution. It will be the occasional early, severe drought years that will determine which perennial grasses are best suited to the area. However, we feel that we have identified at least some of the characteristics a perennial grass must possess to be adapted to southwest Oregon foothills ecosystems. Based on this study, we have concluded that those grasses able to initiate growth earliest, to continue at least some growth through the winter and to mature earliest will be the grasses that maintain long-term production potential. They may not be the grasses that provide the best production potential in an average or good year.

In this study, the two grasses that best fit this concept of an ideal perennial grass for southwestern Oregon foothills are the native Idaho fescue and the introduced Berber orchardgrass. They appear to have the broadest range of adaptation. Palestine orchardgrass may have greater production potential than Berber orchardgrass but is not as broadly adapted. More information is needed about its range of adaptability so that we can identify which sites will support Palestine orchardgrass on a long-term basis. The wheatgrasses have high production potential in those above average to good precipitation distribution (i.e. late season) years as was evident in this study, especially 1987. Late season precipitation however, is not frequent enough to allow wheatgrasses to maintain vigorous, productive stands. In the long run, the earlier growing and maturing Idaho fescue and Berber orchardgrass have the growth characteristics that should enable them to maintain themselves, to suppress resident annual plants, and thus to maintain site occupancy.

Table 1. Perennial grass species included in the study.

Agropyron elongatum	Tall wheatgrass
A. intermedium	Intermediate wheatgrass
A. varnense	Rush wheatgrass
Dactylis glomerata	
varieties 'Berber'	Berber orchardgrass
'Paiute'	Paiute orchardgrass
'Palestine'	Palestine orchardgrass
Danthonia californica	California oatgrass (native)
Festuca arundinacea	Tall fescue
Festuca idahoensis	Idaho fescue (native)
Koeleria cristata	Junegrass (native)
Lolium perenne	Perennial ryegrass

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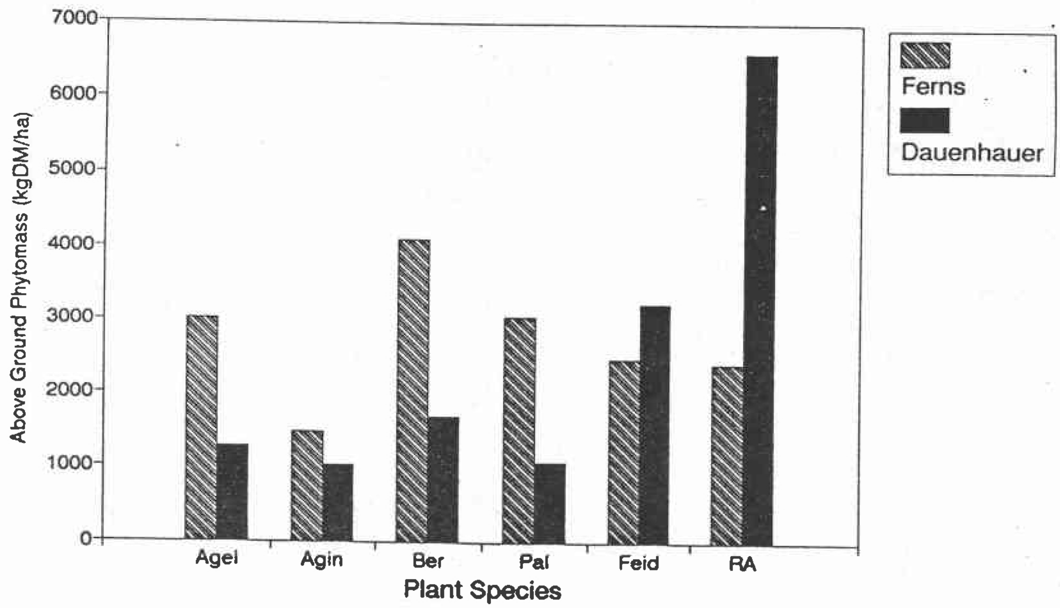

Figure 1. Peak standing crop of selected perennial grasses at two sites in Jackson County, Oregon for 1989. Agel = tall wheatgrass, Agin = intermediate wheatgrass, Ber = Berber orchardgrass, Pal = Palestine orchardgrass, Feid = Idaho fescue, RA = resident annuals.

