Agroforestry Systems **35**: 303–321, 1997.

An assessment of agroforestry systems in the southern USA

F. C. ZINKHAN[1] and D. E. MERCER[2]
[1] *Daniel B. Warnell School of Forest Resources, The University of Georgia, Athens, GA 30602-2152, USA;* [2] *Southern Research Station, USDA Forest Service, Box 12254, Research Triangle Park, NC 27709, USA*

Key words: alley cropping, buffer strips, silvopastoral systems, southern pine, southern hardwood forests, windbreaks

Abstract. An assessment of the southern USA, based on a survey of land-use professionals and a review of the literature, revealed that it is a diverse region with substantial potential for agroforestry to address a combination of problems and opportunities. The survey indicated that silvopastoral systems are the most common form of agroforestry in the region. Increased economic returns, diversification, and enhancement of the timing of cash flows were the most frequently mentioned benefits associated with the establishment of silvopastoral systems. Some of the problems associated with alley-cropping systems – less frequently observed than silvopastoral systems – were lower-than-expected productivity or profitability, damage to trees when cultivating the crop component, and labor/management skill constraints. Based on the findings of the literature review and the survey, special opportunities for implementing agroforestry systems in the region were identified, including the following: to improve marginal lands; to serve as windbreaks and buffer strips for improved water quality and wildlife habitat; to enhance the economics of selected natural pine, hardwood plantation, and pine plantation systems; and to provide specialty products on small landownerships.

Introduction

After two decades of emphasis on the tropics (and New Zealand and Australia), agroforestry is emerging as an important area of land management research and development in northern temperate zones, especially in the United States (Buck, 1995). Evidence of this emergence includes the expanding attendance at the biennial North American Agroforestry Conferences which have been held since 1989, the establishment in 1993 of the Association for Temperate Agroforesty, the 1994 International Symposium: Agroforestry and Land Use Changes in Industrialized Nations (Agroforestry Systems 31(2): 97–198, 1995), and the creation in 1995 of the National Agroforestry Center by the US Department of Agriculture. Assessments of the status and potential for agroforestry in specific temperate zones are needed to complement the broad overviews of northern temperate zone agroforestry by Gold and Hanover (1987); Bandolin and Fisher (1991); and Schultz, Colletti and Faltonson (1995). To address the need for information and analysis regarding agroforestry practices at the regional level, surveys and assessments targeting Washington State (Lawrence et al., 1992; Lawrence and Hardesty, 1992), the Midwest (Rule et al., 1994), and the South (Zinkhan, 1996) were undertaken. Recently, the Association for Temperate Agroforestry prepared a national summary report (Merwin, 1996) based on assessments of agroforestry for every region of the USA. This article summarizes and extends the detailed assessment of the southern USA (Zinkhan and Mercer, 1996).

The southern USA holds considerable agroforestry potential due to its diverse climate and landscapes and the existence of vast areas of forest, crop, and pasture lands that lack sharp demarcations between obviously 'optimal' land uses (Henderson, 1991). To complete an assessment of agroforestry in the region, we combined a survey of land-use professionals with a critical review of research studies involving the southern United States: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee.

In the first section, we investigate the need for agroforestry systems in the southern USA. Then, we describe our survey of southern land-use professionals and evaluate the status of agroforestry in the region. Finally, we list and describe five regional opportunities and needs which can be effectively addressed with agroforestry systems.

Regional overview of land uses and sustainability issues

Land uses

The ten southern states cover approximately 125 million ha. About 83% of the surface area is undeveloped, non-federal rural land, allocated primarily to cropland, pasture land, rangeland, and forestland (Soil Conservation Service, 1989). Of the undeveloped, non-federal rural land, about 57% is allocated to forestland; 22% to cropland, 14% to pasture land; 2% to rangeland; and 5% to other uses.

The high potential for conversion of land uses between agriculture and forestry is commonplace in the southern USA (Soil Conservation Service, 1989). While two-thirds of the nation's potentially prime farmland is in cropland, less than one-half of prime farmland is devoted to cropland in the southern USA. In the south, more than one-third of the current area that has been classified as potentially prime farmland is being used as forestland, with another 16% devoted to pasture land. For the USA as a whole, in contrast, only 13% of potentially prime farmland is in forestland and about 11% is in pasture land (Soil Conservation Service, 1989).

The southern USA has evolved into the nation's 'wood basket' as a result of the productivity of the region's vast forestland base. More than 80% of the region's forestland is capable of growing at least 3.5 m^3 ha^{-1} per year of industrial wood, while less than one-half of the nation's forestland is as productive (Powell et al., 1993). Between 1952 and 1992, southern forestry investment approximately replaced the level of capital lost through harvesting, land-use change, and mortality (Wear, 1993). On forest industry lands alone, the area in southern pine plantations increased from 267 thousand ha to 5.9 million ha during this time period. By 1992, there were a total of 9.3 million ha of pine plantations on all southern ownerships.

Another reason for the southern USA's development as a timber-production region is the dominance of private ownership of the forest resource. About 70% of the region's commercial forestland is owned by nonindustrial private forest landowners (NIPFs); in contrast, less than 60% of the nation's timberland is owned by NIPFs (Powell et al., 1993). The private sector as a whole controls 90% of the southern timberland base, compared with just 73% for the nation.

As for agriculture, an investigation of 1993 farm marketings reveals a balance between crop and livestock production. Crops and livestock represented 52% and 48%, respectively, of the region's $33.6 billion of farm marketings (Statistical Abstract of the United States, 1995). Among the southern USA's principal farm commodities were broilers, cattle, cotton, soybeans, and tobacco.

