Introduction to Agroforestry Alternatives

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Steven Anderson
Assistant Professor of Forestry

Terrence G. Bidwell
Assistant Professor of Range Science

Loren Romann
Professor of Agronomy and Extension Pasture and Forage Specialist

Figure 1. Agroforestry opportunities may allow landowners to diversify their operations and produce more stable cash flows. (Photograph by Terry Clason)

Introduction

Agroforestry is a relatively new term for the practice of growing trees with agricultural crops and/or livestock on the same piece of land. Agroforestry can include forest-range grazing management efforts with native forage species. Specific information regarding forest-range management can be found in OSU Extension Facts No. 2864, "Grazing Forest-Range in Eastern Oklahoma." In addition, agroforestry can also include timber and livestock production with introduced pasture species or growing agricultural crops simultaneously with various tree species. This fact sheet will address the latter two opportunities.

There are both ecological and economical aspects of agroforestry. Reasons for a renewed interest in agroforestry systems include concern about our dependence on fossil fuels, increased attention to soil erosion and marginal land use, increasing costs of pesticides and other agricultural chemicals, land-use conflicts, and need to revitalize our rural economies. Successful agroforestry systems will be ones that not only increase the overall yield of land in a sustainable manner but that are also economically viable, and socially and culturally acceptable. Benefits may include sustained soil fertility, soil conservation, less risk of crop failure, increased pest control, and more stable cash flows. A profitable agroforestry operation will combine enterprises which are compatible.

In further defining agroforestry it is important to realize that deliberately growing woody plants on the same unit of land that crops and/or livestock are grown may occur at the same time or in some sequence in time. For example, if tree seedlings are planted in areas that are to be grazed, it may be necessary to exclude livestock until the seedlings become established. During this time, it may be possible to harvest hay from between the rows of trees. Later, as the trees close canopy and mature, livestock numbers will have to be balanced with current forage production. This is one example of a time sequence in agroforestry. In agroforestry systems, it is not possible to maximize the production of two or more crops on the same piece of land. However, it may be more profitable in the long run to produce a moderate amount of both. This enterprise diversification allows management costs to be distributed among trees, forages, and livestock to improve marketing flexibility.

Following a decision to develop an agroforestry enterprise, the most important component of the operation will be to develop a management plan that describes your resources and states your objectives. This will help guide you in choosing between different agroforestry alternatives and determining the size of the operation.

A critical part of the planning process is a sound analysis of the potential costs and returns of producing various tree species with livestock or crops. Although there are a few examples of successful agroforestry operations in the south, most of the data are from outside of Oklahoma. With no long term studies in Oklahoma, only potential opportunities can be identified in this publication. **It will be necessary for the landowner to be involved in a certain amount of experimentation to refine the agroforestry process on a site-specific basis and to confirm that selected management alternatives are profitable.** The studies described in the following sections are presented to provide the reader with a general understanding of the factors which should be considered in an agroforestry operation. They do not represent recommendations at this time.

Trees and Introduced Pasture

Planting Trees in Pastures

The interaction of cattle grazing with pine establishment and growth has been studied for more than 30 years in the southern United States. One of the most cited studies (Lewis et. al., 1983) examined the growth of Slash pine in Georgia for 20 years with 15 years of grazing under trees planted at 12 X 12 feet spacings, under trees planted at 20 X 20 feet spacings, and with no trees planted. The study plots were established in pastures of Coastal bermudagrass, dallisgrass, and Pensacola bahiagrass. Site preparation included stump pulling and removal, repeated disking, and fertilization with 400 pounds of lime per acre and 500 pounds of 4-5-10 N-P-K fertilizer per acre worked into the soil. Trees were grown weed-free for three years. Grasses were established the fourth year. And grazing by stocker cattle began the fifth year. Then the pastures were fertilized as needed, and grazed and burned annually for 15 years. In native grasses, trees were also planted at each spacing with no site preparation or grazing.

