chapter fifteen

Restoration of bottomland hardwood forests in the Lower Mississippi Alluvial Valley, U.S.A.

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Contents

15.1 *Introduction*

The world's third largest river, the Mississippi, extends more than 3700 km through the central U.S. where it drains 41% of the conterminous U.S. before reaching the Gulf of Mexico. The river historically served as a primary travel corridor and trade route for Native American Indians, provided access for exploration and colonization to early European settlers, and today remains the backbone of commerce for much of the central U.S. The southernmost reach of the river is flanked by a 10 million ha physiographic region, the Lower Mississippi Alluvial Valley (LMAV). The rich alluvial soils in this floodplain historically supported vast expanses of mixed-species, deciduous forests. These bottomland hardwood forests are unique because their species composition and structure are linked to the past and current dynamics of the fluvial processes of the river. Inherently diverse in tree, shrub, and vine species, bottomland hardwood forests provide habitat for a rich fauna, function to abate floodwater and improve water quality, produce an exceptional timber commodity, and offer an abundance of recreational opportunities.

The aims of this chapter are to describe the LMAV and its forests, illustrate land-use history and current extent of forests, and summarize forest restoration activities in the region. Although many of the existing forests in the LMAV have been degraded through indiscriminate timber harvests, alterations to hydrologic regimes, or improper management, the focus of this chapter will be on restoration of deforested areas. Readers interested in management or rehabilitation of existing bottomland hardwood forests are referred to Hodges (1995, 1998) and Kellison et al. (1998).

15.2 *Physiography, climate, soils*

The LMAV is shared by seven states, which include Illinois, Missouri, Kentucky, and Tennessee, with the largest portion (over 85%) situated in the tri-state area of Arkansas, Mississippi, and Louisiana (Figure 15.1). The region roughly extends between 29° and 37°N latitude, and ranges between 89° and 92°W longitude. The LMAV is situated in a humid, subtropical region of the Northern Temperate Zone where annual precipitation ranges between 1000 and 1600 mm. January temperatures range from 3°C in the northern reach, 7.5°C in the central, and 11°C in the southern reach of the region, while temperatures in July average about 27°C across the region, with daily highs often exceeding 38°C (Gurley 1976; Matthews 1980; Scott and Carter 1962). Growing season length is typically 185 days in the northern portion of the LMAV, 229 days in the central, and as long as 245 days in the southern portion of the region (Gurley 1976; Matthews 1980; Scott et al. 1975).

Geological processes giving rise to the dissection of the LMAV began as early as 2 million years before present (ybp) during the late Tertiary to early Quaternary Periods (Saucier 1994). Advances and retreats of several glacial stages cycled during the Quaternary Period, although only the very most northern portion of the LMAV may have contacted glacial ice. Nevertheless, glacial advances generally resulted in dissection and widening of the LMAV, while glacial retreats typically led to alluviation of the LMAV (Saucier 1984). Alluvial deposits of the Holocene Epoch (beginning c. 10,000 ybp) characterize nearly 46% of the current surface

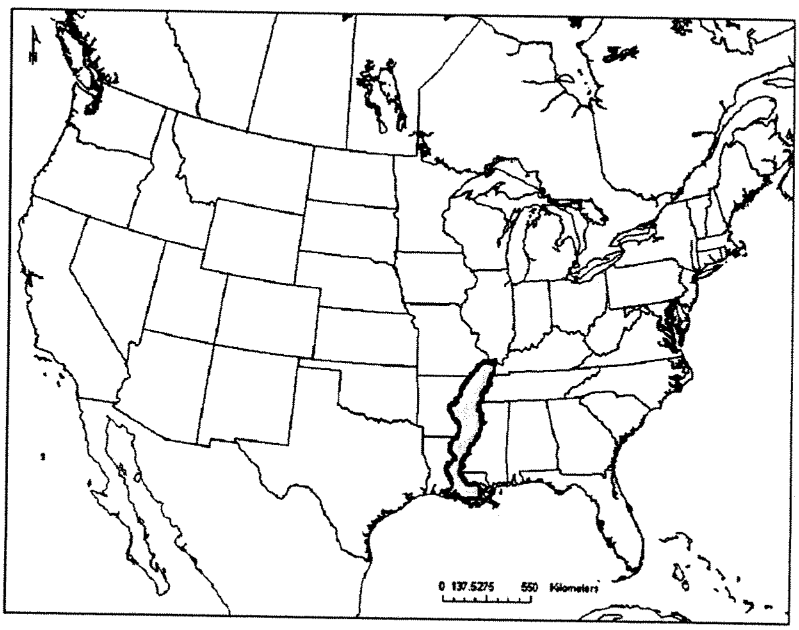

Figure 15.1 Location and extent of the LMAV in North America.