Erosion

The inherent erodibility of cropland is less severe in the southern USA than the nation as a whole. About 18% of the southern land area currently in crop production falls within the two worst Erodibility Index (EI) categories (i.e., '>10–<15' and '>15') compared to 22% nationally (Soil Conservation Service, 1989). As a measure of inherent erodibility based on climate, soils, and terrain, an EI of less than 2 indicates very slight susceptibility to erosion damage; an EI of 15 or more indicates very high susceptibility to erosion damage. About 66% of southern cropland is categorized within the two best classes (i.e., '<2' and '>2–<5') compared to only 52% of the nation's. However, the level of sheet and rill erosion on cropland in eight of the ten southern states exceeded the national average of 8.5 metric tons/ha/year (Soil Conservation Service, 1989). Only cropland in Florida and Arkansas fared better than the national average. The southern Mississippi Valley, with a heavy concentration of sloping to steep cropland, has been identified as one of six 'serious erosion areas' in the USA (Soil Conservation Service, 1981).

Simulations have revealed that about 392,000 additional 'equivalent hectares' will be needed during the next 100 years to compensate for the productivity reductions (on cropland) resulting from sheet and rill erosion in the southern USA (US Department of Agriculture, 1989). Simultaneously, the US forest products industry is continuing to shift its resources to the South. For the period from 1991 to 2040, the USDA-Forest Service has projected an aggregate gain of more than 50% in annual removals of southern softwood timber (Haynes et al., 1995). By comparison, a 14% aggregate reduction in annual softwood removals was projected for the Pacific Coast region. With the likely ensuing pressure on the southern land resource for both crop and timber production, in combination with the need for soil erosion mitigation, landowners should consider the establishment of agroforestry systems on current cropland. The supply of substantial litter to the ground surface, the more extensive rooting systems of trees, and the protective role of tree canopies contribute to agroforestry's potential for controlling erosion (Young, 1989).

Two areas needing 'additional attention' with respect to wind erosion problems are the southern Mississippi Valley Alluvium and the southern Coastal Plain (Robinson, 1991). However, relative to both sheet and rill damage as well as comparable damage for the nation as a whole, soil loss to wind erosion is generally rather modest in the region. In fact, none of the ten southern states experiences wind-caused soil loss even approaching the national average (Soil Conservation Service, 1989).

Water quality

Sediment from soil erosion, nutrient enrichment of surface waters, and pesticide residues are of increasing concern in the southern USA. Agricultural/irrigation activities have been categorized as a 'widespread problem' in nine of the ten southern states with respect to influence on water quality (Myers et al., 1985). This category of problem is reserved for nonpoint sources of pollution that negatively impact at least 50% of a given state's waters. Only in Mississippi was agriculture/irrigation estimated to be merely a 'localized problem'. As a 'localized problem', less than 50% of the state's waters are affected by the nonpoint-source pollution. In contrast, silviculture was perceived to be only a 'localized problem' in nine of the ten states. North Carolina, with a concentration of steeply sloped logging areas in its western region, was the lone state identified as having more than 50% of its waters affected by silviculture.

Pesticides and nitrogen from agricultural fields are the primary ground water quality concerns (Hallberg, 1987). The Coastal Plain of the southern USA is one of the regions with the greatest potential for ground water contamination. Heavy fertilization of shallow-rooted crops on sandy soils is generally associated with water-quality problems. Also, nitrate leaching has been documented in conjunction with the production of citrus crops as well as vegetables and other specialty crops. Relatively high levels of certain pesticides have been observed in ground water in Florida and Georgia. The potential severity of the region's water-quality problem is indicated by the ranking of seven of the ten southern states within the nation's top ten for either vulnerability to pesticides or nitrogen fertilizer pollution (Kellogg et al., 1994).

The establishment of strips of forest along streams and rivers can function as a filtering system, thereby reducing the flow of nutrients, sediments, and chemicals into waterways from adjacent crop production areas (Rietveld and Montrey, 1991). Riparian vegetation is especially effective in removing nutrients from subsurface flow, often the dominant source of nitrates into waterways from southern agricultural fields (Lowrance et al., 1986).

Status of agroforestry in the south

Land-use professionals' perceptions

Methodology. In May, 1993, we conducted a survey of southern public land-use professionals employed by the Cooperative Extension Service, state forestry divisions, and the then-named USDA Soil Conservation Service (now the Natural Resource Conservation Service) to explore their perceptions of southern agroforestry (see Zinkhan (1996) for a detailed description of the entire survey). Usable responses were received from 218 professionals, yielding a response rate of 34.0%. One section of the survey dealt with the 'single agroforestry case with which [the respondents were] most familiar'. In addition to seeking a description of the observed systems, we directed the respondents to list up to three perceived benefits and problems associated with the systems as well as up to three lessons to be learned by other adopters.

Silvopastoral systems

About one-half of the 218 respondents were able to provide opinions regarding an observed agroforestry system. The respondents were directed to limit their feedback to three categories of systems: alley cropping, silvopastoral systems with grazing, and silvopastoral systems without grazing. For this survey, an alley-cropping system was defined as the production of an agricultural crop between rows of trees. Silvopastoral systems with grazing were defined as the intentional integration of trees, pasture, and livestock, whereas silvopastoral systems without grazing were described as the intentional integration of trees and pasture only. Of these three general categories of agroforestry systems, the silvopastoral system with grazing was, as expected, the most commonly observed type. When directed to describe the agroforestry case with which they are most familiar, more than 74% of those responding identified a form of silvopastoral system with grazing. Cattle and pine timber dominated the observed silvopastoral systems. Sixty of the 78 observed silvopastoral systems with grazing consisted of cattle-pine combinations; 8 were cattle-mixed pine-hardwood combinations; 7 were cattle-hardwood combinations; 1 was a goat-pine combination; 1 was a goat-mixed pine-hardwood combination; and 1 was a generic livestock-mixed pine-hardwood combination. In terms of number of respondents reporting silvopastoral systems with grazing, the leading states were Alabama (13), Georgia (13), Florida (9), North Carolina (8), and Arkansas (7).

The perceived benefits noted by the land-use professionals in conjunction with cases involving the establishment of a silvopastoral system with grazing are listed in Table 1. Economic factors dominated the noted benefits. Improved economic returns (listed by 37.2% of the professionals having reported a silvopastoral system with grazing), diversification (30.8%), and shortening the wait for (and increasing the regularity of) income (24.4%) were the most commonly mentioned benefits.

