SYNERGY OF AGROFORESTRY AND BOTTOMLAND HARDWOOD AFFORESTATION

Daniel J. Twedt[1] and Jeff Portwood[2]

[1]USGS Patuxent Wildlife Research Center
Vicksburg, MS

[2]Crown Vantage, Vicksburg, MS

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ABSTRACT

Aforestation of bottomland hardwood forests has historically emphasized planting heavy-seeded tree species such as oak (Quercus spp.) and pecan (Carya illinoensis) with little or no silvicultural management during stand development. Slow growth of these tree species, herbivory, competing vegetation, and limited seed dispersal, often result in restored sites that are slow to develop vertical vegetation structure and have limited tree diversity. Where soils and hydrology permit, agroforestry can provide transitional management that mitigates these historical limitations on converting cropland to forests. Planting short-rotation woody crops and intercropping using wide alleyways are two agroforestry practices that are well suited for transitional management. Weed control associated with agroforestry systems benefits planted trees by reducing competition. The resultant decrease in herbaceous cover suppresses small mammal populations and associated herbivory of trees and seeds. As a result, rapid vertical growth is possible that can "train" under-planted, slower-growing, species and provide favorable environmental conditions for naturally invading trees. Finally, annual cropping of alleyways or rotational pulpwood harvest of woody crops provides income more rapidly than reliance on future revenue from traditional silviculture. Because of increased forest diversity, enhanced growth and development, and improved economic returns, we believe that using agroforestry as a transitional management strategy during afforestation provides greater benefits to landowners and to the environment than does traditional bottomland hardwood afforestation.

Background

Throughout the southeastern United States, alterations in riverine hydrology (e.g., Galloway, 1980), have led to marked decreases in the area of forested wetlands (Turner et al., 1981; Noss et al., 1995). Indeed, with increased protection from flooding, over three-quarters of the bottomland hardwood forests that historically occurred within the vast floodplain of the Mississippi River have been lost (Knutson and Klaas, 1998; Twedt and Loesch, 1999). Most of this land was converted to agricultural production, but continued intermittent flooding and unfavorable agricultural prices often provide for marginal profitability. More recently, environmental concerns associated with the loss of forested wetlands have resulted in conservation initiatives that have established habitat objectives that seek to reverse this loss of forested wetlands (e.g., Lower Mississippi Valley Joint Venture Management Board, 1990; Creasman et al., 1992; Mueller et al., 1999). The Partners in Flight conservation plan (Mueller et al., 1999) recommended establishment of circa 100 forest patches $\geq$ 4,000 ha to support forest-breeding songbirds. Aforestation of land currently in agricultural production is the only avenue through which such formidable habitat ofjectives can be achieved. Both economic distress and increased awareness of the ecological and societal benefits afforded by forested wetlands have spurred afforestation of bottomland hardwood forests. Indeed, > 180,000 ha of aforestation are anticipated within the Mississippi Alluvial Valley by 2005 (Stanturf et al., 1998).

The ecology of bottomland hardwood forests reveals succinct successional progressions influenced by hydrology (Hodges, 1997) and high species diversity (Allen, 1997). Despite temporal and taxonomic mosaics that permeate bottomland hardwood forests, historically only a few heavy-seeded, oak species (*Quercus* spp.), and pecan (*Carya* illinoensis) have been planted on nearly 80% of all forestation in the Mississippi Alluvial Valley (King and Keeland, 1999). Either seedlings or acorns are planted and typically no weed control is provided. Planting predominantly oaks in bottomland restorations is intended to provide a "jump-start" for succession toward seasonally wet oak-hardwood forests (Kennedy and Nowacki, 1997) that have oaks as dominant canopy species. This species selection has been justified because of their high value for subsequent timber harvest, their potential mast production for wildlife food, as well as the assumption that light-seeded species would colonize sites without androchory. Lack of week suppression or other intermediate silvicultural management is attributed to limited financial and personnel resources. Under this afforestation scenario, given sufficient time, the above three suppositions will likely be fulfilled. But in addition to daunted temporal limitations, distance also hinders bottomland hardwood afforestation. Time and distance present impediments such that desired objectives may not be achieved within the lifetime of those undertaking the afforestation.

Limitations Imposed by Historical Afforestation Methods

When distance from existing forest is > 100 m, woody species (both light- and heavy-seeded) are insignificant invaders (Allen, 1990; Wilson and Twedt, in press). Thus if specific species are not planted, they may not be part of the maturing forest. This is particularly true in areas of the Mississippi Allivial Valley that are isolated from extant forest and no longer subject to inundation from natural flood events.

Without chemical or mechanical week control, competing herbaceous plants (annual and perennial, grasses, and forbs) dominate afforested sites for up to 10 years (Wilson and Twedt, in press). Many of these 'weedy' species, especially grasses, are allelopathic or competitively inhibit colonization by woody species (Myster and Pickett, 1992). Dense herbaceous cover on afforested sites may also support high rabbit and rodent populations (P. Hamel, U. S. Forest Service, unpubl. data, 1999) that depredate planted seedlings and acorns (Savage et al., 1996) and consume naturally deposited seeds (Meiners and Stiles, 1997; Reader, 1997).