Results of this study confirmed previous information that increasing tree canopies reduced forage production of all grasses. Bahiagrass was the most shade tolerant while Coastal bermudagrass was the least tolerant. During the 15 years of grazing, cattle gains totaled 3500 pounds per acre from pastures with no pines. This compared to 1350 and 2050 pounds per acre from pastures with Slash pine planted at 12 X 12 and 20 X 20 feet, respectively. Bahiagrass pastures yielded slightly more beef than dallisgrass, and both produced significantly more beef than bermudagrass. Tree growth differences under the different spacings in native and introduced pastures are presented in Table 1.

General conclusions from this growth data are that 1) trees benefitted from weed control and fertilization under the introduced pasture regimes. 2) The diameter increases and height and volume decreases when trees are planted at wider spacings. 3) More beef can be produced at wider tree spacings, and 4) the quality of the site in this study is greater than what generally exists in Oklahoma. No economic data was available for this study, and gains produced by introduced pasture should also consider the net profit aspects of an operation.

Table 1. Height, Diameter, and Pulpwood Volume at age 20.

	Native Pasture spacing		Introduced Pasture spacing	
	12X12	20X20	12X12	20X20
Height (ft.)	52.5	51.5	62.3	55.4
Diameter (in.)	7.7	9.2	11.8	13.5
Volume (ft3/acre)	2080	909	2593	1296

In another study (Clason, 1988), a cost analysis was provided for a possible 35-year timber/pasture situation with Loblolly pine planted in an old field and bermudgrass established in the third growing season. Estimated establishment costs are presented in Table 2. Trees were assumed to be planted on a 6 X 16 foot spacing with about 442 trees per acre. Other costs included pruning 100 crop trees per acre up to eight feet at age six. At age 11, the stand was thinned to the 100 trees per acre with trees being pruned up to 17 feet. Pruning maximizes knot-free wood formation in large diameter trees.

Table 2. Timber management costs incurred during development of a timber/pasture management system.

Practice	Age Applied	Cost ($/acre)
Site Preparation (Burning)	0	5.00
Planting	0	35.36
Weed Control	1	10.00
Insect Protection	1	10.00
Weed Control	2	10.00
Insect Protection	2	10.00
Pruning	6	36.00
Pruning	11	98.00
TOTAL		214.36

Table 3 depicts wood growth and revenue for a 35-year-old Loblolly pine plantation established on an abandoned field at a 10 X 10 foot spacing or 435 trees per acre. This is thought to be a conservative estimate since yield estimates did not include benfits from weed control, insect control, or thinning or pruning that were identified as costs. Assumed stumpage values were $15.16 per cord pulpwood and $153.72 per 1000 board feet sawtimber (Doyle scale).

Estimated costs for the forage/livestock production part of the operation are presented in Table 4. Since bermudagrass was not established until the third year, calculations are for a 33-year production period. Fencing for an 80 acre pasture divided into four blocks was estimated at $37.50 per acre. Annual forage production costs included application of 100 pounds of nitrogen per acre, weed control, and potassium and phosphorus fertilization as required.

Table 3. Estimated timber yields and revenues produced by a timber pasture over a 35-year rotation.

Harvest Age	Harvest Volumes Pulpwood	Harvest Volumes Sawtimber	Harvest Revenue Pulpwood	Harvest Revenue Sawtimber
	Cords/Acre	Bd.Ft./Acre	—— $/Acre ——	
11	7.0		106.12	
30	2.4	4,950	36.38	760.91
35	1.5	7,200	22.74	1,108.32
TOTAL	10.9	12,150	165.24	1,869.23

Table 4. Estimated forage/livestock costs during a 33-year period.

Practice	Age Incurred	Initial Cost	Total Cost
		----------- $/Acre -----------	
Fencing	0	37.50	37.50
Animal Purchase	0,7,14,21,28	450.00	2,250.00
Winter Feed	Annually	160.00	5,280.00
Forage Production	Annually	50.00	1,650.00
Animal Health	Annually	3.00	99.00
Breeding	Annually	10.00	330.00
TOTAL			9,646.50

Animal purchase included one heifer-calf at the end of the pine's second growing season and every seven years afterward. Winter feed included 4 pounds of grain and 15 pounds of hay per day for 150 days.