Some financial evaluations of southern silvopastoral systems have been encouraging. Based on simulations of a loblolly pine (*P. taeda*)-forage-beef cattle system in the Coastal Plain, Dangerfield and Harwell (1990) reported a net present value that was 71% greater per unit area than for a pure forestry operation. Possible sources of the incremental value created in the grazing-based agroforestry system include more intensive use of the land, a reduction of the time between cash inflows, and synergies such as utilization of the manure as a fertilizer by the trees and the climate-stabilizing effect of the trees on the animals' habitat (resulting in less energy consumption by the animals). In a five-year study in Louisiana, Clason (1995) found that establishment of a Coastal Bermuda grass (*Cynodon dactylon*) pasture in a maturing loblolly pine plantation achieved an internal rate of return (IRR) of 13.4%. In contrast, the Coastal Bermuda grass open pasture and timber management only alternatives earned IRR's of only 6.1% and 8.8%, respectively.

As shown in Table 1, the effect of livestock grazing and trampling on

Table 1. Silvopastoral systems with grazing: benefits, problems, and lessons noted by land-use professionals.

	% listing[#]
Benefits:	
Increased economic returns	37.2
Diversification of outputs and income	30.8
Shortening the wait for (and increasing the regularity of) income	24.4
Soil conservation	17.9
Enhancement of wildlife habitat	14.1
Problems:	
Damage to trees/soil by livestock	53.8
Lower-than-expected profitability	20.5
Lack of management skills	16.7
Incompatibility between land uses	10.3
Substantial amount of labor required/high costs	9.0
Lessons:	
Need to carefully manage grazing load and timing	19.2
Need intensive management, especially in early years	16.7
Diversity does not always lead to improvement	10.3
Need to consider economic returns	7.7
Need careful management of tree/livestock interface	6.4

[#] $N = 78$.

seedling survival and soil productivity was the problem most commonly mentioned by the land-use professionals. In relation to the compaction problem, the static ground pressure exerted by mature cattle is approximately equal to the level exerted by a heavy-wheeled tractor. Bezkorowajnyj et al., (1993) observed an increase in soil bulk density from even light cattle grazing. In a laboratory experiment, they found that medium and high levels of soil compaction reduce water infiltration and nitrogen cycling, resulting in slower growth of seedlings.

Boyer (1967) reported that even light cattle grazing on a longleaf pine (*P. palustris*) seedling site in southwest Alabama reduced survival rates by 23% and diameter growth rates by 13% over the first five years of the regeneration period. Although Lewis et al. (1985) found that year-nine survival was 15% less for grazed than ungrazed longleaf pine sites in north Florida, the trees were 50% taller on the grazed sites. Grazing reduced the level of plant competition and allowed full sunlight to reach the seedlings, thus enabling seedlings to break out of the grass stage much earlier. Heavily grazed slash pine (*P. elliottii*) sites in Louisiana experienced incremental losses of 18% of the planted pines in a 5-year period (Pearson, 1991). However, tree survival was not affected significantly under light and moderate grazing conditions. The experiences of a forest products company manager with livestock grazing on forest range in Louisiana were consistent with these mixed empirical findings: 'There is also some grazing damage to young pines, but this has not been a major problem' (Rials, 1984, p. 159).

Not surprisingly, the most frequently noted lesson reported by the land-use professionals in conjunction with the silvopastoral systems was the need to manage grazing load and/or timing (see Table 1). In addition to careful control of the density (and timing) of livestock grazing, electric fences have also been used to control damage to tree seedlings. Pearson et al. (1990) found that pine trampling injury was 8% greater on a cattle-grazed site in central Louisiana than on either an ungrazed site or a grazed site when electric fences were used. By the end of the three-year study, the heights of loblolly pine seedlings were greater on the protected sites than on the grazed sites. In contrast, heights of slash pine seedlings were similar on both sites.

Alley-cropping systems

Alley-cropping systems do not appear to be as common in the southern USA as silvopastoral systems. Only 13 of the southern land-use professionals reported alley cropping as the agroforestry case with which they were most familiar. Seven of the observed systems included pines and either soybeans (*Glycine soja*), corn (*Zea mays*), cotton (*Gossypium* spp.), peanuts (*Arachis hypogaea*), wheat (*Triticum aestivum*), or watermelon (*Citrullus vulgaris*). Pecan (*Carya cordiformis*) plus raspberry (*Rubus* spp.), cottonwood (*Populus deltoides*) plus soybeans, and four generic tree-crop combinations represented the other listed alley-cropping systems. Observations were well distributed across the region, with multiple land-use professionals reporting cases in Georgia (3), Alabama (2), Arkansas (2), Mississippi (2), and North Carolina (2).

As shown in Table 2, economics dominated the observed benefits of alley-cropping systems. Potential sources of improved economic performance include increased utilization of available growing space, enhancement of cash flows early in the rotation cycle, and positive spillovers between the system's components (e.g., enhancement of soil quality, fertilization, cultivation, weed control) (Gold and Hanover, 1987). For example, one landowner was reported to intercrop young loblolly pine trees with watermelons. The watermelons both utilize space between the trees and provide a source of early incremental revenue.

Only one land-use professional noted an alley-cropping system which included planted, fast-growing hardwoods. Cottonwood, grown on a short rotation, was interplanted with soybeans on the Mississippi Delta. Substantial attention has been given in the literature to fast-growing, southern hardwood plantations with a crop component early in the rotation (e.g., Gold and Hanover, 1987). Perhaps the scarcity of observations in our survey was due to the number of practical problems confronting the landowner wanting to establish hardwood plantations, whether including a crop component or not (Moorhead, 1994). These include the following:

Table 2. Alley-cropping systems: Benefits, problems, and lessons noted by land-use professionals.