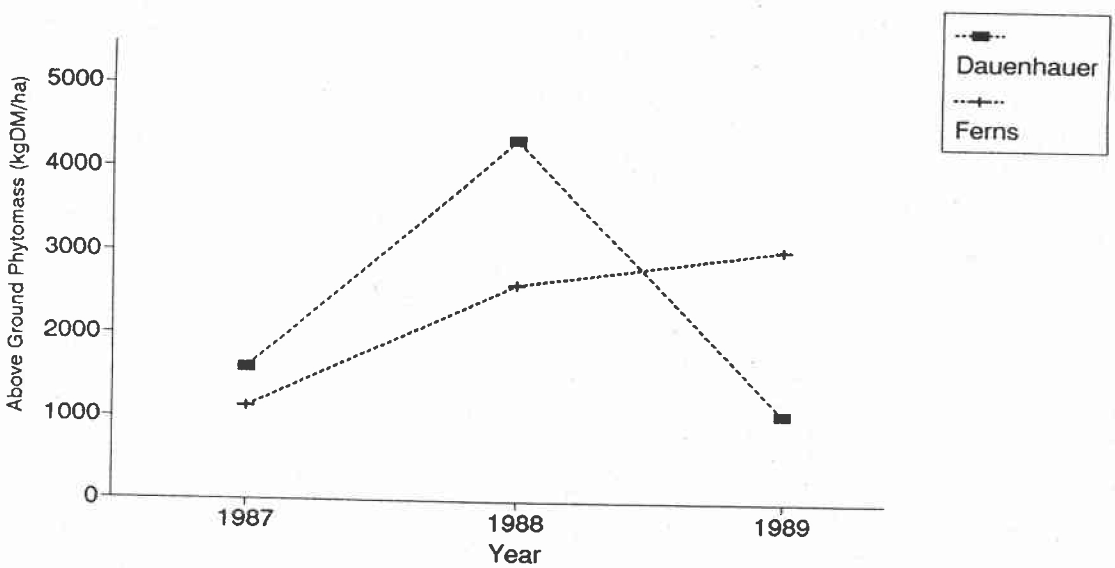

Figure 2. Production of Palestine orchardgrass at two sites in Jackson County, Oregon for the years 1987-1989.

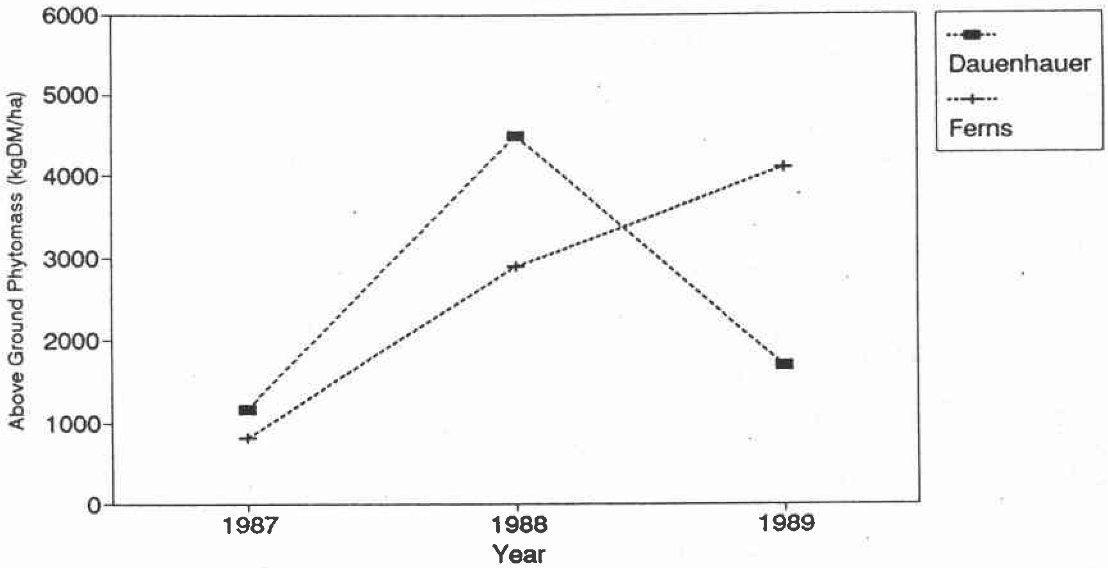

Figure 3. Production of Berber orchardgrass at two sites in Jackson County, Oregon for the years 1987-1989.

