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William Conner
Clemson University, wconner@clemson.edu

John A. Stanturf
USDA - Forest Service

Emile S. Gardiner

Kenneth Outcalt

James M. Guldin

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Chapter 13.

Restoration
of Southern Ecosystems

John A. Stanturf, Emile S. Gardiner, Kenneth Outcalt, William H. Conner, and James M. Guldin[1]

Abstract—*Restoration of the myriad communities of bottomland hardwood and wetland forests and of the diverse communities of fire-dominated pine forests is the subject of intense interest in the Southern United States. Restoration practice is relatively advanced for bottomland hardwoods and longleaf pine (*Pinus palustris *Mill.), and less so for swamps and shortleaf pine (*P. echinata *Mill.). Most bottomland hardwood restoration is taking place on private land, while restoration of swamps and shortleaf pine occurs mostly on public land. Both public and private landowners are involved in the restoration of longleaf pine. Proper matching of species to site is critical to successful restoration of bottomland hardwoods. Techniques for longleaf pine restoration include the reintroduction of growing-season fire and the planting of longleaf pine seedlings and understory species. Safely reintroducing growing-season fire, however, may require initial manipulation of other vegetation by mechanical or chemical means to reduce built-up fuels.*

INTRODUCTION

Forest cover has declined globally, from an estimated 6 billion ha of "original" forest extent (that prevailing during most of the past 10,000 years) to the present 3.87 billion ha (Food and Agriculture Organization of the United Nations 2001, Krishnaswamy and Hanson 1999). Global assessments have identified changing land use, increasing demand for fiber, and exogenous stresses such as global climate change and air pollution as the factors causing loss of forest cover or degradation of forest condition. Many forests in the South are being subjected to similar disturbances and stresses. Restoration of the myriad communities of bottomland hardwood and wetland forests and the diverse communities of fire-dominated pine forests is the subject of intense interest in the Southern United States, as well as in other parts of the world (Parrotta 1992, Stanturf and Madsen 2002).

Our objective is to present an overview of the restoration of four ecologically varied and socially valuable U.S. forest types: bottomland hardwoods, swamps, Coastal Plain longleaf pine (*Pinus palustris* Mill.), and Interior Highland shortleaf pine forests (*P. echinata* Mill.). Restoration practice is relatively advanced for bottomland hardwoods and longleaf pine, and less so for swamps and shortleaf pine. Bottomland hardwood restoration is taking place mostly on private land. Restoration of swamps and shortleaf pine is occurring mostly on public land, while both public and private landowners are attempting to restore longleaf pine.

RESTORATION PRACTICES

Bottomland Hardwood Forests

Restoration of bottomland hardwoods occurs mostly in the Lower Mississippi Alluvial Valley (LMAV), predominantly in three States: Louisiana, Mississippi, and Arkansas (Stanturf and others 2000). The loss of bottomland hardwood forests has been more widespread in the LMAV than elsewhere in the United States. Clearing for agriculture reduced forest cover, and flood control projects drastically changed regional and local hydrologic cycles. Deforestation and

[1] Forest Soil Scientist and Project Leader, U.S. Department of Agriculture Forest Service, Southern Research Station, Athens, GA 30602; Research Forester, U.S. Department of Agriculture Forest Service, Southern Research Station, Stoneville, MS 38776; Research Ecologist, U.S. Department of Agriculture Forest Service, Southern Research Station, Athens, GA 30602; Professor, Baruch Forest Science Institute, Clemson University, Georgetown, SC 29442; and Research Forest Ecologist and Project Leader, U.S. Department of Agriculture Forest Service, Southern Research Station, Hot Springs, AR 71901, respectively.

drainage resulted in a loss of critical wildlife and fish habitat and reduced floodwater retention (MacDonald and others 1979, Sharitz 1992, U.S. Department of the Interior 1988).