	% listing[#]
Benefits:	
Increased economic returns	46.2
Diversification of outputs and income	46.2
Synergistic effects between the components	38.5
Enhancement of wildlife habitat	30.8
Shortening the wait for (and increasing the regularity of) income	15.4
Problems:	
Lower-than expected productivity or profitability	53.8
Damage to trees when cultivating crop component	46.2
Substantial level of labor required; high costs	23.1
Lack of management skills	23.1
Volatile markets for crop output	15.4
Lessons:	
Need intensive management, especially in early years	23.1
Need careful management of tree/crop interface	23.1
Diversity does not always lead to improvement	23.1
Site suitability is critical	15.4
Need to consider economic returns	7.7

[#] $N = 13$.

- seedling costs amounting to several times more than pine seedlings (for quality seedlings, lower bed densities than southern pines are required at nurseries);
- the difficulty associated with storage and handling because of the greater size and bulk of hardwood seedlings;
- the need for larger planting holes; and
- acute sensitivity to site selection.

Many of the observers of alley-cropping systems were concerned with their productivity and profitability as well as residual damage to trees. The most commonly reported problems associated with alley-cropping systems are listed in Table 2. These problems and the reported lessons learned by the land-use professionals (also in Table 2) revealed the significance of considering access to managerial talent, management time, and labor when assessing the feasibility of an alley-cropping system for a given landowner.

Critical decisions associated with the management of the tree-crop interface of an alley-cropping system are the selection of both a planting configuration for the trees and the spacing between alleys. One public land-use assistant mentioned the use of double rows of trees with wide alleys between the pairs of rows. A similar configuration has been adopted for some southern silvopastoral systems in order to accommodate pasture. Lewis et al. (1985), for example, reported that double-row configurations of slash pine with spacing of 1.2 (in rows) × 2.4 (between rows) m, spaced 12 m apart, produced more forage than single rows (with 2.4 × 3.7 m spacing) and with no loss in timber volume as of age 13 years. In the midwestern USA, Garrett et al. (1991) have suggested 3 × 12 m spacing for certain black walnut (*Juglans nigra* L.) alley-cropping systems; relatively close in-row spacing is needed to provide a 'training effect', while relatively wide alleys are needed for sufficient sunlight to reach the crop component and for the maneuvering of equipment.

Policies: tree planting and agroforestry in the south

Forestry cost-share programs have played a major role in promoting tree planting by nonindustrial private forest landowners (NIPFs) in the United States. In 1993, for example, 47% of all tree planting and 20% of all timber stand improvement work by NIPFs in the United States utilized one or more of the Federal cost-share programs (Moulton, 1994a, b). Forestry cost-share programs have been primarily Federal, however, some states (e.g., Mississippi, North Carolina) also provide cost-share incentives for planting and managing trees.

Federal forestry incentive programs for private landowners have existed for over 50 years. Cost-share incentives have predominated, although tax-credits and deductions have also been used. Current Federal programs include the Agricultural Conservation Program (ACP), Forestry Incentives Program (FIP), Stewardship Incentive Program (SIP), and the Conservation Reserve

Program (CRP). All of these programs have the following in common: voluntary participation, financial incentives for landowners to plant trees or improve forest management; and technical assistance to landowners (Moulton, 1994a, b). Only SIP specifically includes agroforestry as one of the approved practices. However, practices not specifically labeled as agroforestry are eligible for cost-sharing in some of the other programs; for example, the CRP was amended in 1990 to allow cost-sharing for windbreaks, shelterbelts, and alley cropping with hardwoods without requiring enrollment of the whole field.

Established by the 1990 Farm Bill, SIP provides up to 75% cost-share to landowners for implementing various forest practices identified in Landowner Forest Stewardship Plans. 'Agroforestry Establishment, Maintenance and Renovation' is one of SIP's nine approved practices. Approved agroforestry practices are establishing, maintaining or renovating windbreaks, hedgerows, living snow fences, livestock shelters, and alley cropping. Although not specified as agroforestry, other agroforestry practices could qualify for SIP if they were consistent with some of the program's other objectives, such as enhancing management and maintenance of native vegetation on lands vital to water quality, growing and managing trees for energy conservation, or managing and maintaining wildlife habitat. The initial response to agroforestry under this program has been anemic. From 1992 to 1995, agroforestry was adopted under SIP on only 82 ha on 6 farms in only one of the region's 10 states (Alabama).

Needs and opportunities for agroforestry in the south

Given both site and owner characteristics, we asked the southern land-use professionals to consider the situation in their territories that they believed would be most appropriate for some form of agroforestry system. Sites already devoted to agroforestry were excluded from consideration. Almost two-thirds (65%) of the land-use professionals reported that they would consider recommending some form of agroforestry for the selected site. Based on both the related survey results (Zinkhan, 1996) and a review of the literature, we propose that future southern USA agroforestry research projects, related economic policies, and agroforestry extension and training programs focus on one or more of the following five needs/opportunities.

Need/opportunity: utilizing marginal lands

Owing to the cover of trees and the support provided by their roots, maintenance of some woody vegetation on a site, versus complete conversion to row crops or pasture for livestock, generally results in less soil erosion and land degradation (Dangerfield and Harwell, 1990; Wojtkowski and Cubbage, 1991). The USDA Forest Service (1988) estimated that almost seven million ha of marginal cropland and pasture land in the region would provide higher economic returns if planted to pine. The incremental net annual growth from the planted pines would represent almost one-third of the current net annual growth of all southern softwood timber. Since about one-third of this area is in highly erodible cropland, establishment of forest cover is anticipated to result in lower soil loss to erosion and thus improving water quality, biological diversity, and the natural filtration effectiveness of riparian zones.

Since generating regular cash flows is a prime objective of NIPFs (Zinkhan, 1993), the incremental economic performance of an agroforestry system (versus pure forestry) may increase the likelihood of establishing tree cover for marginal cropland. In addition to their potential role in avoiding more extensive erosion, agroforestry systems have been recognized as a potential tool for rehabilitating already degraded properties (Bandolin and Fisher, 1991). Simulations developed by Campbell et al. (1991) for the central United States revealed that alley-cropping systems were able to meet a threshold soil loss tolerance level on low-and medium-quality sites; traditional agriculture was not capable of meeting this level.