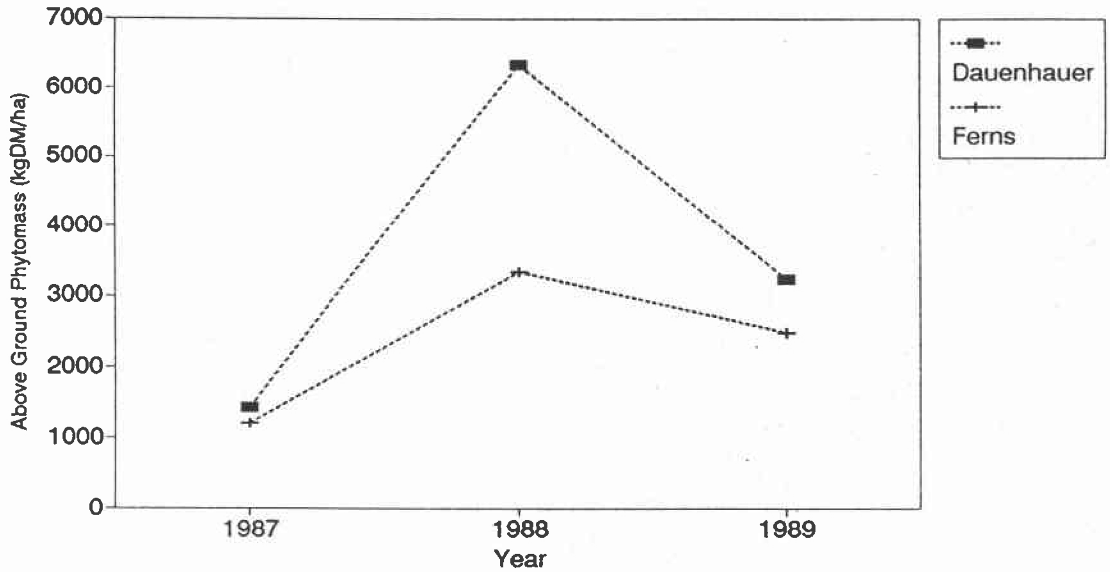

Figure 4. Production of Idaho fescue at two sites in Jackson County, Oregon for the years 1987-1989.

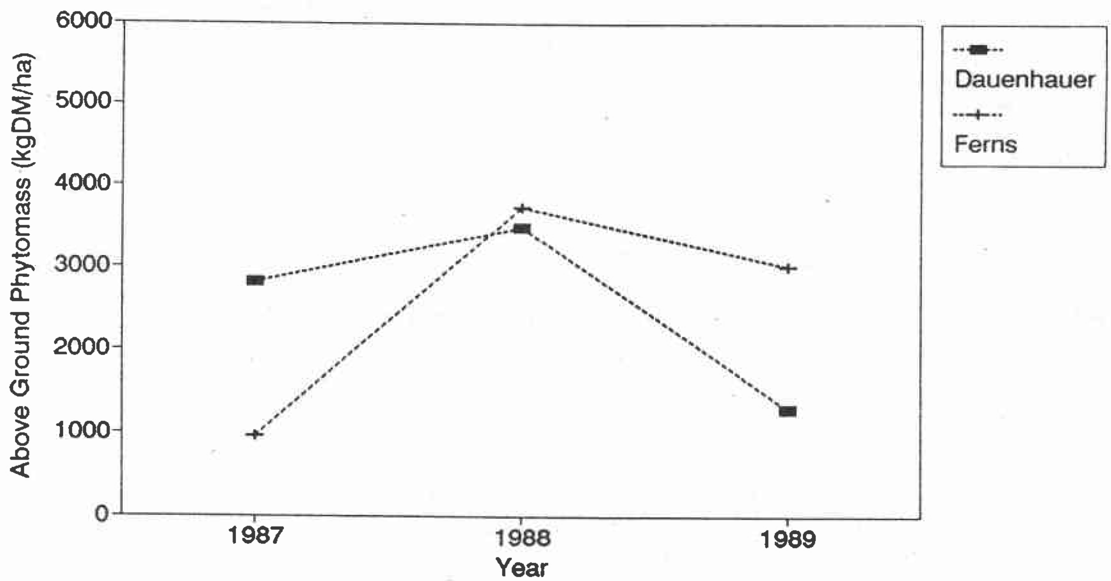

Figure 5. Production of tall wheatgrass at two sites in Jackson County, Oregon for the years 1987-1989.