Revenue from forage/livestock production included salvage cow income of $2000 per acre and calf liveweight production at $9,332.40 per acre for the 33-year period. Liveweight production was assumed to be 404 pounds per acre (85 percent calving rate) with an average market value of $.70 per pound.

Based on these assumptions, estimates of internal rate of return for the timber/pasture management system was 9.4 percent. Return on the forage/livestock system alone was 9.2 percent, indicating that planting and managing a timber crop in conjunction with forage production can improve the economic potential of a pasture. Management costs and revenues for a forage/livestock system vary greatly from year to year and are generally less stable than timber investment returns because of market fluctuations. A combined production system, therefore, may produce more stable returns and cash flows, and additional market flexibility.

NOTE: The two studies just decribed provide the reader with some possible ideas regarding agroforestry and certainly a framework in which to begin your own analysis. Oklahoma landowners should not assume that similar growth rates or revenues exist on their land. It is important to consult professional foresters, range managers, and soil fertility specialists when evaluating the opportunities for an agroforestry operation on a site specific basis.

One traditional concern about combining timber and livestock production is the potential effect livestock can have on early seedling survival. This is the main reason why recommendations usually include exclusion of livestock until pines are 3- to 4-feet tall and/or careful monitoring of stocking rates for livestock to avoid overgrazing. A study of artificially inflicted injury including foliage removal, removal of growing shoots, and stem bending on Slash pine seedlings showed that only the highest levels of combined defoliation and shoot removal reduced survival (Lewis, 1984). In some cases grazing can improve survival by controlling competing vegetation. This was accomplished in Slash pine planted on a 4 X 33 foot spacing. Electric fence was placed directly over the pine seedling rows to provide controlled strip grazing of the ryegrass pasture (Pearson, 1987).

Electric fencing was also used successfully in a later study (Pearson et. al., 1990) where Virginia pine Christmas trees were planted in a 10 acre bahiagrass/ryegrass pasture. Trees were planted in a single row configuration of 8 X 33 feet (165 trees per acre) which effectively removed 13.6 percent of the land base from grazing. From November to May each year, 25 to 40 crossbred Brahman cows with calves grazed in rotation between the pine rows for three to four hours per day. Excess ryegrass was baled in May and bahiagrass was baled during the summer. Cattle grazed the ryegrass as supplemental feed to the native forest range during the winter period. Although annual income from cattle was reduced by $19.04 per acre, the Christmas trees returned $195.40 per acre annually for a three-year period. The conclusion of the study was that farmers already in the livestock business could diversify their operation by using a small portion of their land for an alternative tree enterprise.

The key to success in this type of multiple-use management system is to maintain a careful balance between forage production capabilities and stocking rates. One other practical way to integrate trees and introduced pastures is to graze firebreaks 30 feet or more in width (Gold and Hanover, 1987).

Establishing Pastures in Forested Areas

Another option for Oklahoma landowners is to establish introduced pastures under existing stands of timber. The optimum time to establish introduced pastures would be following timber harvest. If a block of timber is harvested, establishment of introduced pasture should be planned in conjunction with the site preparation and planting operations. In eastern Oklahoma, soils may be rocky and topography may be steep. Site preparation may include mechanical methods and/or use of chemicals in addition to a prescribed burn.

For stand treatments, which include thinning or seedtree and shelterwood regeneration cuts, the canopy may be open enough to establish introduced or released native forages. A prescribed fire in the fall provides a good seedbed for legumes or cool season grasses and has potential in naturally regenerated pine stands or plantations. A prescribed fire releases nutrients and reduces competition by other plants which improves the chances of getting a good stand of forages. Regeneration systems that utilize single tree or selection management are difficult to integrate into an agroforestry system using introduced forages since the uneven-aged timber structure does not favor their establishment. Additional information on timber regeneration alternatives can be found in OSU Facts No. 5028, "Even and Uneven-Aged Forest Management."

