AGROFORESTRY SYSTEMS FOR WESTERN OREGON HILL LANDS

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INTRODUCTION

Agroforestry refers to the joint production of forest and agricultural products by actively managing the interactions between forest and agricultural plants and animals. Forestry and agriculture are the pillars of Oregon's natural resource based economy. Livestock production is the largest single component within Oregon agriculture. Therefore, it is natural that Oregon agroforestry emphasizes forest/livestock systems.

The mark of any good system is that its total productivity as a unit is greater than the sum of its individual components managed separately. In designing agroforestry systems, we attempt to maximize the productivity and sustainability of the agroecosystem as a whole by selecting components which are both productive in their own right, and which provide for the needs of other components. For instance, subclover (*Trifolium subterraneum*) is often included in our agroforestry systems both for its productive role as a valuable livestock feed and for its ability to capture atmospheric nitrogen which can then be used by associated plants such as Douglas-fir trees.

There are approximately 1.2 million acres of hill land in Western Oregon. Much of this land historically supported oak woodland. Because of steep slopes and shallow soils, hill lands are seldom used as croplands. Livestock grazing is the primary agricultural use. The original inhabitants of western Oregon were active land managers who used fire as a tool to produce grassy meadows and to keep oak woodlands open and park-like. Fire suppression in the last century has supported a successional process by which hardwood trees have invaded previously open grasslands and formerly open hardwood forests have become closed canopy forests. Conifers, primarily Douglas-fir, are now beginning to break through the canopy of hardwoods in many areas. Apparently, many hill lands will support conifer forests, but trees are often difficult to establish and growth rates are relatively slow compared to other commercial forest sites in Western Oregon. In addition, many of these lands are sufficiently near to urban centers that land use must be especially sensitive to environmental quality issues including environmental contamination, destruction of native plant or animal habitat, and visual appeal. Agroforestry may present some opportunities to increase land productivity (produce both trees and pasture/livestock), improve cash flow (immediate income from grazing, then later income from sale of trees), and to increase the diversity of plants and animals present (improve wildlife habitat). Because agroforestry systems tend to be self-sustaining, they do not require much pesticide or fertilizer use. They are often park-like in appearance and social acceptability is higher than traditional forestry.

Agroforestry research in western Oregon hill lands began as a effort of Rangeland Resources and Forest Science faculty at Oregon State University in 1952 (Hall et al. 1959) and continues today. To date, three

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agroforests have been established. They will be discussed in chronological order.

HILL PASTURE AGROFOREST

Douglas-fir trees were planted during 1952-53 into oak (*Quercus garryana*) woodland in which oaks had been clearcut, about half of the oaks removed, or all oaks remained prior to planting. The resulting forest plots were seeded with a pasture mix containing orchard grass (*Dactylis glomerata*), tall oatgrass (*Arrhenatherum elatius*), burnet (*Sanguisorba minor*), and subclover. Each plot was split in half and one-half grazed by sheep during 1952-1960. Tree growth and survival data has been collected periodically for over 30 years. Such long-term studies are rare. Interestingly, oak treatment had little effect upon the early survival of Douglas-fir seedlings. However, growth of seedlings during the first 4 years after planting was 40% lower under the unthinned oaks than it was in either thinned or clearcut areas (Hall et al. 1959). Clearcutting did not appreciably increase Douglas-fir growth compared to thinning oaks (Tables 1 and 2, from Jaindl and Sharrow 1988). In 1985, Douglas-fir in thinned oak forest were only 3% taller and 0.7 inches greater in diameter than those in clearcut plots. Inclusion of livestock into the forest management system both provided a second source of production and increased tree growth by controlling understory vegetation which competes with young trees for moisture. Thinned plots produced a total of 50 lbs of meat/acre, and clearcut plots 85 lbs/acre, compared to open pasture which produced 94 lbs/acre during 1955-1957. Grazing capacity declined as Douglas-fir trees and oak sprouts grew. Difficulty in handling sheep in dense oak coppice caused grazing to be abandoned in 1960 (Hedrick and Keniston 1966). Trees in grazed clearcuts grew 59% faster and those in grazed thinned areas grew 13% faster during 1952-1960 than did trees in ungrazed halves of these plots (Hedrick and

Keniston 1966). Increased tree growth on grazed forests was attributed to observed greater soil moisture present during summer on these areas, possibly as a result of vegetation removal by grazing sheep. In 1985, Douglas-fir trees in grazed plots were still 10% taller and 7% bigger in diameter than those from ungrazed portions of the forest (Jaindl and Sharrow 1988).