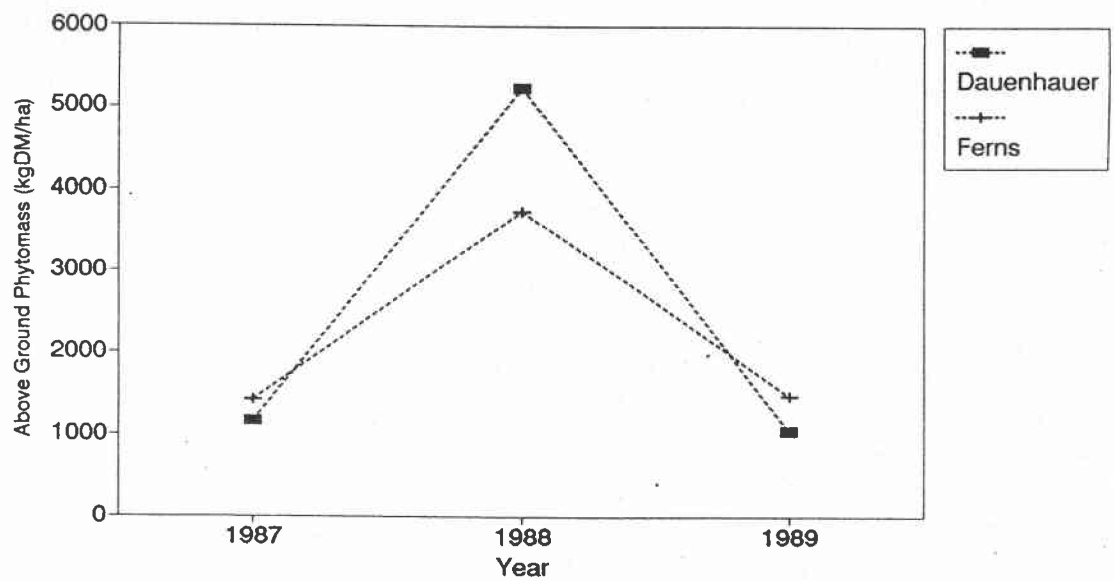

Figure 6. Production of intermediate wheatgrass at two sites in Jackson County, Oregon for the years 1987-1989.

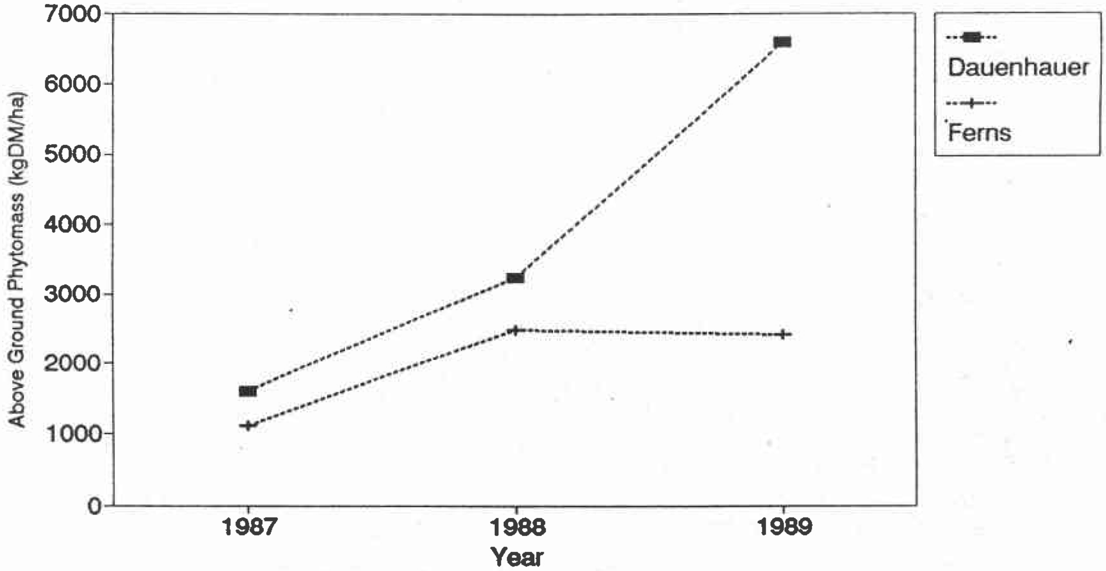

Figure 7. Production of resident annuals at two sites in Jackson County, Oregon for the years 1987-1989.

