Small Clusters of Fast-Growing Trees Enhance Forest Structure on Restored Bottomland Sites

Daniel J. Twedt[1,2]

Abstract

Despite the diversity of trees in bottomland forests, restoration on bottomland sites is often initiated by planting only a few species of slow-growing, hard mast–producing trees. Although successful at establishing trees, these young forests are slow to develop vertical structure, which is a key predictor of forest bird colonization. Furthermore, when natural seed sources are few, restored sites may be depauperate in woody species. To increase richness of woody species, maximum tree height, and total stem density, I supplemented traditional plantings on each of 40 bottomland restoration sites by planting 96 Eastern cottonwood (*Populus deltoides*) and American sycamore (*Platanus occidentalis*) in eight clusters of 12 trees. First-year survival of cottonwood stem cuttings (25%) and sycamore seedlings (47%) was poor, but survival increased when afforded protection from competition with weeds. After five growing seasons, 165 of these 320 supplemental tree clusters had at least one surviving tree. Vegetation surrounding surviving clusters of supplemental trees harbored a greater number of woody species, increased stem density, and greater maximum tree height than was found on paired restoration sites without supplemental trees. These increases were primarily accounted for by the supplemental trees.

Key words: cottonwood, forest restoration, supplemental planting, sycamore, vertical structure.

Introduction

Throughout the world, and specifically within the southeastern United States, forested wetlands have been lost (Noss et al. 1995). Within the Mississippi Alluvial Valley, over 7 million hectares of bottomland hardwood forest were converted to agriculture (Knutson and Klaas 1998; Twedt and Loesch 1999). However, marginal profitability of agriculture on converted forest land, acting in concert with public and private financial incentives targeting wetland restoration, has led to widespread restoration of bottomland forest (Haynes 2004). In the Mississippi Alluvial Valley, approximately 200,000 ha of agricultural land had been planted with hardwood trees through 2003 (Haynes 2004). Stanturf et al. (1998, 2001) estimated an additional 200,000 ha could be planted during the next 10 years. Moreover, the Lower Mississippi Valley Joint Venture, established under the North American Waterfowl Management Plan, has an objective of restoring 800,000 ha of bottomland forest by 2020 (Haynes 2004).

Despite high diversity of tree species in bottomland forests (Allen 1997), plantings on bottomland sites have historically focused on only a few species of slow-growing, hard mast–producing trees. Although Schoenholtz et al. (2001) reported an increase in the number of tree species being planted from 1985 through 1998, oaks (*Quercus* spp.) and pecans (*Carya* spp.) have been planted on nearly 80% of all restorations in the Mississippi Alluvial Valley (King and Keeland 1999). Planting predominantly oaks for bottomland forest restoration was intended to provide a "jump-start" for succession toward seasonally wet, oak–hardwood forests (Kennedy and Nowacki 1997) with oaks as dominant canopy species. This goal has been justified because of the high value associated with oak when harvested for timber, abundant hard mast produced by oaks for wildlife food, and an assumption that light-seeded and soft mast–producing species would readily colonize restored sites.

Success of restoration plantings has differed among sites, but often sites planted with only heavy-seeded species are slow to develop vertical forest structure. Tree height appears positively correlated with colonization of restored forests by silvicolous birds (Twedt et al. 2002; Twedt and Best 2004). Additionally, when restoration sites are far (>200 m) from existing seed sources (i.e., mature trees), natural invasion by woody species may be slow (Allen 1990; Twedt 2004), resulting in forests that are depauperate in woody species. Colonization by woody plants may be particularly restricted in some areas of the Mississippi Alluvial Valley where restoration occurs several kilometers from existing forest. Under these growth and colonization constraints, restoration sites may be dominated by grasses and forbs, and thus, remain inhospitable to forest-dwelling birds for up to 20 years.

Growth of planted trees can be enhanced when competing weeds are controlled or through other types of early-age silvicultural management. However, because of limited

[1] USGS Patuxent Wildlife Research Center, 2524 South Frontage Road, Suite C, Vicksburg, MS 39180, U.S.A.
[2] Address correspondence to D. J. Twedt, email dtwedt@usgs.gov

financial and personnel resources, few restoration sites have weeds controlled nor is early-age or intermediate-age silvicultural management undertaken. Not only do weeds inhibit growth of planted trees, but also they may induce mortality of some species of fast-growing trees (Ezell 1995). Because of their inability to provide weed control, most managers are reluctant to risk increased tree mortality by planting species susceptible to weed competition.