There are many legumes and grasses that have forage production potential in combination with forestry operations. A list of these forages is presented in Table 5. Soil tests should be made to develop an appropriate soil fertility program, especially to establish forages. Forested soils in eastern Oklahoma tend to be acidic so plant species that are acid tolerant should be selected when necessary. The species listed in Table 5 are generally well suited to acid soils.

Table 5. Potential forage plants for agroforestry in eastern Oklahoma.

Name	Season of Growth
Legumes	
Korean Lespedeza	warm
Arrowleaf Clover	cool
Crimson Clover	cool
Bighop Clover	cool
Subterranean Clover	cool
Vetch	cool
Red Clover	warm/cool
Grasses	
Switch Grass	warm
Bahiagrass	warm
Dallisgrass	warm
Tall Fescue	cool
Ryegrass	cool

Selection of an introduced forage will depend on a variety of factors such as tolerance of low pH soils and whether it is a warm or cool season forage. Other factors include establishment costs, fertilization and water requirements, maintenance costs, shade tolerance, and nutritional value. Legumes have the added advantage of contributing some nitrogen to the soil which can enhance tree growth during the rotation. If cool season forages are selected for newly regenerated forest areas, it is important to establish the forage throughout the plantation or disperse forage plots across the total grazing area. If established in only small portions of the plantation, cool season forages will attract livestock and wildlife and result in damaged seedlings from overgrazing.

One study on the coastal plain in Louisiana established coastal bermudagrass into a 30-year old pine stand (Clason, 1989). Forage production was maintained with fertilization, broadleaf weed control, burning, and periodic timber removal. During an 18-year period, this timber-pasture supported seven months of grazing for 1.5 animal units per acre and annually produced 300 board feet sawtimber per acre.

In a more recent effort, coastal bermudagrass and bahiagrass were established in thinned 20-year old Loblolly pine plantations. Forage establishment procedures included a herbicide treatment to remove understory hardwoods, a prescribed burn, and fertilization with nitrogen, phosphorus, and potassium at 10, 42, and 53 pounds per acre. Seedbed preparation for bahiagrass was limited to burning while Coastal bermudagrass seedbed preparation included an initial disking, a second disking after spreading sprigs, and a packing operation. Coastal bermudagrass sprigs were applied at 20 bushels per acre and bahiagrass was seeded at 30 pounds per acre. Total establishment costs were estimated to be $145.65 per acre for bahiagrass and $204.20 per acre for bermudagrass. Annual production costs of $41.10 per acre for both grasses included nitrogen fertilization at 100 pounds per acre, a winter prescribed burn, and broadleaf weed control. Yields after 168 days were 2,849 pounds bahiagrass per acre and 5,090 pounds Coastal bermudagrass per acre.

In Oklahoma, agroforestry has been practiced for a number of years in native Pecan orchards. Currently, there are about 185,700 acres of pecan orchards in Oklahoma, 16,700 of which are listed as improved (Thompson, 1990). At the Noble Foundation Red River Demonstration and Research Farm a 13-year summary showed that harvesting of pecans returned $45.89 per acre per year to the operation. During 1988 and 1989, grazing was allowed at the same time for 205 days per year on the pecan orchard understory vegetation. Animals were rotated according to forage production within 335 acres of orchard. Animal production during these two seasons is presented in Table 6. Native pecan orchards can be quite dense, and shading prevents good bermudagrass growth. Similar areas managed as pecan "groves" have numerous open areas and may sustain greater pasture productivity and animal production.

More recent demonstrations at the Noble Foundation have indicated some potential for grazing sheep in orchards less than ten years old, where cattle are usually excluded. Landowners are also encouraged to remember that not all pesticides used in spraying Pecan orchards are listed for use in areas that are to be grazed. Use of appropriate pesticides or pesticide alternatives should be considered when making agroforestry evaluations and production decisions.

Other studies have been initiated in Oklahoma to examine the use of introduced forages under Pecan orchards. The

Table 6. Mean of animal performance and production of steers grazing pecan orchard understory during the 1988 and 1989 grazing seasons in Burneyville, Oklahoma (Mitchell and Wright, 1991).