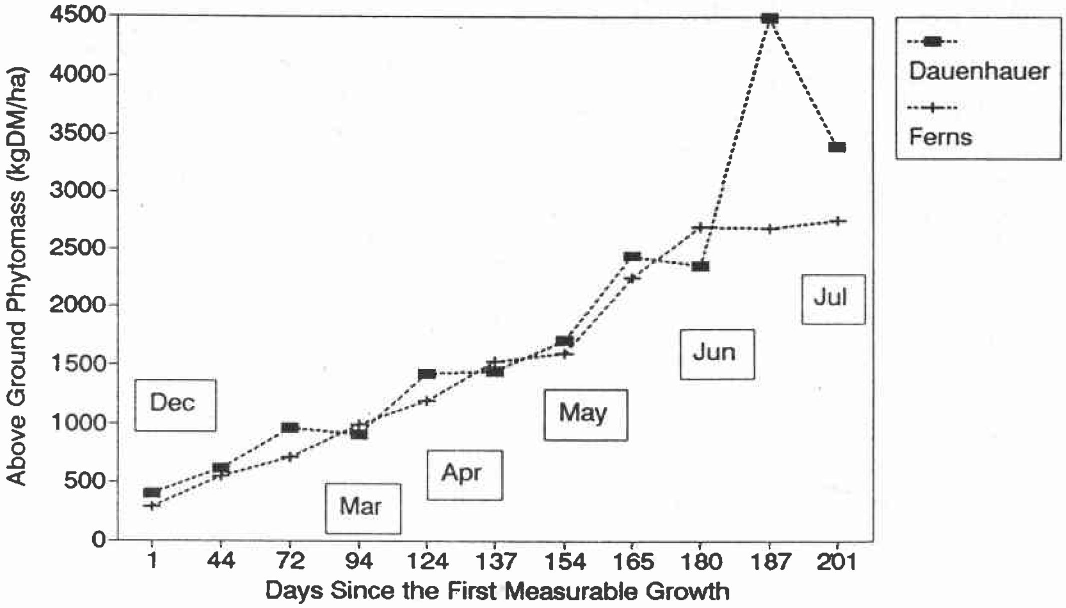

Figure 8. Accumulation of above ground biomass of Berber orchardgrass during 1988 at two sites in Jackson County, Oregon for 1988.

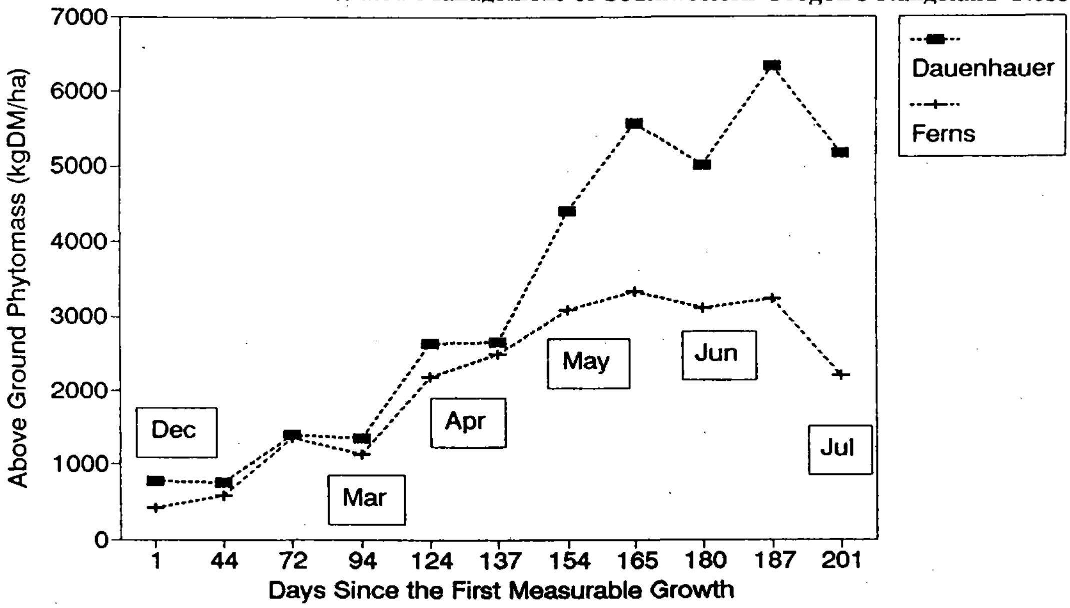

Figure 9. Accumulation of above ground biomass of Idaho fescue during 1988 at two sites in Jackson County, Oregon for 1988.

