AGROFORESTRY: OPTIMIZING LIVESTOCK AND FOREST PRODUCTIVITY[1]

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As the degree and variety of demands on our renewable natural resources increase, the principles of multiple use must play an ever-increasing role in land management planning and operations. Perhaps this explains the considerable attention that agroforestry has received worldwide in recent years.

Simply defined, agroforestry is an integrated system of management whose goal is to optimize the production of agricultural and forest products from a given parcel of land. Such a system holds particular promise for foothill lands in the Pacific Northwest, where profits can be increased through product diversification or through greater overall production of marketable products. A major advantage of this multi-product system may be improved cash flow resulting from the marketing of both short-term (livestock) and long-term (timber) products. Grazing provides immediate financial returns which help to offset the annual costs of timber growing during the early years of a plantation's life, while timber harvest provides a substantial block of income periodically as timber is sold.

A commonly expressed concern relating to agroforestry practices is the potential damage to young trees resulting from browsing or trampling by livestock. Work conducted in both western (Hedrick and Keniston 1966; Leininger and Sharrow 1983) and eastern (Krueger 1983) Oregon suggest that conifer plantations may be grazed by livestock without suffering significant damage if season and degree of grazing are appropriate. In fact, data presented by Hedrick and Keniston (1966), Leininger and Sharrow (1983), and Krueger (1983) all suggest that tree growth may be greater on grazed than on ungrazed plantations. Whether increased tree growth on grazed areas results from reduction or competition between trees and understory vegetation for moisture and light or from a "fertilizer effect" of animal urine and feces remains unclear.

Soil nutrient status and its relation to site productivity is an important concern in both forest and rangeland management. The potential value of using nitrogen-fixing plants to improve soil nitrogen status, in lieu of an expensive fertilizer program, has been recognized on range, pasture, and forestlands for many years. In pasture systems, improved forage production, higher forage quality, and greater livestock gains per acre have generally followed successful introduction of nitrogen-fixing legumes. While the value of nitrogen-fixing species has been postulated for forest production systems, few field trials have actually been conducted.

Since forest soils are often low in available nitrogen, and accelerated nutrient loss may follow timber harvesting, the introduction of nitrogen-fixing plants into timber plantations has great potential to increase site

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productivity. Two basic strategies have been envisioned to incorporate nitrogen-fixing plants into forestry operations: (1) crop rotation systems in which a nitrogen-fixing plant is grown for several years, then removed and the tree crop planted, and (2) various kinds of mixed species systems in which the commercial tree crop is grown concurrently with a nitrogen-fixing plant (Haines and DeBell 1979).

In an agroforestry system, the use of nitrogen-fixing forage species such as clovers should increase the availability of nitrogen to trees, as well as providing a high quality forage base for livestock production. The grazing animal plays several potentially important roles in the production system:

(1) It is the "factory" which harvests and transforms forage into saleable products.

(2) It is a management tool which may be used to control the species composition of the ground vegetation and to minimize competition between the understory vegetation and the timber crop.

(3) It provides a mechanism by which plant material may be rapidly broken down and the nutrients returned to the soil for plant growth.

Little of the nutrients consumed by livestock are retained to build animal tissue; most pass through the animal and are deposited as feces or urine. For instance, approximately 75% of the nitrogen consumed by sheep is returned to the pasture as urine, 90% of which is readily available for use by plants (Whitehead 1970; Whatkin and Clements 1978).

The goal of the work reported here is to test the concepts discussed above by observation of a small-scale mixed-crop agroforestry system employing Douglas-fir (Pseudotsuga menziesii) as a timber crop, subterranean clover (Trifolium subterraneum) as a nitrogen-fixing understory crop, and sheep as the livestock component. Specific parameters which are being measured include tree growth, forage production, forage utilization by livestock, amount and severity of browsing and trampling of trees by livestock, and the amount of nutrients which pass back to the pasture through livestock as urine and feces. Because of the relatively recent initiation of the study, only information pertaining to forage production, forage utilization, and livestock impacts on trees is available.