Table 1. Mean height (cm) of Douglas-fir trees from the site preparation and grazing treatments. Data for 1960 and 1964 from Hedrick and Keniston [4].

	Site preparation			
Year	Unthinned	Thinned	Clearcut	SE
1960	97[a1]	145[b]	183[b]	17.5
1964	183[a]	295[b]	320[b]	25.8
1985	1082[x]	1356[y]	1311[y]	90.7
	Grazing			
	Grazed	Ungrazed		SE
1960	157[x]	124[x]		13.0
1964	297[x]	234[y]		25.7
1985	1311[x]	1189[x]		95.3

[1] Means for each treatment group in a row not sharing a common letter differ x, y = p < 0.10, and a, b, c = p < 0.05.

Table 2. Mean dbh (cm) of Douglas-fir trees from site preparation and grazing treatments. Data for 1964 is from Hedrick and Keniston [unpublished].

	Site preparation			
Year	Unthinned	Thinned	Clearcut	SE
1964	0.8[a1]	2.3[b]	3.6[b]	0.6
1985	10.7[a]	14.5[b]	16.3[b]	1.3
	Grazing			
	Grazed	Ungrazed		SE
1964	2.5[a]	1.8[b]		0.4
1985	14.2[x]	13.2[x]		1.1

[1] Means for each treatment group in a row not sharing a common letter differ x, y = p < 0.10, and a, b, c = p < 0.05.

This first study set the stage for the agroforestry systems which followed by demonstrating that: (1) sheep grazing is compatible with conifer establishment and growth, (2) joint production of conifers and hardwoods is possible on hill lands, and (3) the benefits of sheep grazing during the first few years after timber planting are still evident in tree size many years after grazing has ceased.

Oaks woodlands are both aesthetically pleasing and provide important habitat for native plants and animals. The potential to jointly grow oaks, Douglas-fir, and pasture in hill land agroforestry systems may prove especially useful in designing productive, biodiverse, socially acceptable land use systems for the urban fringe.

PEAVY ARBORETUM AGROFOREST

Most commercial forests are planted in a rectangular grid pattern. Conceptually, grids should space trees as far apart as possible within a given tree density per acre. This reduces potential for competition between trees, but maximizes competition between trees and ground vegetation. The resulting suppression of ground vegetation by rapidly growing trees, which is desirable in forest monocultures, is potentially undesirable in agroforests where ground vegetation is regarded as a valuable component of the ecosystem. Relatively little is known about the effects of alternative planting patterns in forest understory/overstory relationships and total ecosystem productivity. Therefore, work to study agroforest spatial pattern effects was initiated in 1982 on a medium potential forest site near Corvallis. Treatments included forest plantations planted in a conventional 8 X 8 ft. grid, plantations planted in clusters of 5 trees each with 25 ft. between clusters, and 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. The concept behind this study is that trees do not use all of the site resources during the early portion (first 8-15 years) of a timber crop rotation. 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 (Logan 1983). Subclover was chosen as forage because we expected that it would not compete with trees for summer moisture, would enrich the soil by fixing nitrogen (Alston 1981), and would provide nutritious feed for sheep. Sheep provide defoliation required for subclover to prosper (Sharrow et al. 1981), control weeds (Sharrow et al. 1989), and convert organic nitrogen fixed by the clover into a soluble form (urine) available to trees (Sharrow and Leininger 1983). Sheep grazed the agroforests each year with relatively little browsing damage to trees (Table 3, from Sharrow et al. 1992). Although average annual forage production during 1983-1987 was 5000 lb/acre on agroforestry (subclover + trees + grazing) compared to only 2500 lb/acre on forestry plantations, tree height and diameter growth were similar (Figure 1, from Sharrow et al. 1992). Lack of tree response to treatments may reflect the high site potential of Peavy Arboretum, since increased tree growth on agro-silvopastoral plots relative to traditional forest plots was reported for a lower potential timber site (the Hill Pasture Site) only 10 miles away (Jaindl and Sharrow, 1988). Trees did not begin to reduce forage production below levels of open pasture until 1986. Agroforestry plantations produced only 74%, 62%, 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 the number

