A Role for Agroforestry in Forest Restoration in the Lower Mississippi Alluvial Valley

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ABSTRACT

Agroforestry options are explored for restoring important functions and values of bottomland hardwood (BLH) forests in the lower Mississippi River Alluvial Valley (LMAV). Agroforestry practices can augment the size and quality of BLH habitat, provide corridors between BLH areas, and enable restoration of natural hydrologic patterns and water quality. Agroforestry practices are designed primarily to benefit agriculture, which may appeal to farmers in the region. Profit potential from some agroforestry practices is currently competitive with agricultural crops and production forestry on marginal agricultural lands in the LMAV. Lack of experience with agroforestry in this region hinders adoption, but emerging markets for biofuels and ecosystem services could enhance future prospects. Concepts are presented for how agroforestry can be located and designed for restoring BLH forest functions and values in the LMAV and thereby contribute to achieving goals for ecological restoration.

Keywords: agroforestry, ecosystem services, bottomland hardwoods, wildlife, forest restoration

Bottomland hardwood (BLH) forests in the lower Mississippi River Alluvial Valley (LMAV) provide important production and ecosystem services including wood products, wildlife habitat, clean water, and recreation. Today, only one-quarter of the original extent of BLH forests remains while two-thirds of the LMAV has been cleared and converted to agriculture (Twedt and Loesch 1999; Figure 1). As a consequence, supply of some ecosystem services that are linked to the abundance of BLH forests, such as populations of forest wildlife, have declined to alarming levels. The capability of remaining BLH forests to provide those services has also declined because of forest fragmentation, altered hydrology, sedimentation and water pollution, invasive exotic plants, and indiscriminant timber harvesting (Gardiner and Oliver 2005).

Restoration of BLH forests in the LMAV has been a goal of forestry and wildlife interests for many years. A major impetus for this effort has centered on the restoration of forest habitat for migratory birds (Lower Mississippi Valley Joint Venture [LMVJV] 2007). Reforestation often takes the form of conversion of marginal farmland to timber plantations, BLH set-asides, and riparian forest buffers. Agroforestry, generically defined as the integration of trees into productive agricultural systems, may provide additional options to supplement current reforestation strategies. Agroforestry plantings can be located and designed to provide key ecological attributes normally provided by BLH forests. An assessment of agroforestry options in light of current issues and emerging opportunities may identify promising new ways to bolster the success of forest restoration efforts in the LMAV.

Restoring Forest Functions and Values in the LMAV

Restoration of BLH forests has been a key conservation goal in the LMAV since the 1970s. The LMVJV, a partnership of state and federal agencies and private conservation organizations, has established a restoration target of 2 million ac by 2020 (Haynes 2004, Gardiner and Oliver 2005). For economic reasons, marginal farmland has been a major target for conversion to BLH forests. These lands are estimated to cover about 7.5 million ac (Amacher et al. 1997) and mainly include lower-lying areas that are difficult to farm because of inadequate drainage or flood control. Costs for establishing 2 million ac of BLH forests under a 10-year Conservation Reserve Program (CRP)–type contract can range from $1.4 to 1.7 billion based on tree establishment costs of $75–245/ac and a land rental rate of $60/ac (Stanturf et al. 2000, Gardiner and Oliver 2005, Spriggs 2006). Restoration of drier sites, which are needed for roosting and rearing of some forest avian species, may be more expensive to restore. Relatively less area of drier site types remain in BLH forests because it is the most highly valued agricultural land and without greater financial incentives, landowners are more likely to keep it in agricultural production (US Forest Service 2006). Longer program enrollment periods will also increase cost.

A predominant strategy for selecting sites for restoration has been to enlarge

Received July 21, 2010; accepted May 31, 2011; http://dx.doi.org/10.5849/jof.10-061.