EXPERIMENTAL PROCEDURES

The study site is in MacDonald Forest, approximately 7 miles north of Corvallis, Oregon. The experimental design is a split plot with two replications of all possible combinations of three tree planting treatments: (1) unplanted--no trees planted, (2) 8 x 8--trees planted eight feet apart in a grid-like pattern, and (3) cluster--trees planted in a group of five trees/cluster with clusters spaced 25 feet apart; and two management systems: (1) grazed--clover planted and the plantation grazed by sheep, and (2) ungrazed--no clover planted and the plantation not grazed by sheep.

The timber plantations were planted with two-year-old (2-0) Douglas-fir stock in 1979 by Dr. Denis Lavender as the basis for an evaluation of a mixed-crop timber production system employing Douglas-fir as the timber crop and red alder (Alnus rubra) as a non-leguminous nitrogen fixer. The strategy adopted was to allow several years for the Douglas-fir trees to become established, then to plant red alder between the clusters in the cluster planting. The 8 x 8 plantings serve as control areas.

These original plots were split, and half of each plot was planted with 20 pounds/acre of subterranean clover seed in fall 1983. The resulting plots are approximately 0.15 and 1.1 acres in size for 8 x 8 and cluster treatments, respectively. All plots were fertilized with approximately 370 pounds/acre of 10-24-0-12 fertilizer in October 1982. Grazed plots were grazed by a flock of 33 ewes from June 13 to July 21, 1983, and again by a flock of 20 ewes from January 11 to January 22, 1984. The flock of sheep spent from one to four days in each plot. Sheep were removed from plots when it was judged that tree damage would occur if they were to remain longer.

Browsing, trampling, and barking impacts of sheep on study trees were evaluated by examination of trees immediately before and after sheep were in each plantation. Browsing which occurred when sheep were not on the plantations was attributed to wildlife, primarily deer. Differences in the status of trees before vs. after sheep grazing were attributed to sheep. Browsing impacts were expressed in three ways: (1) % of trees browsed = # of trees browsed/# trees examined, (2) % of laterals browsed = average # of lateral branches browsed/ # trees browsed = severity of a browsing event, and (3) % of terminals removed = # of trees with terminal leaders removed/# of trees examined.

Forage standing crop and forage utilization by sheep were estimated using the movable cage technique. Ten 2.2-foot^2 quadrats were harvested both within and outside of exclosure cages immediately after sheep left each plantation. Forage utilized was calculated as the difference between the standing crops within and outside of each cage. Total yearly forage production was calculated from 15 quadrats which were harvested in every treatment plot during late June 1983.

RESULTS AND DISCUSSION

A dense stand of subterranean clover was established on the grazed treatment plots by spring 1983. Vegetation on the ungrazed plots consisted primarily of annual grasses.

Forage production was substantially greater on grazed than on ungrazed plots (Table 1), probably as a result of the introduction of clover on grazed plots rather than a grazing effect per se. The spring 1983 grazing period was delayed until June to avoid grazing the plots when young Douglas-fir trees had succulent new growth present. Experience (Leininger and Sharrow 1983) suggests that grazing use of young Douglas-fir plantations be avoided during the period from bud burst until the new foliage has "hardened off", as the palatability of conifer foliage is highest at that time. By the time sheep were introduced into the plantations, the forage had become very dense and somewhat rank.

It was difficult to achieve high levels of utilization while minimizing browsing impacts on trees under these conditions. Levels of herbage utilization ranged from 40% on unplanted plots to approximately 20% on plots with trees. This level of forage use was accomplished with relatively little livestock grazing impact on trees (Table 2). Approximately 30 to 40% of the trees on grazed plantations showed some sign of browsing by sheep. However, when browsing did occur it was very light with less than 2% of current year's foliage growth removed from browsed trees.

Compared to sheep, wildlife had a substantial impact on the plantations. Not only was a large proportion of the trees browsed by wildlife, but the amount of foliage removed from each tree browsed was greater from wildlife than from sheep grazing. The study plantations border a forested area which provides habitat for a large deer population. Most of the wildlife use measured on our plantations is believed to be from deer which graze the trees primarily during late winter and early spring.