of trees planted per acre in determining the degree of competition between trees and understory forage plants (Figure 2, from Sharrow 1991). For example, a 10-year-old plantation of 45 trees/acre (110 trees/ha) planted in a grid has the same predicted forage production as 182 trees/acre (450 trees/ha) planted in rows of clusters. Clearly, spatial distribution of trees offers a powerful tool to optimize joint tree/pasture production in timber plantations. The importance of pattern also raises questions about the applicability of much current silvicultural data, which is based upon grid plantations, to more intensively managed agroforests which may be 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 period 3 only. Tree growth shows no effect of pattern yet, however, we would not expect this to become evident until period 4.

The establishment phase of our timber stand was completed with the first pre-commercial thinning in 1988. Grazing was terminated in 1987. Effects of tree planting pattern on tree growth and stand development will continue to be monitored. Lessons gained from the Peavy Arboretum agroforests formed the basis for design of the third generation agroforest at the Witham Hill site.

Table 3. Forage utilization levels (% dry matter) and livestock impacts on Douglas-fir trees in cluster and grid tree planting treatments for each grazing period during 1983-1987. Data are $\bar{x} \pm$ S.E.

| Season/ Year | % Utilization | Livestock impacts | | | |
		% Lateral browsing	% Terminals browsed	% Trees with breakage	% Trees debarked
Cluster tree planting					
1983-84					
Summer	24 ± 6	1.6 ± 1.2	4.5 ± 0.4	8.7 ± 0.4	4.2 ± 1.8
Fall/winter	28 ± 1	1.8 ± 1.5	0	0.5 ± 0.3	0.8 ± 0.1
Spring	49 ± 2	5.3 ± 1.9	0.4 ± 0.4	2.7 ± 0.4	0.4 ± 0.4
1984-85					
Summer	30 ± 9	3.2 ± 0.8	1.2 ± 1.1	5.6 ± 2.7	1.5 ± 0.7
Fall/winter	29 ± 7	4.6 ± 0.8	0	0	0
Spring	39 ± 6	2.8 ± 0.2	0.8 ± 0.7	7.0 ± 0	0.8 ± 0
1986					
Spring	50 ± 11	---	0	---	7 ± 3.5
Summer[1]	54 ± 15	---	0	---	0
1987					
Spring	56 ± 11	---	0	---	10 ± 0.3
Summer[1]	50 ± 9	---	0	---	0
Grid planting					
1983-84					
Summer	16 ± 1	5.7 ± 0.5	7.0 ± 0.1	13.9 ± 3.3	9.5 ± 7.7
Fall/winter	28 ± 3	4.0 ± 1.6	0	1.7 ± 0.1	0
Spring	36 ± 3	9.9 ± 3.9	0.9 ± 0.9	6.1 ± 4.4	0
1984-85					
Summer	24 ± 2	7.1 ± 0.1	9.6 ± 6.2	7.9 ± 0.9	7.9 ± 4.4
Fall/winter	19 ± 4	4.1 ± 0.1	0	0	0
Spring	21 ± 8	3.3 ± 1.3	0	5.2 ± 1.9	0.9 ± 0.9
1986					
Spring	54 ± 6	---	0	---	20 ± 0.7

[1] Trees protected by electric fencing in Summer 1986 and 1987.