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blocks of existing BLH forests (LMVJV 2007). This strategy is intended to maximize interior forest habitat and is driven mainly by interests in increasing populations of forest-breeding birds. A minimum BLH block size of 10,000 ac has been recommended for creating viable habitat for forest-breeding birds, which includes a 0.3- to 0.6-mi-wide (3000–6000 acre) BLH buffer around a core of desired interior BLH habitat (Llewellyn et al. 1996, Mueller et al. 1999). By 1992, 98 forest patches met this criterion in the LMAV, most of which are located in the southern half of the LMAV (Twedt and Loesch 1999).

The present restoration strategy has had some success. It is estimated that 0.77 million ac of cleared land has been restored to forest cover over 30 years through 2005 (King et al. 2006). More recently, over 30 thousand additional ac have been restored since 2004 under the Ivory-Billed Woodpecker Recovery Plan (US Fish and Wildlife Service [USFWS] 2010). At this pace, however, reaching the goal of 2 million ac by 2020 set by the LMVJV will require substantial additional gains. Strategies that supplement current forest restoration practices may help to sustain and enhance progress toward achieving this conservation goal.

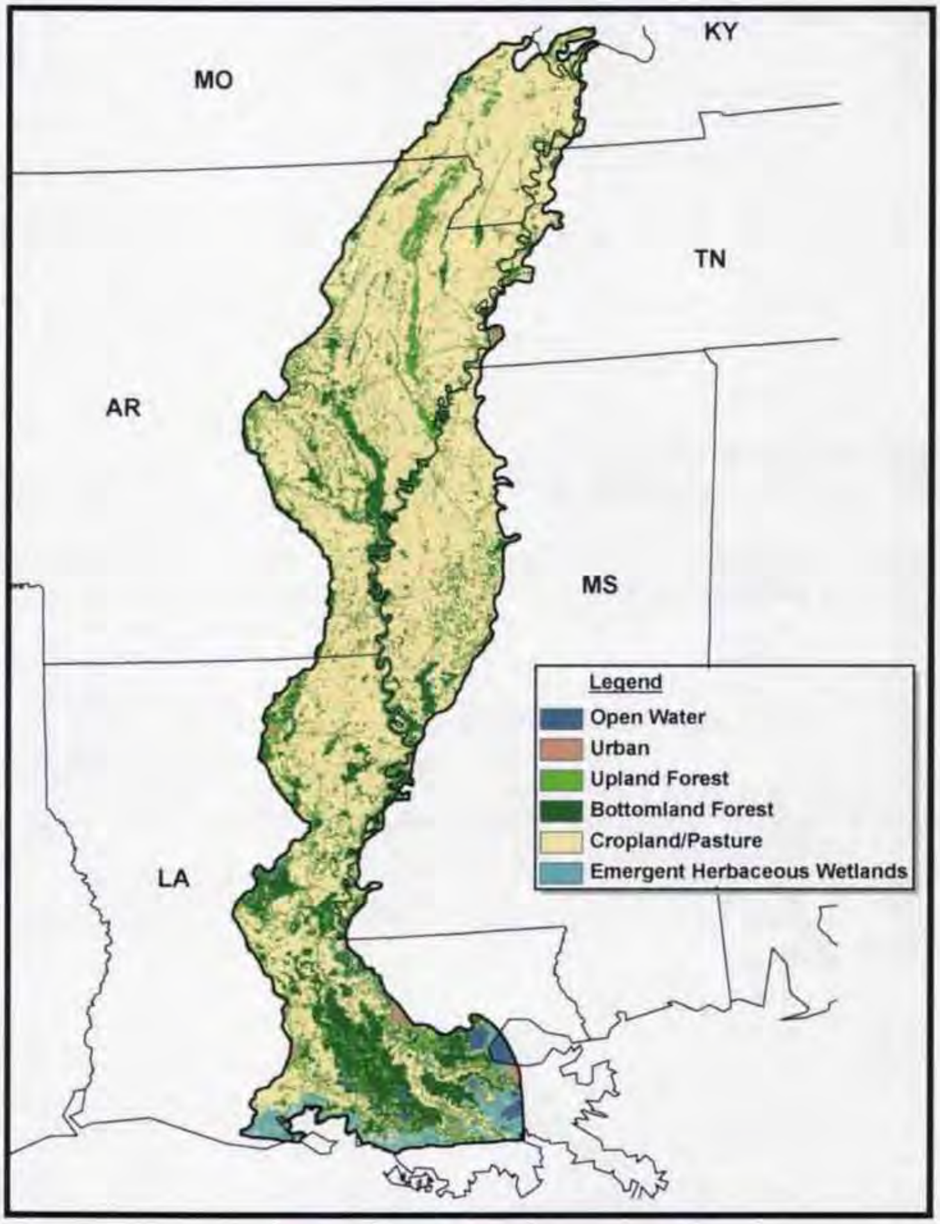

Figure 1. Location and land cover of the LMAV. Land cover adapted from the 2006 National Land Cover Database (Multi-Resolution Land Cover Consortium 2011).

Agroforestry Restores Forest Functions and Values

Agroforestry is the integration of trees into agricultural systems to aid the management of the agricultural component. In an agroforestry system, the "forest" areas are intentionally designed and managed to enhance agricultural production and to mitigate environmental problems generated by agricultural activities. It is distinguished from forestry by the interaction between the trees and nearby agriculture. In contrast, a woodlot or riparian forest on one corner of a farm that does not beneficially interact with crops or livestock is not agroforestry.

Agroforestry could supplement current forest restoration strategies. Agroforestry practices can create forest habitat and improve water quality on productive agricultural lands (Figure 2). When properly located, they can enhance habitat and water quality within adjacent BLH areas. Agroforestry presents income options that may appeal to landowners that want to continue in farm production. Income can be generated from improved yields of adjacent crops, various nontimber forest products, sawtimber and pulpwood, biofuel feedstock, hunting and recreation leases, and from emerging markets for water quality and carbon storage credits (Montagnini and Nair 2004, Keoleian and Volk 2005, Garrett 2009). Agroforestry can add to the palette of choices presented to landowners for restoring forest functions and values to the LMAV.