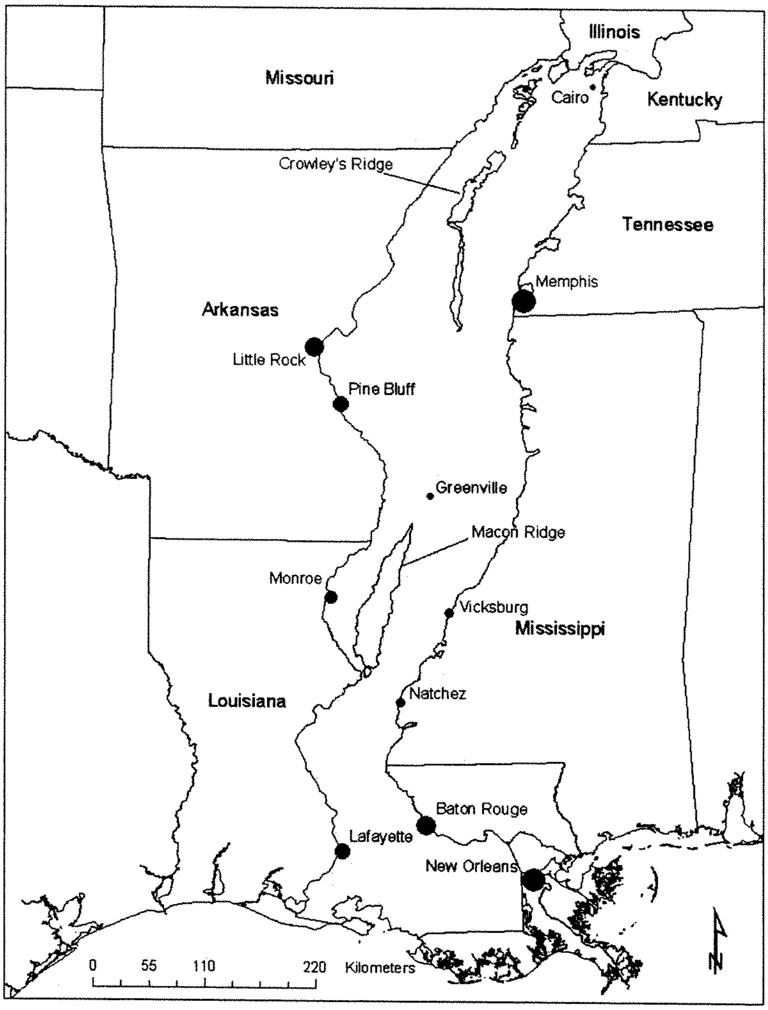

Figure 15.2 Prominent physiographic and urban areas in and adjacent to the LMAV.

geology of the LMAV, with other prominent terrace features such as Maçon Ridge (early Wisconsin Stage, c. 70,000 ybp) dating to much earlier geologic times (Figure 15.2). Crowley's Ridge, a prominent inclusion in the LMAV, is a significantly older upland remnant that is thought to have divided earlier valleys of the Mississippi and Ohio Rivers (Saucier 1994).

During the last 10,000 years, fluvial processes in the LMAV created geomorphologic features that are recognized today in the Holocene deposits of the floodplain. Characteristic features in former meander belts of the LMAV include ridge and swale topography, as well as abandoned channels or oxbow lakes that exhibit a range of alluviation (Saucier 1984). Alluvium from as far away as the Rocky Mountains, the northern Appalachian Mountains, and the upper Midwestern U.S. provides parent material for soil in the LMAV (Stanturf and Schoenholtz 1998). Fluvial processes of the river guide the distribution of these parent materials as it meanders through or inundates the floodplain. Due to the dynamics of fluvial processes, textures of surface soil horizons range from coarse sands to fine clays. Coarse soil particles (sands) are generally deposited near the channel, medium-textured particles (very fine sand and silt) are deposited away from the channel, and fine-textured soil particles (clays) are deposited in backwater areas v stream energy is lowest (Hodges 1997; Stanturf and Schoenholtz 1998). The activ these alluvial soils ranges from alkaline to acid, with relatively young soils exhibitin highest pH. Vertisols, Inceptisols, Entisols, and Alfisols are among the most prevaler orders developing from the alluvial substrates in the LMAV.

The importance of fluvial processes of the Mississippi River to the landscape LMAV was tempered by extensive anthropogenic modification during the 20th ce Engineering projects designed to maintain navigability of the Mississippi River a tributaries, protect populated areas from flooding, and secure land for agriculture duction altered the natural hydrologic regime and reduced the connectivity c Mississippi River to its floodplain (Smith and Winkley 1996). Much of the alluvial no longer functions as an active floodplain since the river is largely contained with artificial levee network. Documented alterations to the hydrologic regime and f processes include an increase in the water surface slope and stream power of the channel, reduced erosion and accretion adjacent to the main channel, alteration to stage fluctuations, and a reduction in the magnitude and duration of high- and low events (Biedenharn et al. 2000; Franklin et al. 2003). These and other engineered moc tions to the channel and floodplain impact critical processes, such as lateral channel n tion, flood pulses, and point bar and cutoff formation, which drive biogeochemical c in low-gradient alluvial floodplain ecosystems. Ecological implications of these engi ing activities radiate from modification of the natural disturbance regime of the rive are potentially manifest throughout the LMAV ecosystem.

15.3 The Forest

Bottomland hardwood forest types have predominated throughout the LMAV since a 5000 ybp up through the present (Delcourt et al. 1980; King and Allen 1977). The r rise in dominance of deciduous tree species in the LMAV followed the end of a 3500 dry period (the Hypsithermal Period), during which grassland and marsh species the predominant flora (King 1981; King and Allen 1977). By examining documentati early naturalists and field notes of surveyors working in the LMAV, some authors attempted to reconstruct the structure of pre-European settlement bottomland hardv forests (Foti 2001; Ouchley et al. 2000). However, problems with note interpretation, ple methods, and species taxonomy limit the strength of these descriptions. Tanner (published perhaps the most cited description of an ancient bottomland hardwood f of the LMAV. His work was based on a vegetation sample collected five decades pri the publication of his findings. Of the more than 60 tree species endemic to bottom hardwood forests of the LMAV (Little 1971; Putnam et al. 1960), dominant species inc sweetgum (*Liquidambar styraciflua* L.), green ash (*Fraxinus pennsylvanica* Marsh.), bal press (*Taxodium distichum* [L.] L.C. Rich.), sugarberry (*Celtis laevigata* Willd.), maples (spp.), American sycamore (*Platanus occidentalis* L.), water tupelo (*Nyssa aquatica* L.), ern cottonwood (*Populus deltoides* Bartr. ex Marsh.), black willow (*Salix nigra* Marsh.), (*Ulmus* spp.), hickories (*Carya* spp.), and at least nine species of oak (*Quercus* s (Putnam et al. 1960). In addition to a highly diverse composition of overstory species, tomland hardwood forests are characteristically rich in woody vines and shrubs, anc understory may feature large monocots such as switchcane (*Arundinaria gigantea* [Wa Muhl.) and palmetto (*Sabal minor* [Jacquin] Persoon). The composition and density of story and understory layers, however, are generally determined by hydrologic regi with the best-drained, less frequently flooded sites exhibiting the rankest vegetation.