Lack of available soil nitrogen limits the production of slash and loblolly pine in many areas of the Southeast. While fertilizer can be used to increase productivity of these pines, its addition is both expensive and can have negative environmental impacts – namely, leaching and runoff into both surface and underground water. Legumes such as subterranean clover (*Trifolium subterraneum*) can be used to enhance the availability of soil nitrogen in those forests where it is lacking, as well as to reduce erosion and provide a source of nutritious forage. Ziehm et al. (1992) found that management of the subterranean clover understory to combat competition from warm-season herbaceous vegetation can increase the pine growth rates.

Matta-Machado and Jordan (1995) compared the aboveground net primary productivity, the pool of cycling nutrients, and the yield of sorghum (*Sorghum bicolor*) on two systems in northeastern Georgia: an annual legume-based cropping system versus an alley cropping system incorporating mimosa (*Albizia julibrissin*) as the hedgerow. Although the alley cropping system produced more biomass and enlarged the pool of cycling nutrients, its output of sorghum was less (after three years) than the annual legume-based cropping system. The pair of researchers hypothesized that since the nutrient pool was still increasing, the effect of the greater competition for resources on sorghum yield attributed to the hedgerow might be overcome in the future.

Since it is capable of fixing atmospheric nitrogen, black locust (*Robinia pseudoacacia* L.) is able to tolerate infertile sites without fertilization (Hanover et al., 1991). The species is quite adaptable, evidenced by its presence in all 48 contiguous states. According to Hanover et al. (1991), black locust has many other positive traits for inclusion in an agroforestry system, including (among others) a rapid growth rate; an attractive, high-density wood; high leaf protein; and a desirable bee forage. Thus, it deserves more attention as a component of southern agroforestry systems on infertile sites.

Need/opportunity: windbreaks and buffer strips

Among other benefits, trees can help to soften the impact of the climate, soil movement, and chemical movements on soil productivity (Robinson, 1991). Although the use of trees as windbreaks and buffer strips has not received the attention in the region that it has in the Great Plains, their utilization in the southern USA is worthy of additional research.

The southern Mississippi Valley Alluvium and some of the Coastal Plain soils are especially subject to wind erosion. Robinson (1991) recommended windbreaks for the long-term protection of the problem soil types: sands, loamy sands, and sandy loams. Perhaps more important than erosion, some of the important crops grown on these soils, such as soybeans, cotton, cucumbers (*Cucumis sativus*), and squash (*Cucurbita* spp.) often suffer from abrasion caused by shifting sands (Baldwin, 1988; Robinson 1991). By providing a physical barrier (Sanchez, 1995), trees not only reduce wind erosion, but also alleviate abrasion damage to such crops. For example, tobacco (*Nicotiana tabacum*), an important cash crop in the South, benefits from windbreaks (Baldwin, 1988). Since they are typically grown on sandy-textured soils, the seedlings are vulnerable to abrasion damage during the spring and early summer when vegetative cover is minimal. Sheltered plants were found to be taller with higher quality leaves and lower nicotine content, thereby receiving a 15% bonus when sold (Baldwin, 1988). Small grains, planted between every four to eight rows of tobacco, can effectively complement evergreen windbreaks.

According to Norton (1988), windbreaks provide multiple benefits for orchard and vineyard crops, which are of considerable importance to the southern USA agricultural industry. Less mechanical damage to leaves, branches, buds, flowers, and fruit enhances fruit quality. The more stable environment also improves pesticide application, water management, and frost management. Finally, wind protection can reduce the incidence of disease and boost the number of pollinating insects.

Windbreaks may also improve the efficiency of poultry and pork production, important agribusinesses in the southern USA. Specifically, by buffering the facilities containing the animals, less energy is needed to maintain the targeted temperature (Brandle and Hintz, 1988). Also, such tree barriers should improve the esthetics of these sites, an area of considerable current controversy in large poultry and pork producing states like North Carolina. Projects involving the use of alley-cropping to treat municipal sludge have been reported for other regions, and it has been suggested that similar systems could be developed for the disposal of manure from the large livestock production facilities (Schultz et al., 1995). Synergies between the tree and herbaceous crop components can enhance the total productivity of the system beyond the levels expected when each crop is grown separately, thus increasing the utilization of manure. The trees improve crop productivity by reducing wind flow, thereby increasing CO_2 concentrations above the crop and reducing evapotranspirational losses. In turn, the space occupied by the herbaceous crops (rather than other trees) enables additional sunlight to reach the edges of the tree canopy, contributing to increased productivity.

Riparian buffer strips can be effective in reducing nonpoint-source pollution in intensive agricultural areas (Robinson, 1991; Schultz et al., 1995). For example, multi-species buffer strips incorporating fast-growing species such as cottonwood near the waterways and slower-growing valuable hardwoods such as various oaks (*Quercus* spp.) in outside rows could provide timber revenue and serve as excellent wildlife habitat, as well as functioning as a filtering system (Schultz et al., 1995). Preliminary economic analysis of cottonwood interplanted with Nuttall oak (*Quercus nuttallii*) indicates that real IRR's of more than 5% can be achieved from timber production alone on marginal sites in riparian zones of the Mississippi Delta (Amacher et al., 1996). The cottonwood, planted three years prior to the oak, can quickly stabilize the soils. After a pulpwood harvest of the cottonwood at about age 10 years, coppicing of root collars and other sprouts provide for a second rotation of cottonwood. Following a second 10-year pulpwood rotation, the landowner would own a stand of 17-year-old Nuttall oak, likely to be managed on a rotation of 40–60 years.

Need/opportunity: enhancing the economics of natural pine management

The rapid disappearance of the southern natural pine ecosystems, primarily to pine plantations, suggests that landowners are seeking management systems offering greater financial returns. Recent research (Baker et al., 1991), however, indicates that the financial performance of well managed, natural stands can earn returns at least comparable to those of plantation systems.