Regardless of which tree species are planted, long-term survival of trees is dependent on their compatibility with edaphic and hydrologic conditions (Patterson and Adams 2003). However, when species selections are appropriate for site conditions, restorations that incorporate fast-growing tree species are more conducive for colonization by silvicolous birds than are similarly aged sites restored using traditional methods (Twedt and Portwood 1997; Twedt et al. 2002; Hamel 2003).

Short-rotation hardwood plantations have been used to achieve diverse forest conditions (Keenan et al. 1997; Lugo 1997) that can be further enhanced by "underplanting" slow-growing forest species (Gardiner et al. 2004). Intercropping or alley cropping (i.e., growing agricultural crops between tree rows) using wide (>12 m) alleyways is another agroforestry management option that is suitable for transitioning large areas of cropland to forest (Twedt and Portwood 2003). Unfortunately, many land managers are reluctant to adopt these progressive agroforestry methods for restoration because they (1) perceive the tree species commonly used in agroforestry as not beneficial to wildlife; (2) lack resources to reduce competition from weeds; and (3) continue to believe that forest diversity, particularly light-seeded species, will result from natural colonization of woody species.

An innovative restoration technique that could provide more rapid vertical development and greater species richness on sites restored using traditional afforestation methods is to supplement oak-dominated plantings with a series of systematically distributed clusters of fast-growing trees. I sought to increase vertical forest development and provide elevated sites for avian perches and nest platforms through the addition of small clusters (12 trees each) of Eastern cottonwood (*Populus deltoides*) and American sycamore (*Platanus occidentalis*). In addition to the direct increase in species diversity and stem density afforded by supplemental trees, their vertical structure should provide perch and nest sites for breeding birds. I assumed that prolonged visitation by birds would increase tree diversity through recruitment of woody species that use birds as vectors for seed dissemination (McClanahan and Wolfe 1993; Shiels and Walker 2003). In this study, I summarize the survival and development of supplemental planted cottonwood and sycamore and assess the effect of supplemental trees, planted within traditionally planted restoration sites, on woody species richness, stand density, and vertical development.

Methods

At each of 40 locations, within the Mississippi Alluvial Valley or its adjacent bottomlands, I selected paired sites that had been recently planted with hardwood seedlings (Fig. 1). All sites were agricultural fields that formerly supported bottomland hardwood forests. Paired sites were either separate neighboring fields or divided large fields. Sites were planted predominately with Water oak (*Quercus nigra*), Nuttall oak (*Q. nuttallii*), Willow oak (*Q. phellos*), and Cherrybark oak (*Q. pagoda*) seedlings following traditional restoration methods that provided approximately 750 stems/ha (302 stems/acre). However, the mix of species varied among sites, with seedlings of Sweet pecan (*Carya illinoensis*), Bald cypress (*Taxodium distichum*), Persimmon (*Diospyros virginiana*), Sweetgum (*Liquidambar styraciflua*), or Green ash (*Fraxinus pennsylvanica*) planted along with oaks on some sites. One randomly chosen site, from the pair at each location, was selected as an untreated control. On the other site within each pair, I supplemented existing plantings with 96 additional fast-growing trees. I planted 21 sites during 1998 and 19 sites during 1999.

On all treated sites, supplemental trees were planted within eight systematically distributed clusters of 12 trees. Within each cluster, trees were planted 4 m apart in a 3 × 4 grid, with clusters located at least 60 m apart and greater than 50 m from field edges. Stem cuttings of cottonwood were planted in four of the clusters, whereas seedlings of sycamore were planted in the other four clusters.