Many tree species of bottomland hardwood forests are segregated in associations are distinct to particular floodplain site types (Putnam 1951; Putnam and Bull 1932; Put et al. 1960; Shelford 1954; Tanner 1986) (Figure 15.3). This stratification results from spe

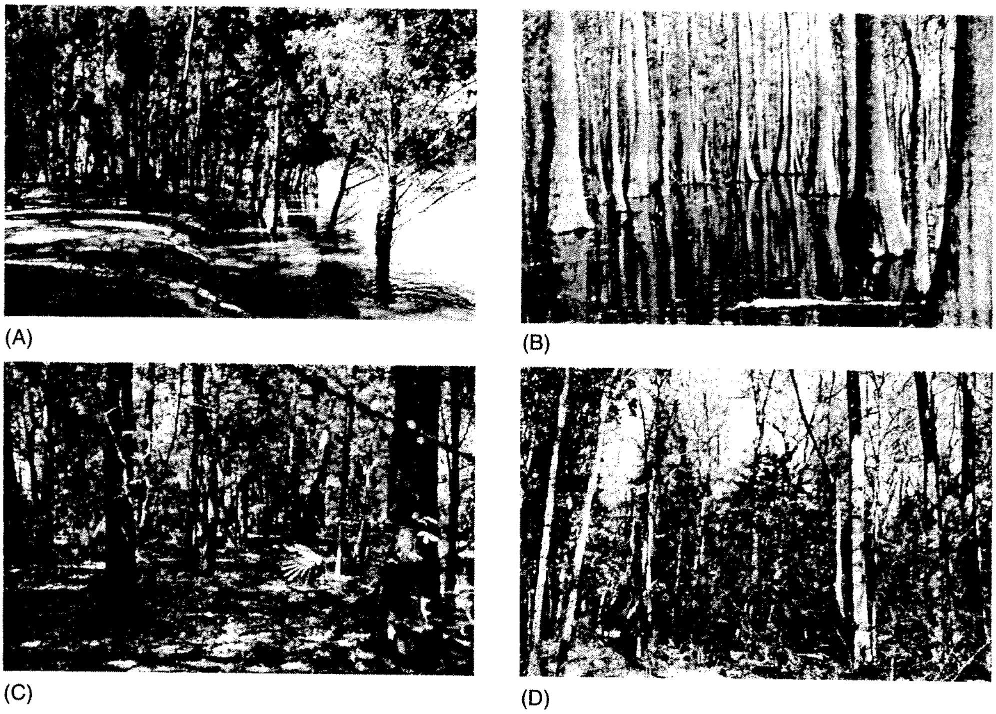

Figure 15.3 Examples of species–site associations that can be found in bottomland hardwood forests of the LMAV: (A) black willow growing on newly accreted land on a bar adjacent to the river channel; (B) baldcypress and water tupelo growing in a swamp; (C) green ash, American elm, sugarberry, and Nuttall oak growing on a low flat; and (D) water oak and sweetgum growing on a ridge.

physiology interacting with the edaphic and hydrologic conditions inherent to each site type. As a result, the abundance of a particular species in a given forest is determined mainly by the availability of the particular site or sites on which it thrives, and the abundance and distribution on the floodplain of these sites are a function of fluvial processes of the river.

The work of Tanner (1986), Putnam and Bull (1932), Putnam (1951), and Putnam et al. (1960) provides an insight into species associations and distribution in natural bottomland hardwood forests, but they fail to fully illustrate the complexity of bottomland hardwood forest structure across the LMAV landscape prior to European settlement, particularly in estimating the extent of anthropogenic disturbance. Hamel and Buckner (1998) recognized that cultural activities of Native Americans impacted the structure and composition of the early forests, and argued that most historical descriptions were based on observing forests that developed after the decline of extensive Native American cultural activities due to population crashes as a result of introduced disease. The earliest evidence of humans in the LMAV dates back to nomadic hunters of the late Pleistocene (12,000 – 11,000 ybp) (Brain 1971). However, the period 9,000 – 8,500 ybp marked the expansion of grasslands during the Hypsithermal, and the apparent influx of a more localized bison-hunting, plains Indian culture into the LMAV.[1] A shift from grassland vegetation to forest, fostered by climate change subsequent to the Hypsithermal, accompanied more sedentary occupation of the LMAV by Native Americans. Archeological evidence indicates that apparently sedentary human societies were established in the LMAV prior to 5,000 ybp (Connaway 1977; Smith 1986). One of the most studied cultures, the extensive Poverty Point Culture,

[1] Presented in 1996 by S. O. Brookes and M H. Reams at the 61st Annual Meeting of the Society for American Archaeology, New Orleans, LA.

was the epicenter of economy and technology throughout the LMAV during the period 3,700 to 3,300 ybp (Gibson 1999). This culture comprised several societies that inhabited numerous permanent villages ranging in size from less than 1 ha to more than 40 ha, all linked by the Mississippi River and its tributaries (Gibson 1999). One might surmise that a culture as extensive as the Poverty Point Culture would have cleared extensive areas of the LMAV to sustain its societies with agriculture, but it is believed that societies based on agriculture did not inhabit the LMAV until more recent times (c. 900 ybp) (Fritz and Kidder 1993). Nevertheless, the vast network of these early villages undoubtedly had a significant influence on the structure of bottomland hardwood forests in the LMAV. Science has yet to reveal the actual extent and distribution of clearing, burning, and cultivation by prehistoric man in the LMAV. It appears that Native American disturbance to the forests of the LMAV rose dramatically and apparently peaked in the period between 3,200 and 1,350 ybp (Galloway 1994). Thus, the existing bottomland forests of the LMAV have apparently always received anthropogenic disturbance.