Since livestock grazing of pine forests can enhance financial returns (Pearson, 1991), more landowners should consider natural pine-cattle systems prior to deciding to clearcut and artificially regenerate pines. Lundgren et al. (1983) suggest that the level of herbage production under standing timber determines whether or not a grazing system will be economically feasible. Thus, the availability of a shade-tolerant forage species is critically important (Muir and Pitman, 1989). Searches for and evaluations of such species have been promising. For example, Muir and Pitman found that *Galactia elliottii* N., a naturally occurring legume, is adapted to shaded flatwoods environments and can contribute forage as well as nitrogen to an agroforestry system in the Gulf Coast. Further investigation of shade-tolerant forages for such southern systems is needed. In addition, investigations (Clason, 1995) of the relationships between basal area management and forage production under southern pine plantations should be considered by managers of natural pine stands. Combinations of thinning and prescribed burning activities can contribute to increased forage production and reduced hardwood competition.

Need/opportunity: establishment of tree plantation-crop systems

Hardwood-based systems. From 1976 to 1991, the volume of southern hardwood timber removals increased by 40% versus 31% for southern softwoods (Powell et al., 1993). A further 54% aggregate increase in southern hardwood removals is expected through the year 2040. With removals anticipated to exceed growth, the USDA Forest Service projects that the inventory of standing southern hardwood timber volume will decrease by 15% through the year 2040 (Haynes et al., 1995).

The anticipated tightening in availability of southern hardwoods should increase the attention paid to hardwood plantations – and not just on marginal lands or as riparian buffers. To help offset the relatively high regeneration costs, landowners engaged in the establishment of hardwood plantations should consider the inclusion of a crop component during the early years of the rotation. Black walnut-crop management systems represent one promising candidate for selected southern sites.

Black walnut-crop management systems are one of the more commonly cited examples of US agroforestry. Most attention has been placed on walnut alley-cropping systems in the midwest. Kurtz et al. (1984) and Garrett et al. (1991) estimated that a timber-nut-winter wheat system in Missouri would achieve a greater IRR than either timber-only or timber-nut systems. Walnut is a good choice for an agroforestry system for a variety of reasons. It is one of the last tree species to break dormancy in the spring and one of the first to defoliate in the fall, thus providing a longer-than-ordinary period of close-to-full sunlight for an intercrop species such as winter wheat (Slusher, 1991). The spacing required for walnut crown development in a nut-producing enterprise permits substantial sunlight to reach the soil surface (Garrett et al., 1991). Its wood is highly valued while nut production can supplement other sources of income. Finally, the annual income from the crop component is often welcomed by landowners facing a 60–70 year timber rotation.

Pine-based systems. The softwood timber growth-to-removal ratio has dropped below 1 in the south (Powell et al., 1993). A fully-regulated forest, in which the volume of harvests (the dominant form of timber removals) equals growth, has a growth-to-removal ratio of 1. When the growth-to-removal ratio falls below 1, that implies total timber inventory is being depleted. It is likely that a reduction in Federal funds for financial and technical assistance to nonindustrial private landowners will curtail the establishment of southern pine plantations (Moulton et al., 1995), thereby further exacerbating the timber supply/demand situation. These factors are indicative of a favorable price environment for southern pine timber producers. When the site is appropriate and cash flow is a problem, tree farmers should consider interplanting a crop between wider-spaced rows during the early years of the rotation. Such an activity should also be considered by the timberland investment management organizations who manage about $4 billion of properties for institutional investors. Given their focus on financial returns rather than meeting the supply needs of a mill as well as the appetite of the institutional investors for current income, a pine plantation-crop system may be an attractive land-use alternative in selected cases.

Need/opportunity: small-scale specialty products systems

The number of southern farms decreased by 4% from 524,000 in 1990 to 503,000 in 1993. Simultaneously, the average size increased slightly from 87 to 90 ha. On average, farms in the south were still much smaller than for the nation as a whole: 90 ha *versus* 193 ha (Statistical Abstract of the United States, 1995). With the regional trend toward fewer, larger farms, surviving producers are searching for creative approaches for improving efficiency and increasing revenues. Agroforestry alternatives can be consistent with the growing interest in the production of highly priced niche products, including those produced with organic and/or environmentally sensitive forms of gardening. In addition, with the gap in the rural nature between the USA (where 80% of the population lives in a metropolitan area) and the south (where only Florida exceeds 80%) decreasing (Statistical Abstract of the United States, 1995), it is likely that more southerners will be seeking means to return to their agrarian roots and will take an interest in labor-intensive, sustainable forms of crop, tree, and livestock production.

Specialty outputs produced within southern agroforestry systems have gained increased attention of researchers. Hill (1991) suggests such combinations as beehive-woodlot systems (especially if there are sizable populations of sourwood (*Oxydendrum arboreum*), yellow poplar (*Liriodendron tulipifera*), or basswood (*Tilia americana*)); ginseng (*Panax quinquefolius*) production within woodlots; and Shiitake mushrooms on small-diameter hardwood timber. Mount (1991) chronicled the success of individuals undertaking such enterprises as an azalea (*Rhododendron* spp.) nursery operation under a rather mature southern pine stand and the growth of Spanish moss (*Tillandsia usneoides*) (for use as packaging for live plants) on hardwoods in moist areas.

The use of pasture trees such as honeylocust (*Gleditsia triacanthos* L.) have been reported to improve both the financial performance and environmental conditions of a working farm (Wilson, 1991). Ripe pods drop gradually from the trees, providing a nutritional food source to grazing livestock during the fall when grass production is declining. Each 10-year-old tree on an Alabama research project produced an average of 94 kg of pods. Importantly, if not planted too densely, the trees do not significantly reduce understory grass production. Wilson notes that honeylocust is especially well suited for sheep (as opposed to cattle) pasture land, since the pods are digestible by the sheep and the trees can be protected in a cost-effective manner from the smaller animals. Further investigation of these and other feasible niche products within small-scale agroforestry systems is warranted.