Agroforestry practices encompass a diversity of forms and arrangements. Some general types include riparian forest buffers, windbreaks, silvopasture, alley cropping, forest farming, and strip-type arrangements of short-rotation woody crops, among others (sidebar). Agroforestry practices can be adapted in the LMAV in several ways to promote BLH forest restoration goals, including:

• Provide habitat buffers between existing BLH areas and intensively farmed areas. Current strategy calls for BLH forests to provide a 0.3- to 0.6-mi-wide buffer zone around a core BLH forest patch. The buffer zone requirement alone can more than double the required forested area. Agroforestry practices could be used to create those buffer zones. By creating the necessary tree structure to function like a forested buffer, agroforestry can enlarge the area of effective interior BLH forest habitat and turn smaller, less-viable BLH forest patches (5,000–10,000 ac) into effective interior habitat

Agroforestry is the integration of trees into agricultural systems to provide an optimal mix of ecosystem services and economic benefits. It is distinguished from forestry by its designed interaction with nearby agricultural crops. Detailed description of most agroforestry practices can be found in Garrett (2009). Short-rotation woody crops are described by Dickmann (2006). The major agroforestry types practiced in temperate regions of North America include:

Riparian Forest Buffers: Forest vegetation located adjacent to waterways primarily to enhance and protect the aquatic environment from adverse impacts of nearby agricultural land uses. The forest vegetation provides shade, organic debris, and stability to channels and shorelines; filters pollutants out of agricultural runoff; and creates forest habitat and corridors. Although typically installed as narrow strips, their size, vegetative composition, and management can be varied to match site conditions, desired ecological functions, and opportunities for economic products.

Windbreaks: Linear strips of forest vegetation designed to protect agricultural soil from wind erosion, crops from desiccation and soil abrasion, and livestock from the stress of hot summer and cold winter winds. Windbreaks also provide forest habitat and corridors for wildlife and water erosion control and runoff filtering for water quality protection.