Land-use practices that removed forest cover accelerated in the LMAV with the onset of European settlement in the 1700s. The settlers found very fertile soils that could be cleared and drained for growing agricultural crops, particularly cotton (*Gossypium hirsutum* L.). Waves of settlement and the demand for farmland in this region were such that by the early 1900s only about half of the estimated original forest remained (MacDonald et al. 1979; Stanturf et al. 2000). Additional deforestation throughout the region was facilitated in the early 1900s by the expansion of rail transportation through the region and by the Flood Control Act of 1928, federal legislation that authorized construction of the mainline levee system (Kelley 1963; MacDonald et al. 1979). This 2500 km system, which supplanted earlier local and state attempts at levee construction and maintenance, straddles the river channel and prevents overland flooding of the Mississippi River onto much of its original floodplain. Deforestation continued throughout the 20th century as the levee system was constructed and clearing peaked in the 1960s and 1970s as the global market demand for soybean (*Glycine max* [L.] Merrill) escalated (MacDonald et al. 1979; Sternitzke 1976).

Drainage and land clearing, primarily for agricultural production, has reduced forest cover in the region to about 26% of the original extent (Figure 15.4). Settlement and deforestation began on the highest and driest sites, and progressed towards lower and wetter sites (Kelley 1963). Indeed, the well-drained riverfront soils were particularly favored for cotton production because of their arable qualities and proximity to water transportation (Winters et al. 1938). As with land impacted by cultural activities of Native Americans, land deforested for agriculture by European settlers sometimes reverted back to forest cover after abandonment for crop production (Hudson 1979). For example, significant areas of abandoned farmland reverted to bottomland forests in the northeastern Louisiana portion of the LMAV during the Civil War (1861–1865) and the Great Depression of the 1930s (Winters et al. 1938). The extent of land-use cycling over time in the LMAV has not been critically assessed. Yet, an example of the magnitude can be found in Winters et al. (1938), who during 1933–1934 documented that 6.5% of agricultural land in the northeastern Louisiana portion of the LMAV was either abandoned or idle.

Of the estimated 2.6 million ha of bottomland forest existing in the LMAV today, the largest contiguous tracts remain primarily where land is not protected from flooding, and most of the current bottomland forests exist on land too wet to sustain profitable agricultural production. Examples of large forested tracts remaining in the LMAV include the Atchafalaya Basin, Delta National Forest, Tensas National Wildlife Refuge, and White River National Wildlife Refuge. The Atchafalaya Basin (c. 240,900 ha) in south Louisiana contains the greatest amount of forested land remaining in the LMAV. The basin is largely privately owned, but portions are maintained by the U.S. Army Corps of Engineers as floodways to divert water from the main channel of the Mississippi River when it

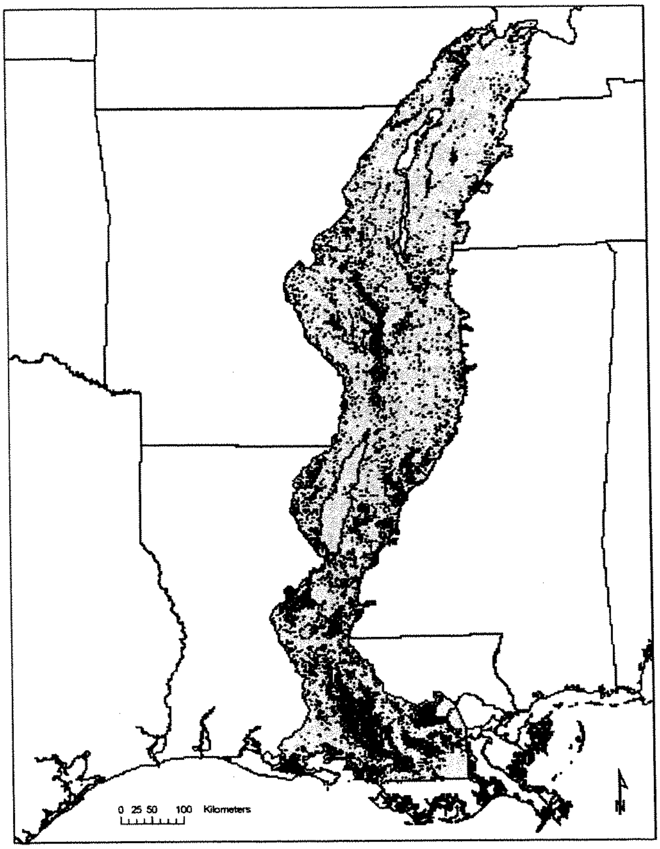

Figure 15.4 Status of deforestation and forest fragmentation in the LMAV.

approaches flood stage. The Delta National Forest (c. 25,000 ha), Tensas National Wildlife Refuge (c. 22,000 ha), and White River National Wildlife Refuge (c. 65,000 ha) represent the largest public holdings of bottomland hardwood forests in the LMAV.