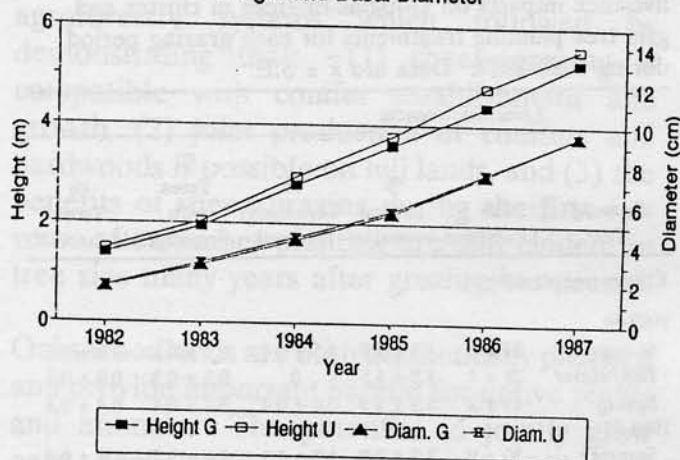## Douglas-fir
Height and Basal Diameter

Figure 1. Mean height and basal diameter Douglas-fir trees in grazed (G) agroforests and ungrazed (U) forest plantations during 1982-1987. Data are average of grid and cluster plantations. Tree height and diameter of grazed and ungrazed plantations did not differ in any year (P < 0.05).
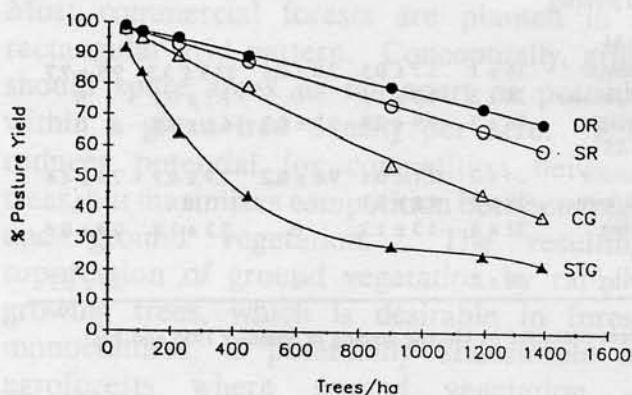

Figure 2. Predicted forage production for 7 tree densities planted in single-tree grids (ST), 5-tree clusters in grids (CG), 5-tree clusters in single rows (CDR). Data are percentage of forage production observed in open pasture.

WITHAM HILL AGROFOREST

The underlying hypothesis for this work is that total productivity of agroforests will exceed that of either forest or pasture components alone. The extent to which tree management variables such as pruning, tree spacing, and tree density may be manipulated to maximize agroecosystem productivity is being evaluated.

Knowledge obtained from past practical experience and from available literature were incorporated into agroforestry plantations which were planted on a low potential forest site near Corvallis in 1988-89. Treatments include three replications of open pasture (0.6 acre each), forest plantations of 230 trees/acre (570 trees/ha) planted in a grid (0.6 acre each), and agroforests (1 acre each) with 230 trees/acre planted in single rows (8 ft. between trees, 23 ft. between rows) + subclover (20 lb/acre) planted in 1988 + sheep grazing each spring. Agroforest trees were planted in rows in order to reduce competition between trees and pastures ,to facilitate handling of livestock, and to provide access for forage harvesting machinery should haying be desired (Lewis et al. 1984). Rows are orientated predominately east-west so that tree shadows are mainly cast down along the row rather than onto the pasture between rows. East-west orientation also maximizes protection of trees from wind which at our latitude mostly blows from the west. Agroforests and pastures are grazed by sheep during spring each year.