Conclusions

A variety of factors suggest considerable potential for agroforestry in the southern USA. These include the region's diverse forest and agricultural lands, changing rural and urban lifestyles, and the need to resolve a variety of environmental and economic problems associated with rural land use. In addition, land-use professionals in the southern USA appear willing to recommend agroforestry. For example, despite rather modest education, training, or professional experience with agroforestry, almost two-thirds of the professionals in our survey reported that they would consider recommending agroforestry for certain situations. The most common reason, however, for rejecting the agroforestry option by southern land-use professionals was the high degree of uncertainty with what they considered an unproven land use.

While the environmental benefits from agroforestry systems are relatively well understood, considerable uncertainty remains about the potential profitability of various agroforestry systems. Given the current Federal budget problems, the probability of enhancing subsidies, cost-share, or other incentives to promote agroforestry are slim. Therefore, landowners will bear a greater portion of the risk in adopting environmentally friendly but economically unproven land-use systems like agroforestry. They need assurance through expanded economic research that the returns from their investments in agroforestry will produce returns at least as large or larger than traditional land uses. Reducing the financial uncertainties associated with agroforestry, through better economic analysis of this land use and expanded research and dissemination of research results, is probably the most critical factor for expanding agroforestry in the southern USA.

In addition to research into the profitability and adoptability of southern agroforestry systems, enhancement of agroforestry extension and training is crucial for popularizing agroforestry. Among the extension needs are more intensive training of extension personnel, distribution of guidelines for establishing and managing agroforestry systems, expanding publicity of agroforestry options, improving inter-agency cooperation, and increasing the number of extension personnel trained in agroforestry. Finally, a series of demonstration, research, and development projects are needed across the southern USA to educate landowners and land-use professionals about the potential of agroforestry while improving and developing new systems.

Acknowledgments

This research was supported by funds provided by the National Agroforestry Center, Lincoln, NE, and by the USDA Forest Service, Southern Research Station, Research Triangle Park, NC.

References

Amacher, GS, Aust WM, Grebner D, Groninger J, Shabman L, Sullivan J and Zepp L (1996) Land Owners' Financial Returns to Reforestation of Marginal Farmlands in the Mississippi Alluvial Plain: Estimates, Interpretations, and Policy Implications. Virginia Tech, Blacksburg, VA, Unpublished document, 91 pp

Baker JB, Guldin JM and Guldin RW (1991) Natural regeneration methods for loblolly and shortleaf pines. For Farmer 50: 59–63

Baldwin CS (1988) The influence of field windbreaks on vegetable and specialty crops. Agric, Ecosyst Environ 22/23: 191–203

Bandolin TH and Fisher RF (1991) Agroforestry systems in North America. Agrofor Syst 16: 95–118

Bezkorowajnyj PG, Gordon AM and McBride RA (1993) The effect of cattle foot traffic on soil compaction in a silvo-pastoral system. Agrofor Syst 21: 1–10

Boyer WD (1967) Grazing hampers development of longleaf pine seedlings in southwest Alabama. J For 65: 336–338

Brandle JR and Hintz DL (1988) Windbreaks for the future. Agric Ecosyst Environ 22/23: 593–596

Buck LE (1995) Agroforestry policy issues and research directions in the US and less developed countries: insights and challenges from recent experience. Agrofor Syst 30: 57–73

Campbell GE, Lottes GJ and Dawson JO (1991) Design and development of agroforestry systems for Illinois, USA: silvicultural and economic considerations. Agrofor Syst 13: 203–224

Clason TR (1995) Economic implications of silvipastures on southern pine plantations. Agrofor Syst 29: 227–238

Dangerfield CW and Harwell RL (1990) An analysis of a silvopastoral system for the marginal land in the southeast United States. Agrofor Syst 10: 187–197

Garrett HE, Jones JE, Kurtz WB and Slusher JP (1991) Black walnut (*Juglans nigra* L.) – its design and potential as a land-use alternative. For Chron 67: 213–218

Gold MA and Hanover JW (1987) Agroforestry systems for the temperate zone. Agrofor Syst 5: 109–121

Hallberg GR (1987) Agriculture chemicals in groundwater: extent and implications. Am J Alternative Agric 2: 3–15

Hanover JW, Mebrathu T and Bloese, P (1991) Genetic improvement of black locust: a prime agroforestry species. For Chron 67: 227–231

Haynes RW, Adams DM and Mills JR (1995) The 1993 RPA Timber Assessment Update. Gen Tech Rep RM-259. Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO, 66 pp

Henderson D (1991) Opportunities for agroforestry in the Mid-South. In: Henderson DR (ed) Proceedings: Mid-South Conference on Agroforestry Practices and Policies, pp 85–100. West Memphis, AR. Nov 28–29, 1990. Winrock International Institute for Agriculture Development

Hill, DB (1991) Alternative forest products. In: Henderson DR (ed) Proceedings: Mid-South Conference on Agroforestry Practices and Policies, pp 49–52. West Memphis, AR. Nov 28–29, 1990. Winrock International Institute for Agriculture Development

Kellogg RL, Maizel MS and Goss DW (1994) The potential for leaching of agrichemicals used in crop production: a national perspective. J Soil Water Conser 49: 294–298

Kurtz WB, Garrett HE and Kincaid WH (1984) Investment alternatives for black walnut plantation management. J For 82: 604–608

Lawrence JH and Hardesty LH (1992) Mapping the territory: agroforestry awareness among Washington State land managers. Agrofor Syst 19: 27–36

Lawrence JH, Hardesty LH, Chapman RC and Gill SJ (1992) Agroforestry practices of non-industrial private forest landowners in Washington State. Agrofor Syst 19: 37–55

Lewis CE, Monson WG and Bonyata RJ (1985) Pensacola bahiagrass can be used to improve the forage resource when regenerating southern pines. South J Appl For 9: 254–259