Although deforestation in the LMAV has nearly halted and forest restoration predominates current land-use changes, several factors continue to contribute to degradation of functions and values associated with the remaining bottomland hardwood forests. Alterations to hydrologic regimes, deposition of agricultural runoff, invasion by exotic plant species, indiscriminate timber harvesting, and forest fragmentation are some of the factors contributing to continuing degradation of existing forests (Kellison et al. 1998; Rudis 1995). Afforestation of deforested land in the LMAV not only promises to restore forest functions and values directly but will also indirectly reduce the severity of degradation of existing forest tracts.

15.4 *Current land ownership and use in the LMAV*

A significant majority of the 10 million ha land base in the LMAV is under private ownership, with federal, state, or local governments retaining ownership of a much smaller percentage of the area. Major land-use categories in the LMAV include agriculture (> 65%), forests (26%), open water (4%), municipalities (2%), and aquaculture (1%). Cotton, corn (*Zea mays* L.), soybeans, rice (*Oryza sativa* L.), sorghum (*Sorghum vulgare* Persoon), and wheat (*Triticum aestivum* L.) are the primary agricultural crops raised in the LMAV. Of the forestland in the LMAV, 77% is privately owned, leaving 23% under public ownership.

Metropolitan areas in or adjacent to the LMAV include New Orleans, LA (population 1,305,479), Baton Rouge, LA (population 578,946), Lafayette, LA (population 377,238), Monroe, LA (population 146,627), Little Rock, AR (population 559,074), Pine Bluff, AR (population 80,785), and Memphis, TN (population 1,105,058). Additionally, a substantial population exists in rural areas and smaller towns and cities established throughout and on the fringes of the LMAV. A range of these population centers includes Cairo, IL (population 4,846), Natchez, MS (population 18,732), Vicksburg, MS (population 26,407), and Greenville, MS (population 46,000) (Figure 15.2). The proximity of metropolitan areas and the network of developed urban and rural communities within the LMAV have created a significant demand on forest and aquatic resources of the region. Fishing and hunting are primary forms of recreation provided on public property, and private landowners can readily draw a premium by leasing hunting and angling rights. Because of the high demand from urban residents, management of bottomland hardwood forests for quality wildlife and fish habitat often supersedes management for other objectives such as timber production.

15.5 Restoration policy, goals, and objectives

Beginning in the late 1960s, forest restoration efforts instituted on federal or state property were aimed to reestablish forest cover for wildlife habitat (Haynes and Moore 1988; Savage et al. 1989). The primary objective for most of these early plantations was to provide a hard mast, primarily oak, component on the site, because acorns are favored in the diet of many wildlife species found in bottomlands, and the seeds are not readily dispersed (Allen 1997; Newling 1990). Goals achieved by these initial plantings usually did not extend beyond the boundaries of public property. As the early plantations aged, and forest restoration gained political support, a greater array of restoration objectives and goals emerged from a growing awareness of the unique functions and values of bottomland hardwood forests of the LMAV. Current objectives are linked to the particular missions of the conservation agencies and private organizations implementing forest restoration programs, and established goals often encompass issues relevant to the entire LMAV or beyond.

Several key federal government actions during the 1980s led to the current policy in the LMAV emphasizing conservation of existing forested wetlands and facilitating forest restoration on private land (Haynes and Moore 1988). Included in this legislation was Section 906 of the Water Resources Development Act of 1986, which required mitigation of bottomland hardwood forest impacted by Federal water projects (Haynes and Moore 1988). However, widespread restoration of bottomland hardwood forests on private land began with the approval of federal legislation, including the Food Security Act of 1985 and the Food, Agriculture, Conservation, and Trade Act of 1990 (Loesch et al. 1995). These and subsequent "Farm Bills" have encouraged afforestation of agricultural land through the creation and funding of the Conservation Reserve Program and particularly the Wetland Reserve Program (Kennedy 1990; Loesch et al. 1995).

Numerous public agencies currently play key roles in promoting, facilitating, and implementing afforestation in the LMAV. The Wetland Reserve Program is administered through the U.S. Department of Agriculture, Natural Resource Conservation Service, with the objective of restoring and protecting farmed wetlands, and a primary goal of "achieving the greatest wetland functions and values, along with optimum wildlife habitat, on every acre enrolled in the program." Likewise, the Conservation Reserve Program, administered through the U.S. Department of Agriculture, Farm Service Agency, targets protecting "the Nation's long-term capability to produce food and fiber; to reduce soil erosion and sedimentation, improve water quality, and create a better habitat for wildlife." The U.S. Fish and Wildlife Service is another federal agency pivotal in forest restoration throughout the LMAV. Their primary mission is to provide for and maintain habitat for migratory birds. In addition to work conducted on the National Wildlife Refuge System, the Service promotes forest restoration for wildlife habitat by facilitating structured partnerships, including the Lower Mississippi Valley Joint Venture and the Southeast Regional Working Group of Partners in Flight (Loesch et al. 1995). The Southeast Regional Working Group of Partners in Flight, for example, has established a strategy to restore forested patches that would provide critical habitat for forest-breeding birds (Twedt et al. 1999). The U.S. Army Corps of Engineers has secured and reestablished forest cover on extensive tracts of agricultural land in the LMAV to mitigate impacts to bottomland hardwood forests sustained through various development projects, particularly flood control. Additionally, the U.S. Forest Service has begun promoting forest restoration in the LMAV by organizing a partnership program designed to integrate federal, state, and nongovernmental organizations as partners in afforestation (Young et al. 2002). The goal of this partnership program, which was organized in 2000, is to restore forest cover to 800,000 ha within the LMAV over a 20-year period. State agencies continue to play a fundamental role in forest restoration efforts throughout the LMAV. State conservation agencies in all states of the LMAV promote forest restoration on public land, and most are active members of conservation partnerships.