Because of competition with herbaceous plants, long distances to natural seed sources that limits seed dispersal, and depredation of dispersed seeds, light-seeded tree species may be as limited as heavy-seeded species in their ability to colonize afforested sites. Thus, the composition of the maturing forests is often dominated by planted, heavy-seeded, slow-growing species.

Slow initial development of trees planted following historical afforestation methods may be compounded by shade tolerance of planted species. For example, height and diameter development of cherrybark oak - a commonly planted oak species - are reduced when grown in 100% sunlight compared to trees grown in 27% or 53% sunlight (Gardiner and Hodges, 1998). Additionally, development of oaks in full sunlight encourages epicormic branching and decreases their potential for desirable, limb-free, bole development suitable for timber production.

We believe that afforestation using agroforestry practices as a transitional management strategy will provide more rapid and ecologically based forests. This is particularly true when fast-growing, early-successional trees are integrated into the agroforestry system.

Transitional Agroforestry Management for Afforestation

Planting of tree species compatible with on-site edaphic and hydrologic conditions is essential to ensure success of any bottomland hardwood afforestation. However, with species selections that match site conditions, we believe that transitional management using agroforestry is more effective at converting cropland to forests than are historical afforestation practices. Production of short-rotation woody crops, "under-planted" with other forest species, is one agroforestry option that rapidly produces forest conditions. Intercropping (alley cropping) using wide (>12 m) alleyways represents another transitinal agroforestry management option that is particularly suitable for converting large areas of cropland to forest.

Short Rotation Woody Crops

By definition, short-rotation, woody crops are fast-growing trees that quickly achieve substantial vertical development. Typically, these species are very shade intolerant species such as yellow poplar (*Liriodendron tulipifera*) on well-drained sites, cottonwood (*Populus* spp.) on mesic sites, and willows (*Salix* spp.) on moist sites. Characteristically colonizing species, these trees are able to maximally use available sunlight and thereby achieve impressive growth rates. If unmanaged, stands of short-rotation woody crops would likely "break-up" relatively rapidly and because of their shade intolerance, these species would not succeed themselves. For example, when planted on a 3.7 m x 3.7 m spacing only 30% of cottonwoods survived after 20 years (Krinard and Johnson, 1984). However, establishing monocultures of early-successional tree species is rarely the objective of afforestation efforts. Fortunately, in the Mississippi Allivial Valley, yellow poplar, eastern cottonwood (*Populus deltoides*), and black willow (*Salix nigra*) are all preferred or desirable species for timber production (Meadows and Stanturf, 1997).

When short-rotation woody crop are managed for pulpwood, harvest in < 12 years is common. Alternatively short-rotation woody crops can be thinned at an early age for pulpwood while retaining trees at optimal spacing for future sawtimber production. We propose underplanting tree species that are desired in the second generation forest to direct the forest succession. Additionally, selective harvest of short-rotation woody crop species accelerates desired successional changes (Twedt and Portwood, 1997).

Twedt and Portwood (1997) advocated intensive cultivation of short-rotation woody crop for two years at which time the desired second generation forest species would be underplanted within every other row (Figure 1). When short-rotation woody crops reached merchantable size at circa 10 years, partial or complete harvest would be accomplished by felling and skidding from within unplanted rows. Under appropriate conditions, short-rotation woody crop species could be coppiced to provide a second pulpwood harvest.

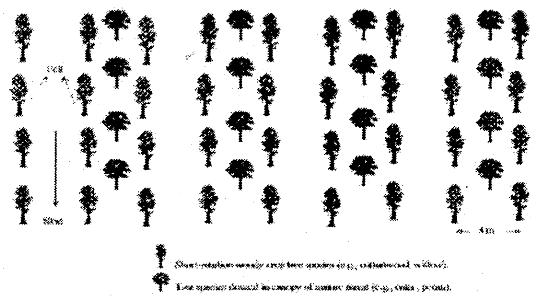

Figure 1. Short-rotation woody crops underplanted with tree species that are desired in the canopy of mature bottomland hardwood forest.

Intercropping (Alleycroppping)

Under intercropping agroforestry, only narrow linear strips (usually single tree rows) are initially afforested with the remaining land retained in agricultural production. Although generally crops are grown between rows of high value trees until either trees are harvested or the crops are shaded out, when the intention is to convert the entire area to forest, we recommend the initial plantings be of fast-growing trees planted in multiple rows (tree belts; Figure 2). When large areas are being converted to forest, initial tree belts should be directed to less productive areas or more frequently flooded areas. Temporarily retaining more productive areas in crop production increases the potential for profitable economic return. Alternatively, tree belts can be located within the landscape to function as travel corridors between existing forest patches.