Silvopasture: A system of forage and/or livestock production in the understory of tree plantations. Forage and livestock provide the landowner with near-term cash flow while the trees mature into a marketable commodity. Silvopasture can be practiced among pines (*Pinus* spp.) and hardwoods such as oak (*Quercus*), walnut (*Juglans*), and pecan (*Carya*).

Alley Cropping: Widely spaced rows of trees between which agricultural crops are grown. The trees provide timber, biomass feedstock, nuts, or other products and the companion alley crop produces row and cereal crops, forages, or specialty crops. The alley crop provides near-term cash flow, and the tree crop provides protection for the crop, erosion control and water quality benefits, and periodic financial returns over a longer term.

Forest Farming: Management of forest canopy for the production of specialty products in the understory. Product options include food (berries and mushrooms), botanicals (herbs and medicinals), decoratives (floral greenery and dyes), and handicrafts (basket and wood craft materials). Forest overstory is modified to provide the appropriate understory microclimate but not enough to greatly interfere with its contributions to wildlife habitat, erosion control, and water filtering. Alley cropping and silvopasture can provide a transitional stage until a forest canopy is created.

Short-Rotation Woody Crops: Fast-growing tree species such as poplar (*Populus*) and willow (*Salix*) grown for fiber and biofuel with rotation ages of 3–12 years. When grown in strip configurations, they can function as windbreaks, riparian forest buffers, and the tree component of alley cropping. Cutting some strips every few years creates a diversity of structure that may function better for some wildlife

without actually increasing the size of the BLH forest patches.

• Provide tree corridors that connect BLH forest habitat patches. Fragmentation of BLH forests has created numerous small patches that are not viable for area-sensitive species of forest wildlife. Connecting small BLH forest patches with tree corridors across croplands will facilitate the movement of forest wildlife between patches and effectively increase the habitat viability of each small BLH forest patch (USDA Natural Resources Conservation Service 1999, Hilty et al. 2006). Agroforestry practices can be used to create those wildlife corridors.

• Improve water quality in existing BLH forest patches. Runoff flowing from agricultural lands into existing BLH forest areas carries sediments, nutrients, and pesticides that can impair the health of both aquatic and terrestrial wildlife (Hoover and Killgore 1998). High sediment loads from eroding farmland and stream banks degrade water quality and fill-in seasonal forested flood zones and backwater pools that are required for reproduction of many fish and amphibian species; nutrients in runoff lead to eutrophication and hypoxia in sloughs and oxbows that degrade open water habitat for fish and amphibians; pesticides in runoff can be toxic toward the health and development of all species, but particularly for sensitive larval fish and amphibians (Hoover and Killgore 1998, 2002). In turn, degraded aquatic health reduces the food supply for forest wildlife that feed on aquatic plants and animals. Agroforestry practices located in critical agricultural areas can improve BLH forest habitat quality by reducing the flow of sediments, nutrients, and pesticides from agricultural lands into existing BLH forest areas.

• Enable restoration of hydrology in existing BLH areas. Drainage and flood control improvements designed to protect flood-sensitive annual crops, such as cotton and soybeans, have altered the hydrology and hydroperiod of remaining BLH forest areas (King and Keeland 1999). Installing agroforestry practices that have tree species and intended uses that are more compatible with wetness and periodic flooding can reduce the need for drainage and flood control and enable the restoration of natural hydrologic patterns.

• Provide rapid development of early succession forest structure and accelerate development of mature BLH forests. Tree structure is the main determinant of bird species occurrence and community composition in the LMAV (Twedt and Portwood 1997, Hamel 2003, Twedt and Best 2004). By selecting fast-growing agroforestry tree species and practicing weed control, agroforestry practices can promote rapid initial development of forest cover and accelerate the development of habitat for later-succession forest birds (Twedt and Portwood 2003, Wilson and Twedt 2005). Agroforestry can be used as a transition toward BLH forest restoration (Twedt and Portwood 2003).