In addition to the forest restoration activities of public entities, private interests are proving essential in increasing forest restoration opportunities and management alternatives for landowners. Landowner assistance programs offered by forest industry in the LMAV often provide technical assistance with afforestation efforts, and provide landowners an opportunity to draw revenue from investments in forest plantation establishment. Private interest in forest restoration promises to increase in the LMAV as a market for carbon sequestration develops in the U.S. Several utility cooperatives, speculating that a market for carbon offsets will soon develop, have already invested in afforestation.

15.6 Previous restoration and extent of current restoration needs

Documented forest restoration efforts in the LMAV date back to the 1940s with the establishment of experimental hardwood plantations to "reclaim abandoned submarginal agricultural land" (Maisenhelder and McKnight 1962). USDA Forest Service researchers working at the Stoneville Experimental Forest, Washington County, Mississippi, initiated these early experiments on forest restoration techniques. Early plantations, such as those established on the Stoneville Experimental Forest, are probably scattered through the LMAV, but they were established infrequently, poorly documented, and were of minor significance in relation to the extent of deforestation occurring at the same time.

The earliest sustained forest restoration effort in the LMAV probably dates back to the late 1960s, with the establishment of oak plantations on former agricultural fields. The majority of this effort focused on public property recently acquired from the private sector by federal and state natural resource management agencies, such as the U.S. Fish and Wildlife Service and the Louisiana Department of Game and Fish. The U.S. Fish and Wildlife Service, for example, upon acquiring agricultural land in their National Refuge System, began a concerted effort to restore forest cover in order to improve wildlife habitat (Haynes and Moore 1988; Allen 1990). This afforestation effort continued primarily on public holdings until the 1990s, when governmental incentives were instituted to encourage private landowners to remove land from agricultural production (Figure 15.5). Over the past three decades, forest restoration in the tri-state LMAV portions of Louisiana, Mississippi, and Arkansas has increased dramatically, leading to a significant removal of land from agricultural production by establishing hardwood plantations. Current esti-

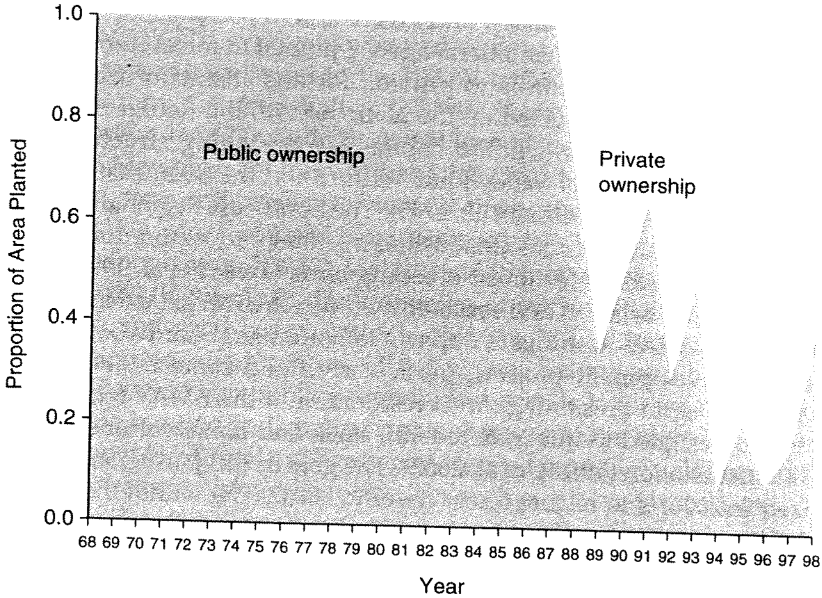

Figure 15.5 Relative proportion of afforestation supported by State or Federal appropriated dollars practiced on public vs. private land in the Louisiana, Mississippi, and Arkansas portions of the (LMAV) (unpublished data filed by S.H. Schoenholtz at the Department of Forestry, Mississippi State University, Mississippi State, MS, U.S.A.).

mates of afforested land in the LMAV approach 194,000 ha. With this increase, the effort has shifted from a predominance of afforestation on public land to predominantly private land (Schoenholtz et al. 2001) (Figure 15.5). In the tri-state area of Louisiana, Mississippi, and Arkansas, an estimated 75% of the acreage converted to forest cover as of 1999 is under private ownership (unpublished data filed by S.H. Schoenholtz at the Department of Forestry, Mississippi State University, Mississippi State, MS, U.S.A.).

Since federal conservation programs that provide the impetus for afforestation target economically marginal farmland, it is the wettest soils that are generally removed from agricultural production. If a proposed tract of land meets qualification requirements for a particular conservation program, participation is based on ranking of the land according to an environmental benefits index (see www.fsa.usda.gov for Conservation Reserve Program guidelines). Environmental benefit indices typically generate a ranking by factoring wildlife habitat benefits, water quality benefits, air quality benefits, and other conservation priorities associated with the land and proposed restoration practice.

In addition to the almost 200,000 ha already removed from agricultural production, much additional land appears available to be restored to forest cover. In 2002, Louisiana, Mississippi, and Arkansas had 95,000 ha that qualified for easements under the Wetland Reserve Program and were awaiting funding. Provisions of future Farm Bills will determine to a large degree the amount of land that will be enrolled in the future. Additionally, the development of a market for carbon sequestration could potentially influence future land-use trends involving forest cover in the LMAV.