	YEAR	
	1988	**1989**
Initial grazing date	12 April	05 April
Grazing season days	205	205
Steer per acre, mean	0.80	0.81
Steer Weights and Gains (lbs./steer)		
Final weight	714	809
Gain	192	280
Daily gain	0.94	1.37
Grazing and Beef Production		
Animal grazing, days per acre	181	188
Beef production, lbs. per acre	169	243

Figure 2. Cool season forages such as crimson clover allow winter grazing under Pecan orchards. (photograph by Steven Anderson)

Kerr Center for Sustainable Agriculture is examining winter grazing from November to May using orchard grass, red-clover, rye, wheat, subteranean clover, crimson clover, and improved varieties of crabgrass. Additional studies involving Black walnut are also in progress.

Multi-cropping Hardwoods with Agricultural Crops

Multi-cropping is not a new idea. As early as 1914, J. Russell Smith urged farmers in the southeast United States to grow trees with companion crops. These ideas were rekindled in the 1970's under the new "agroforestry" idea. In a 1981 study, a Black walnut timber and nut production regime was explored. In this study, early annual yields from nut production supplemented the returns from timber, resulting in greater profit to the landowner (Garrett and Kurtz, 1981). Multi-cropping embraces the same idea because early financial returns can help offset plantation establishment costs and improve cash flows during the rotation (Gold and Hanover, 1987).

Among the recent efforts to examine agroforestry alternatives in the United States, some of the most intensive work has been done with Black walnut. One study examined four plantation management options (Kurtz et al, 1984). These were timber production; timber and nuts; timber, nuts, and winter wheat; and timber, nuts, winter wheat, soybeans, and livestock grazing. The rotation age was assumed to be 60 years on site index land of 65 (medium) and 80 (high) on a 50-year basis.

In the timber option, Black walnut seedlings were planted on a 12 X 12 foot spacing, or 300 trees per acre. Using selective thinning throughout the rotation, the number of trees per acre are reduced to 27 to 40 by the final harvest. At the final harvest, the medium-quality site was expected to yield 14-foot logs averaging 20 inches at breast height. While on the high-quality site, 16-foot logs would average 30 inches in diameter. Two prunings on each site were assumed to help development of veneer quality logs. Weed control, applied to a minimum 3-foot radius around each tree, would occur at planting and during the following three years.

In the timber and nuts option, trees are planted on a 10 X 40 foot spacing, or 108 trees per acre. Herbicide and corrective pruning are conducted in a manner similar to the timber-alone treatment. At final harvest, logs from the medium-quality site are expected to be 10 feet in length and averaging 20 inches in diameter, while being 14-feet long and 30 inches in diameter from the high-quality site. Nut production will be commercially harvestable beginning in year 20. Average nut yields are projected to be 1,324 to 2,128 pounds per acre on the medium site and 1,818 to 2,937 pounds on the high site. The researchers, however, reported that production of 22 pounds of nuts from one tree had been recorded on an upland site.

Adding winter wheat to this production system produces little competition for soil moisture, nutrients, or light between the walnut and wheat. A minimum of three feet is left between the trees and crop and increases to six feet as the trees grow. Annual wheat yields average about 36 and 40 bushels per acre on the medium and high sites, respectively.

Under the most complex management options of timber, nuts, wheat, soybeans, fescue hay, and grazing, double cropping of soybeans and wheat occur for the first 10 years. A 6- to 7-foot space between the trees and soybeans is used to avoid competition for moisture and nutrients and to allow chemical weed control. As tree crowns enlarge, annual soybean yields would decrease from 16 to 12 bushels per acre on the medium quality site during the second five years and from 20 to 16 bushels per acre on the high-quality site. Fescue is established in year 11 and grown through year 15 for production of hay and seed. Livestock grazing begins in year 16 and continues through the remainder of the rotation. Stocking rates are one cow per 4 acres and one cow per 3.6 acres on the medium and high sites, respectively, with a grazing season of eight to nine months.