In addition to the June grazing period, sheep were placed on the study plantations in January to consume forage which had accumulated during the fall and early winter growing period (Table 3). This grazing use was deemed necessary to achieve maximum establishment and growth of subterranean clover by removing the herbage overburden and reducing competition between clover and the grasses present on the plantations. Since Douglas-fir trees had only mature, relatively unpalatable foliage at this time of year, mid-winter presented an opportunity to "clean up" the pastures before spring growth. This was accomplished without significant browsing impacts on the trees (Tables 3 and 4).

CURRENT STATUS

It is much too early to draw any conclusions from the information gathered in this study. The project is expected to continue until the understory forage base is lost because of tree canopy closure on the cluster plots. The experiences which we gained this year have been encouraging. A considerable amount of forage was consumed by sheep with little browsing impacts on the timber crop. Height and diameter growth of the Douglas-fir trees are being measured. Within the next two or three years, we expect to have some indication of whether the clover/grazing program is affecting tree growth.

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Table 1. Forage production and utilization for the 1983 grazing period. Data are mean $\pm$ standard error.

	No Trees		8 x 8 Tree Planting		Cluster Tree Planting	
	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed
Herbage Produced (lb/AC)	4987 $\pm$ 729	2196 $\pm$ 44	6116 $\pm$ 903	1987 $\pm$ 161	5295 $\pm$ 152	2643 $\pm$ 88
Herbage Utilized (lb/AC)	2147 $\pm$ 187	--	1272 $\pm$ 54	--	1259 $\pm$ 309	--
Herbage Utilized (%)	40.4 $\pm$ 2.3	--	22.1 $\pm$ 4.1	--	20.8 $\pm$ 5.1	--
Sheep Days of Use/AC	663	0	443	0	219	

Table 2. Browsing impacts sustained from wildlife (before study) and sheep (during 1983 grazing period) in relation to herbage use. Data are mean ± standard error.

	8 x 8 Tree Planting		Cluster Tree Planting	
	Grazed	Ungrazed	Grazed	Ungrazed
1) % of Trees Browsed:				
Wildlife	81.8 ± 0.5	88.8 ± 7.2	76.5 ± 1.1	72.7 ± 6.4
Sheep	41.8 ± 1.5	--	32.6 ± 16.6	--
2) % of Laterals Browsed:				
Wildlife	15.1 ± 5.0	14.9 ± 1.0	12.5 ± 2.9	4.0 ± 0.3
Sheep	1.9 ± 0.8	--	0.4 ± 0.3	--
3) % of Terminals Taken:				
Wildlife	18.3 ± 3.2	19.9 ± 5.4	9.1 ± 2.1	5.5 ± 0
Sheep	7.0 ± 0.1	--	3.8 ± 2.6	--
4) % Herbage Utilization	22.1 ± 4.1		20.8 ± 5.1	

Table 3. Standing crop and utilization of forage for the 1984 late winter grazing period. Data are mean ± standard error.

	No Trees, Grazed	8 x 8, Grazed	Cluster, Grazed
Standing Crop (lb/AC)	1622 ± 121	2119 ± 22	2008 ± 60
Herbage Utilized (lb/AC)	327 ± 12	624 ± 31	504 ± 24
Herbage Utilized	20.3 ± 0.8	29.5 ± 1.8	25.1 ± 0.5
Sheep Days of Use/AC	174	128	95

Table 4. Browsing impacts from wildlife and sheep for the 1984 late winter grazing period. Data use mean ± standard error.

	8 x 8 Planting		Cluster Planting	
	Grazed	Ungrazed	Grazed	Ungrazed
1) % of Trees Browsed:				
Wildlife	0.4 ± 0.3	0	0.4 ± 0.2	0
Sheep	34.7 ± 10.9	--	20.0 ± 1.0	--
2) % Laterals Browsed:				
Wildlife	0	0	0	0
Sheep	4.3 ± 1.7	--	1.5 ± 1.1	--
3) % of Terminals Taken:				
Wildlife	0	0	0	0
Sheep	0	--	0	--
4) % Herbage Utilization	29.5 ± 1.8	--	25.1 ± 0.5	--