15.7 Restoration techniques

Guidelines for restoring bottomland hardwood forests have been published by Allen and Kennedy (1989) and Allen et al. (2001), providing basic information to landowners interested in establishing forest cover on former agricultural land. These guides are useful starting points to gain a knowledge of recommended afforestation practices, commonly used materials, and general costs. Additional information on current incentive programs and enrollment procedures is provided in local field offices of federal and state conservation agencies, particularly field offices of the Natural Resource Conservation Service.

The general approach to restoring forest cover on former agricultural land in the LMAV has been extensive rather than intensive application of plantation establishment practices. This extensive approach of afforesting to most areas at the least cost has been fostered by the agencies that administer the governmental incentive programs that target the removal of land from agricultural production. The relatively large size of enrolled easements also contributes to this approach.

Site preparation practices employed for afforestation vary by conservation organization, but are generally minimal. If plantations are to be established on land immediately removed from agricultural production, site preparation is generally not practiced (Gardiner et al. 2002). One exception is that subsoil plowing is sometimes applied to break up plow pans and facilitate seedling planting. Herbicide applications for weed control and fertilizer applications to improve the nutrient status of soils are rarely practiced. Where fields have been removed from agricultural production for several years prior to plantation establishment, site preparation typically involves mowing, primarily as a method of facilitating the planting job. Disking is also used to break up heavy herbaceous vegetation, and provides the additional benefit of reducing rodent habitat (Gardiner et al. 2002).

Early plantations established in the LMAV were primarily bottomland oak plantings. The various oak species were deployed because most of the early research on plantation establishment in the LMAV was conducted on oak species, and oaks are favored for their timber and wildlife habitat value. Furthermore, it was believed that if heavy-seeded oaks were established, light-seeded species would naturally invade the site (Allen 1990). This has not proven true where mature stands of light-seeded species are not immediately adjacent to the restoration site (Stanturf et al. 2001). In current practice, species assignments are based on soil types, with mixtures of 2 to 3 overstory species established on each soil type. Thus, combinations of 8 to 10 species may be planted in a single afforestation project that encompasses several different soil types. Although current afforestation practices encourage establishment of a greater diversity of species than past practices, species mixtures are not established based on compatibility (Gardiner et al. 2002). Additionally, little effort has been directed toward developing reliable techniques for establishing the midstory and understory species endemic to bottomland hardwood forests.

Bottomland hardwood plantations can be established with various types of stock depending on the target species. Cuttings can be used for vegetative reproduction of fast-growing species such as black willow and eastern cottonwood (Stanturf et al. 1998). Direct seeding provides a cost-effective method of establishing hard-mast or heavy-seeded species such as the oaks and hickories (Bullard et al. 1992; Lockhart et al. 2003; Stanturf et al. 1998), while seedlings, bareroot or container, can be deployed to establish any bottomland hardwood species. The primary stock type used in afforestation in the LMAV is a 1-0 bareroot seedling. King and Keeland (1999) reported that over 60% of the plantations established before 1997 were established with bareroot seedlings, and this percentage has continued to increase as conservation agencies have greatly reduced the use of direct seeding (Schoenholtz et al. 2001). Bareroot seedlings are typically grown from unimproved seed, and the seedlings are produced and sold by state and private nurseries. Most agencies place a minimum standard on the size of bareroot seedlings suitable for outplanting; seedlings generally have to be greater than 45 cm tall with a root-collar diameter of 10 mm. These seedling quality standards are primarily based on ease of handling and are not reflective of an optimal seedling size for survival or growth (McKnight and Johnson 1975).

On the majority of afforestation sites in the LMAV, planting density is typically se 746 seedlings per ha. The selection of this planting density is quite arbitrary, but i expected to produce at least 309 surviving seedlings per ha at year three. Although ha site factors such as excessive flooding, herbivory, and heavy competition can reduce s vival, planting density is generally not altered to account for potential risks of these f tors. Seedlings can be hand or machine planted equally as successful so long as conscientious planting crew is employed (Gardiner et al. 2002; Schoenholtz et al. 20 (Figure 15.6), but machine planting is generally limited to relatively drier soils that c sustain machine traffic. The density of sown seed is typically much greater than the de sity of planted seedlings and generally targets about 2,470 to 3,700 seed per ha. Dir seeding is generally accomplished with modified agricultural seeders.

Although postplanting cultural practices have demonstrated increased survival a growth of hardwood seedlings, current forest restoration activities generally do not inc porate such practices as weed control, seedling protection from herbivory, and fertilizati (Gardiner et al. 2002). Silvicultural practices that increase seedling growth could redu mortality risks on flood-prone bottomland sites and sites with high rodent populations

With the strong emphasis of forest restoration in the LMAV, alternative afforestati practices have been developed that offer landowners the ability to meet several objectiv not optimized by conventional afforestation practices. For example, it has been demo strated that the establishment of a fast-growing pioneer species can be interplanted wi slower-growing hardwoods such as oaks (Gardiner et al. 2001). This interplanting syste enables the manager to establish a plantation that provides a quick economic return recoup the costs of afforestation (Stanturf and Portwood 1999), provides a rapid establis ment of vertical structure that advances the development of forest bird habitat (Ham 2003; Twedt and Portwood 1997), and may be beneficial in rapid restoration of soil qua ity and other ecosystem processes. Another innovative approach can be found in th northern reaches of the LMAV. Some practitioners are deploying "Root Productio

Figure 15.6 Hand planting bareroot hardwood seedlings on a former agricultural field in the LMAV.