Lewis CE, Tanner GW and Terry WS (1985) Double vs. single-row pine plantations for wood and forage production. South J Appl For 9: 55–61
Lowrance R, Sharpe JK and Sheridan JM (1986) Long-term sediment deposition in the riparian zone of a coastal plain watershed. J of Soil Water Conser 41: 266–270
Lundgren GK, Conner JR and Pearson HA (1983) An economic analysis of forest grazing on four timber management situations. South J Appl For 7: 119–124
Matta-Machado RP and Jordan CF (1995) Nutrient dynamics during the first three years of an alley cropping agroecosystem in southern USA. Agrofor Syst 30: 351–362
Merwin, ML (ed) (1996) The Status, Opportunities and Needs for Agroforestry in the United States. Association for Temperate Agroforestry. Columbia, MO, 57 pp
Moorhead DJ (1994) Artificial regeneration techniques. In: Moorhead DJ and Coder JD (eds) Southern Hardwood Management, pp 56–58. USDA-Forest Service, Forest Service Southern Region
Moulton RJ (1994a) Sorting through cost-share assistance programs. Tree Farmer 53: 24–26
Moulton, RJ (1994b) Reforestation. In: Conference Proceedings: When Conservation Reserve Program Contracts Expire: The Policy Options. Soil and Water Conservation Society. Feb 10–11, 1994, Arlington, VA
Moulton RJ, Lockhart F and Snellgrove JD (1995) Tree Planting in the United States 1994. USDA-Forest Service. Washington, DC, 18 pp
Mount P (1991) Perennial intercropping. In: Henderson, DR (ed) Proceedings: Mid-South Conference on Agroforestry Practices and Policies, pp 53–56. West Memphis, AR. Nov 28–29, 1990. Winrock International Institute for Agriculture Development
Muir JP and Pitman WD (1989) Response of the Florida legume Galactia elliottii to shade. Agrofor Syst 9: 233–239
Myers CF, Meek J, Tuller S and Weinberg A (1985) Nonpoint sources of pollution. J Soil Water Conser 40: 14–18
Norton RL (1988) Windbreaks: benefit to orchard and vineyard crops. Agric Ecosyst Environ 22/23: 205–213
Pearson HA (1991) Silvopasture: forest grazing and agroforestry in the southern coastal plain. In: Henderson DR (ed) Proceedings: Mid-South Conference on Agroforestry Practices and Policies, pp 25–42. West Memphis, AR. Nov 28–29, 1990. Winrock International Institute for Agriculture Development
Pearson HA, Baldwin VC and Barnett JP (1990) Cattle grazing and pine survival and growth in subterranean clover pasture. Agrofor Syst 10: 161–168
Powell DS, Faulkner JL, Darr DR, Zhu Z and MacCleery DW (1993) Forest Resources of the United States, 1992. Gen Tech Rep RM-234. Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO, 133 pp
Rials P (1984) Livestock grazing on forest range: a panel discussion by forestland managers and cattlemen. In: Linnartz NE and Johnson MK (eds) Agroforestry in the Southern United States. 33rd Annual Forestry Symposium, pp 159–174. Baton Rouge, LA
Rietveld WJ and Montrey H (1991) A public policy perspective of agroforestry. In: Henderson DR (ed) Proceedings: Mid-South Conference on Agroforestry Practices and Policies. West Memphis, AR. Nov 28–29, 1990. Winrock International Institute for Agriculture Development, pp 53–56
Robinson JL (1991) Windbreaks and tree barriers for sustainable agriculture in the Mid-South. In: Henderson DR (ed) Proceedings: Mid-South Conference on Agroforestry Practices and Policies, pp 43–48. West Memphis, AR. Nov 28–29, 1990. Winrock International Institute for Agriculture Development
Rule LC, Colletti JP, Liu TP, Jungst SE, Mize CW and Schultz RC (1994) Agroforestry and forestry-related practices in the Midwestern United States. Agrofor Syst 27: 79–88
Sanchez PA (1995) Science in agroforestry. Agrofor Syst 30: 5–55
Schultz RC, Colletti JP and Faltonson RR (1995) Agroforestry opportunities for the United States of America. Agrofor Syst 31: 117–132

Slusher JP (1991) Alley cropping with eastern black walnut in Missouri. In: Henderson DR (ed) Proceedings: Mid-South Conference on Agroforestry Practices and Policies, pp 13–24. West Memphis, AR. Nov 28–29, 1990. Winrock International Institute for Agriculture Development

Soil Conservation Service (1981) America's Soil and Water: Conservation and Trends. USDA. Washington, DC, 32 pp

Soil Conservation Service (1989) Summary Report 1987 National Resources Inventory. Iowa State Statistical Laboratory. Stat Bull No 790, 37 pp

Statistical Abstract of the United States (1995) US Department of Commerce, Economics and Statistics Administration, Bureau of the Census, Washington, DC

USDA (1989) The Second RCA Appraisal. Washington, DC

USDA-Forest Service (1988) The South's Fourth Forest: Alternatives for the Future. Forest Resource Report No. 24. Washington, DC, 512 pp

Wear DN (1993) Private Forest Investment and Softwood Production in the US South. Gen Tech Rep RM-237. Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO, 11 pp

Wilson AA (1991) Browse agroforestry using honeylocust. For Chron 67: 232–235

Wojtkowski PA and Cubbage FW (1991) A bordered matrix approach to the bioeconomic modeling of agroforestry systems. Agrofor Syst 14: 81–97

Young A (1989) Agroforestry for Soil Conservation. CAB International, Wallingford, UK

Ziehm RW, Pearson HA, Thurow TL and Baldwin VC (1992) Agrofor Syst 20: 267–274

Zinkhan FC (1993) Timberland investment management organizations and other participants in forest asset markets: a survey. South J Appl For 17: 32–38

Zinkhan FC (1996) Public land-use professionals' perceptions of agroforestry applications in the South. South J Appl For 20: 162–168

Zinkhan FC and Mercer DE (1996) Agroforestry and Sustainable Systems in the South. Warnell School of Forest Resources, University of Georgia, Athens. Unpublished document, 65 pp