Similar to previous observations from the Peavy Arboretum agroforest trial, Witham Hill pastures and young agroforests had similar forage production. Three-year (1990-1992) annual mean forage production was 4800, 5100, and 3300 lb/acre for agroforests, pastures, and forests, respectively. Approximately 50% of the forage produced each year was consumed by sheep. Herbage in agroforests and pastures was predominantly subclover in 1990 (58% of canopy cover), 1991 (41%) and 1992 (44%), while forest herbage was mostly annual grasses (33%) and weedy forbs (21%). Agroforest trees grew 40% more in height (Figure 3) and 20% more in diameter (Figure 4) than did forest trees during 1989-1992. Height growth differences between agroforest and forest trees was concentrated in spring (April-June) which

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accounted for approximately 75% of total height growth each year. Differences in diameter growth (Figure 5), however, were equally divided between spring and summer-fall (July-December) periods. Greater diameter growth of agroforests during the dry season suggests that they are better supplied with soil moisture than are the adjacent forests. Increased access to water in agroforests may reflect control of competing vegetation by sheep grazing or may be related to larger root systems of the more vigorous agroforest trees.

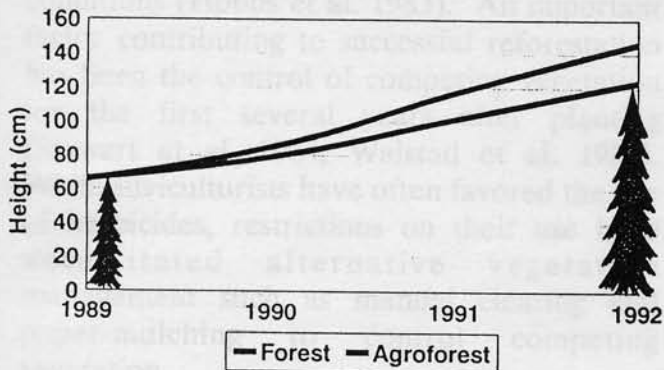## Douglas-fir Height

Witham Hill Agroforestry Trial

Figure 3. Height growth of trees in forest and agroforest plantations near Corvallis.

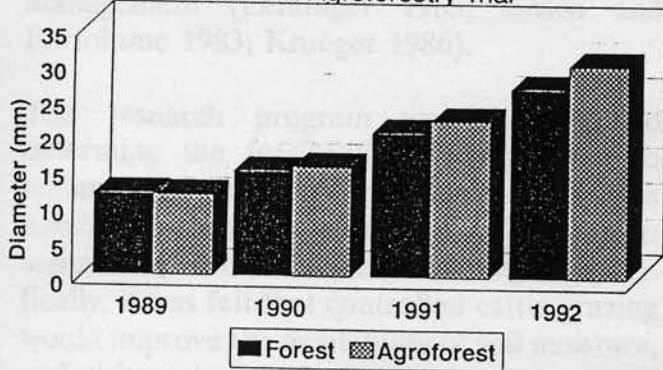## Douglas-fir Diameter

Witham Hill Agroforestry Trial

Figure 4. Diameter growth of trees in forest and agroforest plantations near Corvallis.

Seasonal Diameter Growth

Douglas -fir
(mm)

Forest — Spring 3.69 58.3%; Fall 0.19 3.0%; Summer 0.6 9.5%; Winter 1.85 29.2%

Agroforest — Spring 4.63 57.1%; Fall 0.52 6.4%; Summer 1.24 15.3%; Winter 1.72 21.2%

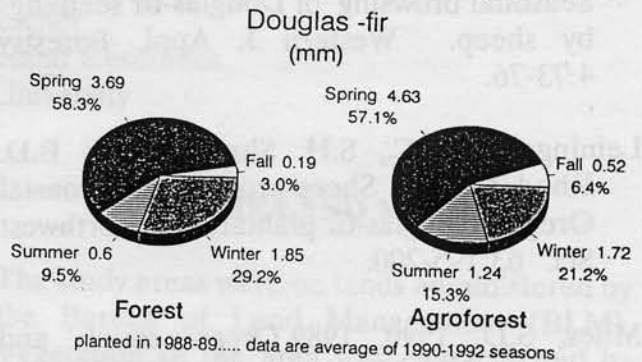planted in 1988-89..... data are average of 1990-1992 seasons

Figure 5. Seasonal diameter growth of trees in forest and agroforest plantations near Corvallis.

The Witham Hill site is bounded by apartments on one side and by single-family housing subdivisions on two sides. This is truly forestry on the urban fringe. To date, relations with the neighbors have been good.

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