Because my objective was to provide rapid vertical structure as well as diversify restoration sites, I evaluated the effects of fertilization and weed control within treated sites. Fertilization promotes vigor of planted trees (Devine et al. 2000), whereas survival and growth are enhanced with reduced competition from weeds (Krinard and Kennedy 1987; Schuette and Kaiser 1997). On 23 randomly selected

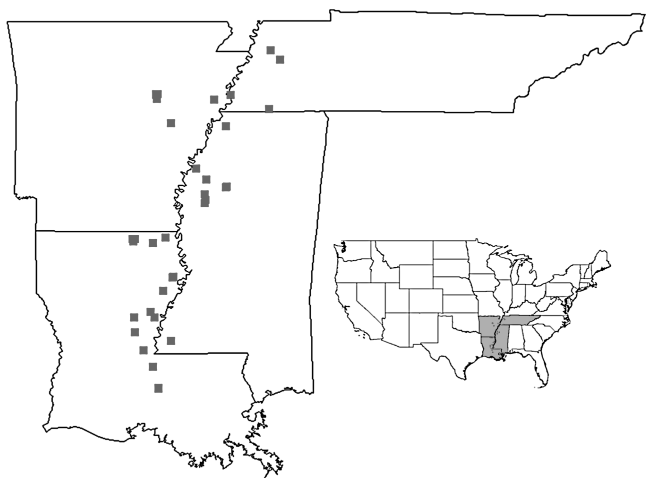

Figure 1. Locations of paired study sites used to assess the effect of planting supplemental fast-growing trees on bottomland restoration sites with regard to woody species richness, total stem density, and maximum height.

treated sites, 10 g of fertilizer (18-6-6 or 20-10-5) was applied to each supplemental tree. On all treated sites, I applied one of four levels of weed protection to a cluster of each supplemental species: (1) no weed control; (2) physical weed barriers (RTI Mulch Mats, Reforestation Technologies International, Monterey, CA, U.S.A., or VisPore Tree Mats, Treessentials Company, Mendota Heights, MN, U.S.A.); (3) single application of dual-chemical weed control (Accord and Oust, DuPont Agricultural Products [sycamore], Wilmington, DE, U.S.A., or Accord and Goal 2XL, Dow AgroSciences [cottonwood], Indianapolis, IN, U.S.A.) at time of planting following practices used and recommended by industrial pulpwood producers; and (4) combined physical and chemical weed control. Details of study design and the results of an assessment of survival and tree height of supplemental trees after one and two growing seasons were reported by Twedt and Wilson (2002).

After five or six growing seasons, I assessed the number of woody species (excluding vines), their total stem density, and maximum height within treated sites and compared these to similar data from control sites that lacked supplemental trees. Species, number, and height of woody stems were obtained within 0.04-ha sample plots at every supplemental tree cluster that had at least one surviving tree and at an equal number of sample plots within paired control sites. I compared species richness, stem density, and maximum height of woody stems between treated and control sites using analysis of variance, wherein study locations (paired sites: $n = 36$) were experimental units and 0.04-ha sample plots (1–8 per site) were sampling units.

Results

Survival varied between tree species and among levels of weed protection (Twedt and Wilson 2002). First-year survival of cottonwood (25%) and sycamore (47%) was poor, but second-year survival of extant trees improved: 52% for cottonwood and 77% for sycamore. Of the 96 supplemental trees planted on each site, 26.6 ± 3.6 ($\overline{X}$ ± SE) trees survived after two growing seasons, with maximum survival of 81 trees (Twedt and Wilson 2002).

After greater than or equal to five growing seasons, four sites had no surviving supplemental trees; these sites were excluded from further evaluation. Of the remaining 288 tree clusters (36 locations × 8 tree clusters), 165 clusters had at least one surviving tree.

I encountered 39 woody species within sample plots (Table 1). Sites with supplemental trees had a greater ($F_{[1,35]} = 14.0$, $p < 0.01$) number of woody species (5.9 ± 0.2 species) than did paired control sites that lacked supplemental trees (4.3 ± 0.2 species). However, this increase in species richness was attributed primarily to the presence of supplemental trees. When supplemental trees were removed from analysis, species richness on treated sites was reduced to 4.7 ± 0.2 species that did not differ from richness on control sites ($F_{[1,35]} = 1.1$, $p = 0.30$).

Table 1. Number of trees detected five to six years after planting, within 165 sample plots (0.04 ha) on 36 restoration sites provisioned with supplemental trees planted in four clusters (12 trees) of American sycamore (*Platanus occidentalis*) and four clusters of Eastern cottonwood (*Populus deltoides*) and within 165 sample plots on paired control sites that lacked supplemental plantings.