After estimating reasonable costs and returns based on the production systems described, the authors calculated present net worth and the internal rate of return for the

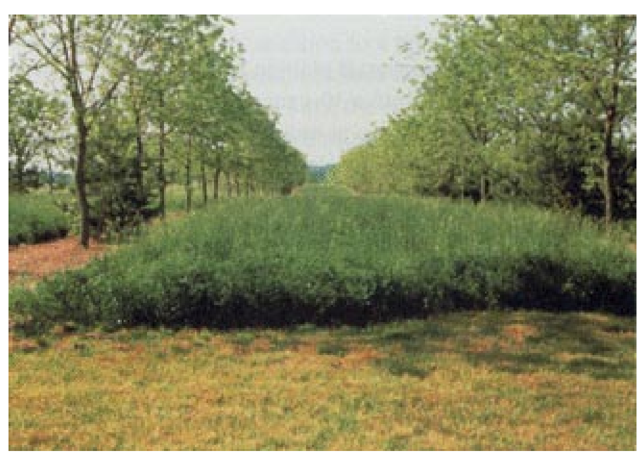

Figure 3. Soybeans intercropped between rows of Black walnut. (photograph by Bill Kurtz)

Table 7. Present net worth (PNW) and internal rate of return (IRR) of alternative eastern Black walnut management regimes, site index 65 and 80.

Option	Site Index 65 PNW ($/acre)	Site Index 65 IRR (%)	Site Index 80 PNW ($/acre)	Site Index 80 IRR (%)
Timber	-1,198	4.3	-575	6.7
Timber and nuts	- 559	5.9	134	7.7
Timber, nuts, wheat	65	7.8	822	9.4
Timber, nuts, wheat, soybeans, fescue and grazing	261	8.7	1,290	10.9

alternative management options (Table 7). These calculations assumed a 7.5 percent interest rate while stumpage prices for timber were projected to increase at an average annual real rate of 1.5 percent over and above all other costs and returns.

The results indicate that the greatest returns are produced from the more intensive management regimes, indicating that diversifying an operation can improve profits. With multi-cropping, intermediate revenues from agricultural crops offer significant financial benefits, but multi-cropping also requires additional management expertise.

The previous discussions of explorations into agoforestry alternatives indicate that a much closer relationship between forestry and agriculture should be developed. In the 1990 farm bill, a Center for Semiarid Agroforestry was authorized but has not yet been funded. Although additional research is needed before solid recommendations regarding agroforestry alternatives can be made, farmers and tree growers are encouraged to examine these ideas in their land-management plans.

Additional Information

Several organizations in Oklahoma can provide technical assistance to landowners who want to consider an agroforestry operation. Since agroforestry efforts involve several disciplines, the landowner should be prepared to deal with a variety of specialists. A good starting point, however, is your local County Extension Center. Some of the organizations to contact in Oklahoma include:

Samuel Roberts Noble Foundation
2510 Highway 199
P.O. Box 2180
Ardmore, OK 73402
(405) 223-5810

Kerr Center for Sustainable Agriculture
P.O. Box 588
Poteau, OK 74953-0588
(918) 647-9123

Oklahoma Cooperative Extension Service
013 Agriculture Hall, Forestry Dept.
Oklahoma State University
Stillwater, OK 74078
(405) 744-9431
or
373 Agriculture Hall, Agronomy Dept.
Oklahoma State University
Stillwater, OK 74078
(405) 744-6421

Oklahoma State Dept. Of Agriculture-Forestry Services
2800 North Lincoln Blvd.
Oklahoma City, OK 73105
(405) 624-4437

Conclusion

Agroforestry is a system of management where trees are grown together with agricultural crops and/or livestock. Many forms of agroforestry are possible, including planting trees in existing pastures, establishing pastures under existing canopies of trees, and multicropping a variety of agricultural crops with hardwood or fruit tree species. Such an enterprise diversifies an operation which can lead to decreased total risk, more stable cash flows, and improved marketing flexibility. It also requires much more management expertise which may require additional training and experimentation by the landowner.

There are several organizations in Oklahoma that can provide technical expertise for landowners considering an agroforestry alternative. Landowners should be prepared to examine alternatives on a site-specific basis to determine both biological and financial viability.

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