Agroforestry can also provide benefits in the LMAV beyond protecting and enhancing existing BLH forests. Agroforestry practices themselves create valuable habitat for a broad range of birds and other forest-dwelling wildlife (Twedt and Portwood 2003, Heitmeyer et al. 2005) including game birds and fish that improve hunting and fishing opportunities (Burger 2005). Shifting land from annual crops to agroforestry can improve regional drinking water quality and reduce erosion of valuable agricultural soil. Agroforestry can also provide economic diversification that improves the financial well-being of farms and communities, especially those of small-to-medium resource farmers (Henderson 1991).

Functional Quality of Agroforestry

Although agroforestry can produce the kinds of environmental benefits that BLH forests do, it is not likely that it produces them to the same levels as BLH forests. This is particularly true for wildlife because habitat suitability and quality can be sensitive to vegetation species and structure, management activities, and conditions in the surrounding landscape. Generally, agroforestry tree species and spacing will differ from BLH planting designs. Various management activities such as weed control, grazing, intercropping, and tree harvesting are conducted periodically that would not generally occur in a true BLH forest restoration. In light of these differences, it is important to consider what level of ecological benefit agroforestry can provide compared with BLH forests.

Because conservation of birds is a major goal of BLH forest restoration, a good measure is comparing avian habitat value from agroforestry-type plantings to that from mature BLH forests. Nuttle and Burger (1996) and Nuttle (1997) compared hardwood planting sites of different ages in the LMAV in Mississippi to mature BLH forests (Table 1). Although these young plantings were not agroforestry practices per se, they are, nevertheless, similar in structure and provide a basis for what level of avian benefits could be expected from agroforestry practices. The results clearly show substantial habitat value of young hardwood stands for forest birds (Table 1). By the age of 21–27 years old, hardwood planting sites were frequented by large populations of many forest species (high Morisita Index). Some high-priority forest species were also observed (high Conservation Value Index), such as prothonotary warbler (*Prothonotaria citrea*) and yellow-billed cuckoo (*Coccyzus americanus*), but not as many high-priority species as observed in mature BLH forests.

Faster-growing tree species can provide forest habitat sooner. Twedt et al. (2002) estimated that 5- to 9-year-old cottonwood (*Populus deltoides*) had twice the conservation value of oak plantings at the same age and attributed it to more rapid development of vertical structure. Selection of fast-growing tree species plus weed control in agroforestry systems would promote even faster tree growth and more rapid development of forest bird habitat.

Figure 2. Agroforestry practices offer a variety of options for landowners: (A) riparian forest buffers, (B) windbreaks, (C) silvopasture, (D) alley cropping, (E) forest farming, and (F) short-rotation woody crops. (Photos provided courtesy of the USDA Forest Service and Natural Resources Conservation Service (A, B, and F), the University of Missouri (C and D) and the University of Minnesota (E).)

Younger treeplantings can contribute habitat for other important bird communities (Table 1). New planting sites up to 15 years old supported grassland and shrub-succession bird communities, including high-priority dickcissel (*Spiza americana*), northern bobwhite (*Colinus virginianus*), yellow-breasted chat (*Icteria virens*), and painted bunting (*Passerina ciris*). These birds are not present in older treeplantings and mature BLH forests. These results indicate that some high-priority bird species may benefit from management-related disturbance and replanting of tree stands associated with agroforestry practices that are not provided by BLH forests.

Even narrow plantings can provide important habitat in fragmented landscapes. Kilgo et al. (1998) reported that strips as narrow as 165 ft provided habitat for BLH forest species such as hooded warbler (*Wilsonia citrine*) and Acadian flycatcher (*Empidonax virescens*). However, forest strips as wide as 1,500 ft or more may be necessary for area-sensitive species such as Swainson's warbler (*Limnothlypis swainsonii*). Large mammals may also benefit from narrow plantings. A study in Louisiana documented black bears (*Ursus americanus*) using wooded corridors 15–250 ft wide to access habitat patches for foraging and breeding (Anderson 1997).