Species	*Treated*	*Control*
Acer negundo	51	26
A. rubrum	116	113
Bacharis halimifolia	293	232
Betula nigra	8	0
Carya illinoensis	136	114
Catalpa bignonioides	0	3
Celtis laevigata	497	451
Cephalanthus occidentalis	44	35
Cornus spp.	346	17
Crataegus spp.	22	33
Diospyros virginiana	115	102
Fraxinus pennsylvanica	843	469
Gleditsia triacanthos	22	11
Hypericum spp.	5	9
Ilex decidua	8	10
Juniperus virginiana	135	90
Liquidambar styraciflua	525	1,123
Malus spp.	3	0
Nyssa sylvatica	3	1
Pinus taeda	29	15
P. occidentalis	770	7
P. deltoides	594	0
Prunus serotina	1	0
Prunus spp.	18	10
Quercus lyrata	39	2
Q. michauxii	39	60
Q. nigra	146	136
Q. nuttallii	864	731
Q. pagoda	228	246
Q. palustris	42	55
Q. phellos	708	525
Q. shumardii	310	357
Rhus spp.	0	1
Sabal minor	5	5
Salix nigra	1,317	28
Sapium sebiferum	9	0
Taxodium distichum	43	147
Ulmus alata	217	188
U. americana	59	47

Sites with supplemental trees also had greater ($F_{[1,35]} = 4.8$, $p = 0.04$) stem density (1,309 ± 131 stems/ha) than control sites (888 ± 132 stems/ha). Similarly, maximum tree height was greater ($F_{[1,35]} = 16.0$, $p < 0.01$) on sites with supplemental trees (381 ± 8 cm) than it was on control sites that lacked supplemental trees (294 ± 8 cm). Removal of supplemental trees from analysis reduced stem density to 1,171 ± 131 stems/ha and maximum tree height to 329 ± 7 cm on treated sites. Thus, as with species richness, supplemental trees accounted for much of the increase, such that on treated sites stem density ($F_{[1,35]} = 2.3$, $p = 0.13$) and maximum tree height ($F_{[1,35]} = 2.9$, $p = 0.09$) differed little from control sites.

Discussion

Clusters of fast-growing trees on reforested bottomland sites contributed to greater species diversity, stem density, and vertical structure. Although significant vegetation differences were detected five to six years after planting, it is unlikely that these differences were sufficient to cause different rates of colonization by birds.

Even where survival was adequate, vertical development rarely met my expectations. In part, this was a result of damage inflicted by White-tailed deer (*Odocoileus virginianus*). In particular, cottonwood stems often approached 3 m in height after one growing season, but as these were generally the only vertical substrates in these fields, they were used extensively as antler rubs by deer. Rubbing against these saplings invariably removed the cambium, thereby girdling these trees. Girdling resulted in regrowth initiating far below the previous terminal bud (usually <1 m above ground) and development of multiple, competing stems. Thus, my expectation of rapid vertical development during subsequent growing seasons was not often realized. Because sycamores were shorter and developed many more lateral branches, deer rubbing of sycamore was less problematic.

I planted Eastern cottonwood and American sycamore on all study sites and made no attempt to ensure tree species compatibility with soil type or hydrology. Matching supplemental tree species with site conditions should increase tree survival. However, even with relatively low survival of supplemental trees, these plantings resulted in increased woody species diversity, greater tree density, and more rapid development of vertical forest structure.

To extend this concept from research to an operational restoration practice, I recommend increasing the number of species that are candidates for supplemental tree planting. Additional species that could be planted in supplemental clusters include Honey locust (*Gleditsia triacanthos*), Yellow poplar (*Liriodendron tulipifera*), and Sweetgum (*Liquidambar styraciflua*). To increase the likelihood that some trees survive within each supplemental cluster, I recommend planting two or more species within each cluster of trees. Increased survival will also be afforded by providing weed barriers to reduce competition from weeds. Finally, planting more trees within each cluster, for example, 18 or 24 trees, will increase the probability that some of these trees will be overlooked by deer and will exhibit substantial height increases between years.

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