Method" (RPM) oak seedlings; these are very large container seedlings that have undergone a root development process that speeds maturation and catalyzes the early production of hard mast on the restoration site. The current emphasis on forest restoration in the LMAV will certainly spawn the development of other viable techniques and practices.

15.8 Costs of restoration techniques and expected benefits

Costs of forest restoration practices in the LMAV are commensurate with the level of intensity of the assigned afforestation practices. Low-intensity plantation establishment practices are generally applied on an extensive basis, while high-intensity plantation establishment practices are applied less extensively (Stanturf et al. 2000). The vast majority of afforestation projects implemented in the LMAV, those established through the Conservation Reserve Program and the Wetland Reserve Program, would be considered low intensity, and as such have received minimal input per ha in terms of silvicultural practices and financial investment. Drawbacks associated with relatively low-input, extensively applied restoration programs include a relatively low confidence level of obtaining desired benefits, a potentially longer time needed to obtain desired benefits, or both. Conversely, establishment of intensively managed plantations usually increases the confidence of meeting desired objectives, but requires significant investment in time and money. It is incumbent upon the landowner to define restoration goals, management objectives, and expected outputs for the restoration project so that an optimal approach with minimal risk to obtaining the objectives can be developed.

Approximate costs of various silvicultural practices that may be performed on afforestation sites in the LMAV are listed in Table 15.1. Prices would typically vary for a particular practice based on the size of the job, experience of the contractor and crew, soil types, and condition of the afforestation site. Research has not provided basic cost–benefit

Table 15.1 Approximate Costs of Silvicultural Practices and Materials Used for Afforestation Purposes on Former Agricultural Land in the LMAV

Practice	Cost
Site Preparation	
Mowing	US$27 – 35 per ha
Disking	US$30 – 45 per ha
Subsoil plowing	US$24 – 32 per ha
Herbicide application	US$30 – 37 per ha
Burning	US$12 – 15 per ha
Plant Material[a]	
Seed	US$2 – 5 per kg
Seedlings	US$185 – 210 per thousand
Cuttings	US$200 per thousand
Establishment	
Direct seeding	US$85 – 100 per ha
Planting	US$85 – 110 per ha
Other Practices	
Fertilization[b]	US$37 – 40 per ha
Postplanting herbicide application	US$27 – 37 per ha
Postplanting disking	US$30 – 45 per ha

[a] Seed prices are based on general collections of uncertified oak seed; acorns are generally seeded at 2,470 to 3,700 per ha with 45 to 230 acorns per kg depending on species. Seedling prices are for 1-0 bareroot seedlings from unimproved stock. Cuttings are 45 cm long from superior clones.

[b] Fertilization cost is for a treatment of 90 kg per ha nitrogen injected 45 to 50 cm deep into the soil.

Table 15.2 Wetland Reserve Program Agreement Options and Benefits Available to Landowners in the Mississippi Portion of the (LMAV), 2003

Option	Landowner Obligation[a] (%)	Subsidy[b] (%)
10-year agreement	25	None
30-year agreement	25	75
Perpetual easement	0	100

[a] Landowner obligation is the percentage of the costs of approved afforestation practices that are paid by the landowner. Approved afforestation practices generally do not exceed a total cost of US$300 to 345 per ha.

[b] Subsidy to the landowner is based on the appraised value of the property and is not to exceed US$2,223 per ha.

analyses for these silvicultural practices, but practices that increase seedling vigor and growth may be beneficial in reducing the risk of plantation failure and the need to replant the site. A few researchers have investigated the economics of hardwood plantation establishment on former agricultural fields of the LMAV. Forest restoration on former agricultural land is generally not a viable economic decision, unless the landowner receives cost subsidies provided by federal or state conservation programs (Amacher et al. 1998; Stanturf and Portwood 1999). Subsidies are particularly important economically if the restoration site is predominated by soil of relatively low productivity (Amacher et al. 1998).

A majority of approved afforestation expenses may be defrayed through subsidies provided by governmental conservation programs. The Wetland Reserve Program, for example, provides three options for subsidizing landowners willing to convert agricultural land to forest cover (Table 15.2). Contract options provided through the Wetland Reserve Program range from 10-year agreements to perpetual easements, and reimburse the landowner for 75% to 100% of the costs of approved practices. Additionally, landowners who engage in relatively long-term agreements benefit by receiving cash subsidies based on agreement length and the appraised value of the enrolled land (Table 15.2).

Landowners throughout the LMAV have readily enrolled land in government conservation programs that remove land from agriculture production and establish forest cover. In the tri-state region of Louisiana, Mississippi, and Arkansas, nearly 900 easement contracts were established between 1991 and 2001 through the Wetland Reserve Program. Through this voluntary enrollment, forest cover was established on more than 139,000 ha of former agricultural fields, at a cost of over $230 million.

15.9 *Research, management, and policy needs*

There is no lack of research, management, or policy needs with respect to restoration of bottomland hardwood forests in the LMAV. Questions abound around topics such as the characterization of suitable planting stocks, sources of appropriate genetic material, development rates of restored ecological functions, development of alternative practices to achieve particular restoration objectives, the appropriate distribution and size of restored forests across the landscape, and proper methods for assessing restoration success. However, economic constraints are probably the primary limitations on the rate, extent, and intensity of current restoration practices in the LMAV. The development of ecologically viable restoration systems that are also economically sustainable would have the potential to shift land-use practices toward a greater balance of forest cover in the LMAV. The bottomland hardwood forest of the LMAV has continued to function and provide valuable resources from the time it migrated into the physiographic region with early man up through the 20th century. The demonstrated resilience to disturbance of this ecosystem over the centuries offers a promise that existing forest restoration practices will provide sustainability to the unique flora and fauna of this magnificent environment into the next century.

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