The habitat value of treeplantings is greatly increased by locating them adjacent to existing BLH forest tracts. Warwick (2004) observed that agroforestry plantings adjacent to forest remnants had more swamp rabbits (*Sylvilagus aquaticus*) compared with agroforestry plantings not adjacent to remnants. Twedt et al. (2006) estimated that targeted BLH forest restoration in the LMAV could increase the effective area of forest interior habitat for birds by 32 times more than by random treeplantings. We hypothesize that targeted agroforestry can have similar impact on interior habitat while also creating habitat for early succession species of concern.

Overall, agroforestry plantings will probably have lower habitat quality per unit area than mature BLH forests for most interior forest species of concern. However, the potential for converting more area to trees, faster tree growth, and targeted installation could translate into a substantial regionwide contribution by agroforestry to conservation of high-priority species.

Table 1. Habitat value of treeplantings of different ages for birds during the breeding season compared with mature BLH forests in the LMAV.

Stand age (yr)	Morisita Index (%)	Conservation Value Index (%)	Observed bird community type
0–4	3–5	34	Grassland
7–15	35–42	46	Shrub succession
21–27	74–85	65	Forest
Mature forest	100	100	Forest

The Morisita Index evaluates similarity of species and abundances. The Conservation Value Index evaluates similarity of species and abundances weighted by the conservation importance of each species.
Source: Data from Burger (2005).

Profitability of Agroforestry in the LMAV

Widespread adoption of agroforestry practices by farmers will depend on developing systems that produce sound financial returns that are at least similar to the agricultural crops they would replace or the timber production and forest easement options that agroforestry may substitute for. Timber and pulpwood plantations and forest Wetland Reserve Program (WRP) easements have been shown to be competitive with agricultural crops on marginal agricultural lands in the LMAV (Amacher et al. 1997, Anderson and Parkhurst 2004). Under current market conditions, agroforestry is also competitive with crops and timber on marginal agricultural lands, particularly if incentive payments are provided by government programs (Table 2; Frey et al. 2010). Competitive agroforestry options include pine silvopasture and cottonwood alley cropping along with riparian forest buffer easements. On average or better agricultural land, however, agricultural crops are more profitable than either forestry or agroforestry (Ibendahl 2008, Frey et al. 2010); therefore, there is currently little economic incentive for landowners to convert good cropland to forest alternatives. These studies did not assess forest farming as an agroforestry option in the LMAV.

Longer-term profit potential from agroforestry is critical to sustain gains in forest restoration. Although CRP and some WRP contracts offset installation costs and crop production losses in the short term, a sustainable flow of profits from marketable goods and services may be necessary to prevent short-term acreage gains from becoming ephemeral after program contracts expire. Future prospects for profitability from agroforestry hinge on many variables, including prices, discount rates, and government programs. Emerging markets for biomass biofuels and ecosystem services present both opportunities and challenges. Profit potential from corn biomass has risen dramatically recently on demand from ethanol producers. In the short term, high profits from corn will discourage conversion to other land uses. In the longer term, however, experts predict that the industry will shift substantially from starch to cellulose feedstocks (DiPardo 2002). If that occurs, the market likely will shift toward trees, such as short-rotation woody crops, and bolster the incentive for land conversion to agroforestry. However, there would need to be a large increase from current biomass prices for short-rotation woody crops to be competitive with agricultural crops (Frey et al. 2010). Emerging markets for ecosystem services including carbon sequestration and water quality credit trading could also enhance financial returns. For example, conversion of cropland to agroforestry can increase carbon storage in soil and standing trees (Tolbert et al. 1999). Credits for the amount of gain in carbon storage can be sold to companies to offset the carbon dioxide that they produce through activities such as the burning of fossil fuels (Ruddell et al. 2006). Conversion of cropland to agroforestry is also widely recognized to improve runoff water quality (Tolbert et al. 1998, Schultz et al. 2009). A landowner can obtain credits based on the estimated level of improvement, and, these credits can be sold to buyers to offset water-degrading activities elsewhere (US Environmental Protection Agency 2007). Markets for ecosystem services represent a new kind of profit potential for agroforestry, but they are not well developed and may be risky until they mature further.