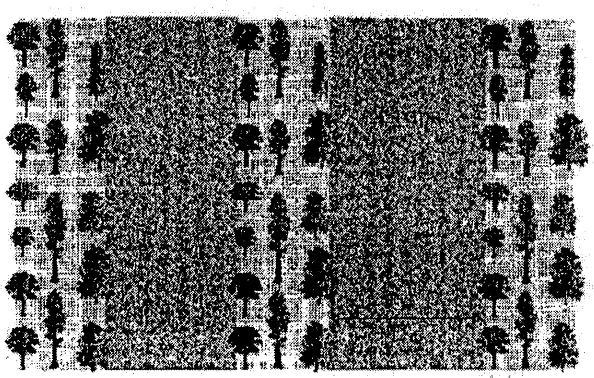

Figure 2. Tree belts used in a transitional intercropping (alley cropping) agroforestry management scheme. Additional cropped area would be planted to trees as original tree plantings develop.

We suggest that initial tree rows (belts) be widely spaced (> 12 m minimum; > 24 m recommended) and that crop rotations and trees be managed to ensure crops receive adequate sunlight. When the initial planting results in broad alleyways, subsequent tree planting can be used to produce multiple narrower alleyways or alleyways can be narrowed through tree plantings that expand the breath of existing tree rows. When alleyways become narrow, crops grown in the alleys may need to be changed from row crop to small grain or forage as trees mature and shade the alley. When planting fast-growing, early successional trees, cropping of narrow alleyways (< 12 m) is probably not practical (J. Portwood, pers. obs.). However, when slow-growing, high-value trees are planted from seeds (nuts), cropping of narrow alleyways (5 - 7 m) may be possible for up to seven years (Oertel, 1997).

Multi-aged forests, highly desirable for wildlife habitat, can be achieved by incrementally afforesting the cultivated alleyways. Alternatively, all alleyways can be afforested simultaneously. Regardless, all alleyways should ultimately be planted to trees. Ideally, these temporally and spatially distinct tree plantings would be of various spjecies that include not only the fast-growing trees planted initially but also slower-growing, nut producing canopy trees and fruit-bearing understory trees and shrubs. Incorporating a diversity of native plants results in afforestation that more closely restores the forests natural functions and increases its attraction to wildlife.

Benefits of Afforestation via Transitional Agroforestry

Under both short-rotation woody crop and intercropping agroforestry systems, planted trees benefit from ongoing weed control. Reduced weedy cover suppresses small mammal populatins and associated herbivory. As a result, rapid vertical growth of planted trees is possible. Vertical forest structure promotes colonization by forest birds (Wilson and Twedt, in press) and provides environmental conditions favorable to invading tree seeds. For the first 10 years after planting, sites reforested with fast-growing early-successional tree species provided four times the "conservation value" to migratory birds asdid sites reforested with slow-growing heavy-seeded tree species (Twedt, unpubl. data). Further, emergent trees within afforested sites promote invasion of the site by woody species that produce soft, fleshy fruits. By serving as perches for fugivorous birds, fecal deposition from atop vertical vegetation enhances the proximate plant species diversity (Robinson and Handel, 1993) and accelerates successional changes within the site (McClanahan and Wolfe, 1993). We believe that increasing within stand biodiversity and development of natural successional sera will enhance the restoration of many of the natural functions of these forests.

The rapid growth of early-successional tree species also provides environmental conditions that are favorable to development of species favored by many restorationists as canopy dominant trees. Providing limited shade can enhance growth of species such as cherryb ark oak (Gardiner and Hodges, 1998). Similarly, current research shows comparable tree growth and survival of Nuttall oaks planted between rows of cottonwood and those grown in the open (E. Gardiner, unpubl. data, 1999). Thus, oaks grown under partial shade have adequate or improved growth and their bole development is improved through "training" provide by nurse trees (Twedt and Portwood, 1997).

Soil condition is beneficially impacted through agroforestry practices. Shade and wind protection provide more stable and favorable soil moisture levels. Root structure and leaf fall contribute to improved soil carbon cycling (S. Schoenholtz, Miss. State Univ., pers. comm., 1999) and the abundance of beneficial invertebrates has been positively associated with agroforestry practices (Hauser et al., 1998).

Perhaps most importantly, afforestation via transitional agroforestry produces annual or short-term financial income. Cropping of alleyways provides annual income from harvested crops or forages. Harvest of short-rotation woody crops for pulpwood or biomass prrovides income more rapidly (circa 10 years) than reliance on traditional silviculture. These annual or short-term economic returns are important to offset the often high cost of establishing trees. Finally, although irrelevant to the ultimate forest restoration, modest economic returns to the landowner actually undertaking the afforestation can be a greater incentive to forest restoration than potentially greater economic returns to the landowner's heirs.

In summary, afforestation via transitional agroforestry results in a more rapid transition to forest conditions, enhances forest biodiversity, restores many natural forest functions, and has favorable economic returns. Therefore, we believe that afforestation using agroforestry as a transitional management strategy is a superior alternative to traditional afforestation practices.

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