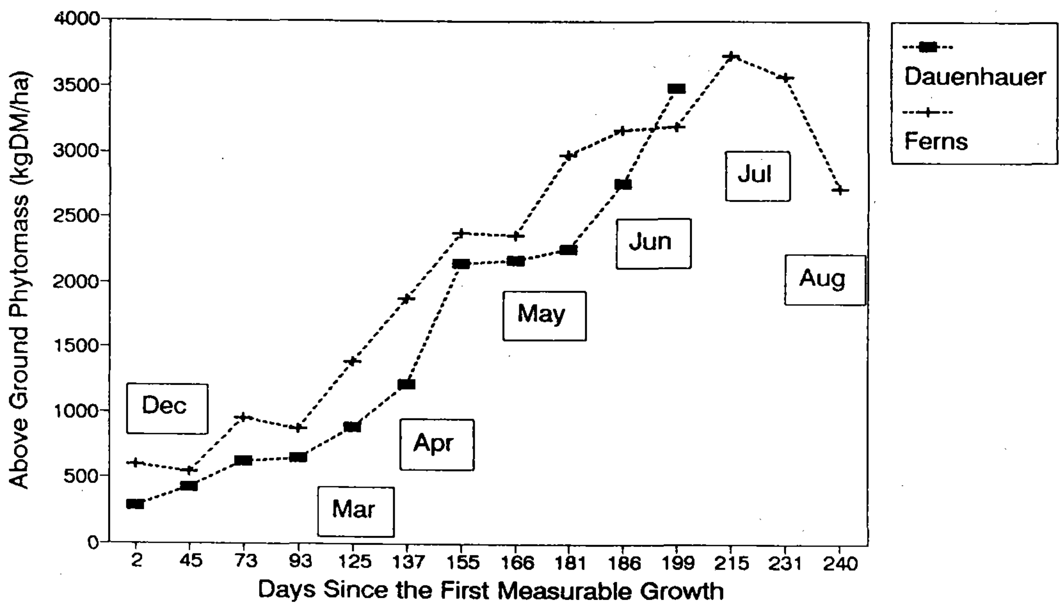

Figure 10. Accumulation of above ground biomass of tall wheatgrass during 1988 at two sites in Jackson County, Oregon for 1988.

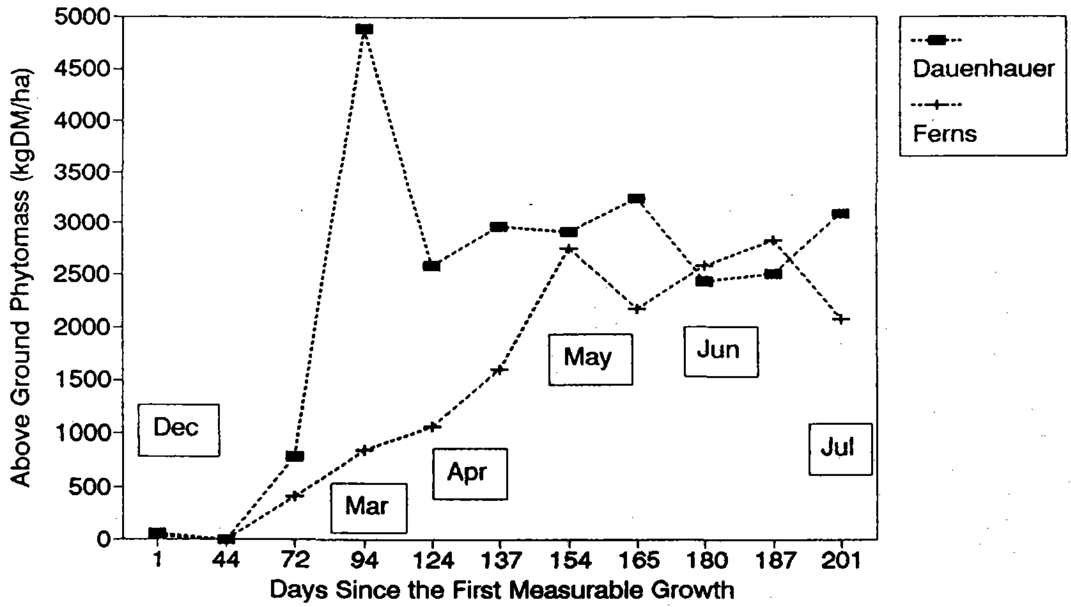

Figure 11. Accumulation of above ground biomass of resident annuals during 1988 at two sites in Jackson County, Oregon for 1988.