Other Factors Affecting Adoption of Agroforestry

Adoption rates for converting crops to agroforestry (and forestry) on marginal agricultural lands in the LMAV have been lower than would be predicted based purely on profitability (Frey et al. 2009). Agroforestry presents greater financial risk than conventional agricultural crops. Many agroforestry products lack well-developed markets and support policies that agricultural crops enjoy. There is also less technical knowledge about agroforestry in the LMAV. Documentation of agroforestry practice in the LMAV is scarce beyond riparian forest buffers. Short-rotation woody crops have been studied occasionally since the 1970s for producing fiber and biofuel feedstock (Wright and Berg 1996, Stanturf et al. 2003). Experimental alley cropping systems have been reported (Gold and Hanover 1987, Zinkhan and Mercer 1997). Grazing cattle in pecan

Table 2. Estimated net present value for production systems without and with government payment programs on average and marginal cropland in the LMAV.

System	Average cropland[a] government payments		Marginal cropland[a] government payments	
	None	Payments (program)[b]	None	Payments (program)[b]
	(2008 $/ha, 5% discount rate)			
Annual Crop				
Soybeans	5,150	5,950 (ACRE, FDP)	925	1,478 (ACRE and FDP)
Rice	7,771		−768	
Forestry				
Cottonwood for pulpwood	−257		−338	
Cottonwood for sawtimber	1,180		1,210	
Hard hardwoods (clearcut)	52	2,233 (WRP)	−129	2,233 (WRP)
Hard hardwoods (sustainable)	−179		−357	
Cottonwood and oak interplanting (clearcut)	158		18	
Cottonwood and oak interplanting (sustainable)	−12		−158	
Agroforestry				
Short-rotation woody crop	−2,217		−2,253	
Pecan silvopasture	1,020		−28	
Hard hardwoods silvopasture	811		321	
Pine silvopasture	2,512		1,861	
Hard hardwoods riparian buffer	−333	3,696 (CRP)	−510	2,184 (CRP)
Cottonwood and oak riparian buffer	−590		−769	
Pecan alley cropping	2,355		−235	
Hard hardwoods alley crop	843		−8	
Cottonwood alley crop	2,144		1,367	

[a] Average and marginal cropland are defined as USDA Natural Resources Conservation Service Land Capability Classification 3 and 5, respectively.
[b] Payment programs include Average Crop Revenue Election (ACRE), Fixed Direct Payment (FDP), WRP, and CRP.
Source: Data extracted from Frey et al. (2010).

orchards (i.e., pecan silvopasture) is practiced in the LMAV, although practitioners may not call it agroforestry (Frey et al. 2010). Lack of local experience creates greater uncertainty and risk to landowners about profitability of agroforestry. Tree-based practices are also less flexible to change back to crops if conditions become unfavorable for agroforestry.

Social factors can also play a role in whether landowners will adopt agroforestry. Blending agroforestry practices into an agricultural landscape can be more complicated to implement and manage than a single land use. Agroforestry practices can also appear nonuniform and messy, because of mixed plantings, which may not conform to a landowner's concept of good land stewardship (Nassauer 1988, Ryan et al. 2003). Increasing landowners' familiarity with the benefits that nonuniformity and landscape complexity can provide may allay some of these concerns.

Agroforestry: A Viable Restoration Option

Agroforestry practices broaden the spectrum of forestry options that might appeal to landowners in the LMAV. Agroforestry can be blended into agricultural landscapes and tailored through placement and design to provide desired mixes of production and conservation benefits. Profit potential from agroforestry can be competitive with agricultural crops and production forestry on marginal agricultural lands in the LMAV. Emerging markets for biofuels and ecosystem services may enhance future prospects for agroforestry profitability. Adoption of agroforestry practices is hindered by the lack of familiarity and experience with agroforestry in this region. Nevertheless, having more options for landowners to choose from increases the chances of finding one that appeals to each landowner's preferences. In this way, agroforestry could supplement current BLH forest restoration practices for restoring forest functions and values in the LMAV.

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