The dominant goal of all restoration programs in the LMAV has been to create wildlife habitat and improve or protect the quality of surface water (Haynes and others 1995, King and Keeland 1999, Newling 1990). Afforestation of small areas (usually no more than 100 ha) within a matrix of active agriculture is typical. Although we know how to afforest many sites (Stanturf and others 1998), recent experience with the Wetlands Reserve Program in Mississippi illustrates the difficulty of applying this knowledge broadly (Stanturf and others 2001).

Afforestation is a process in which something can go wrong at any of several steps. Proper matching of species to site is critical to successful restoration (Baker 1977, Baker and Broadfoot 1979, Broadfoot 1976, Dicke and Toliver 1987, Groninger and others 2000, Krinard and Johnson 1985, Stine and others 1995). Availability of planting stock, however, probably has the greatest influence on the assignment of species to sites. Provenance and family within provenance may account for differences in survival and growth of common species (Dicke and Toliver 1987, Greene and others 1991, Jokela and Mohn 1976, Land 1983). Few foresters in the LMAV specify seed source constraints in purchasing agreements. This lack of quality control, or use of uncertified seed, could potentially reduce establishment success, productivity, and forest health.

Bare-root seedlings were used to stock 64 percent of afforestation area to 1997, with direct seeding applied on 29 percent of the afforestation area (King and Keeland 1999). Descriptions of direct seeding techniques are readily available (Allen and others 2001). Suitable techniques for collecting and storing seed of bottomland hardwood species are well documented (Bonner and others 1994).

Site preparation is used to condition the seed or seedling bed; decrease competing or undesirable vegetation, such as nonnative pests; reduce herbivore habitat; improve nutrient availability; and improve access for the planting operation (Baker and Blackmon 1978; Kennedy 1981, 1993). Site preparation can increase survival and improve early growth of hardwood planting stock (Baker and Blackmon 1978, Ezell and Catchot 1998, Russell and others 1998). Contractors use crews of both hand and machine planters, but differences between the operational rates of establishment success of the two methods are unknown (Russell and others 1998). Observations indicate that either method can be effective if properly supervised (Gardiner and others 2002, Michelak and others 2002).

Swamp Forests

Deepwater swamps, primarily baldcypress-water tupelo [*Taxodium distichum* (L.) Rich.-*Nyssa aquatica L.*], pondcypress-swamp tupelo [*T. distichum* var. *nutans* (Ait.) Sweet-*N. sylvatica* var. *biflora* (Walt.) Sarg.], or Atlantic white-cedar [*Chamaecyparis thyoides* (L.) B.S.P.] swamps, are freshwater systems with standing water for most or all of the year (Johnson 1990, Little and Garrett 1990, Wilhite and Toliver 1990). Other deepwater swamp types include cypress domes and depressional swamps such as the Okefenokee and Dismal Swamps. Large-scale commercial logging of swamp forests did not begin until the late 1800s (Davis 1975, Frost 1987, Little 1950). The introduction of the pullboat, and later the overhead-cableway skidder, enabled loggers to penetrate deeper into swamps and increased the amount of timber harvested. Although declining in area (Dahl 2000), there remain about 2 million ha of this forest type, mostly in second-growth timber (Kennedy 1982). There is less experience in the restoration of deepwater swamps than in the restoration of bottomland hardwoods (Mitsch and Gosselink 1993).

Although there has been little success in planting tupelo (DeBell and others 1982), better results have been obtained with Atlantic white-cedar (McCoy and others 1999, Phillips and others 1993) and baldcypress. Planting of cypress began in the 1950s with good success (Peters and Holcombe 1951). Rathborne Lumber Company planted nearly 1 million baldcypress seedlings on cutover land in Louisiana with 80 to 95 percent survival (Rathborne 1951). The Soil Conservation Service, however, experienced severe herbivory, and they recommended suspension of planting cypress until some means of controlling nutria (*Myocastor coypus* Molina) is developed (Blair and Langlinais 1960). Nutria damage to newly planted seedlings remains a serious problem (Brantley and Platt 1992, Conner 1988, Myers and others 1995), and nutria may also damage mature trees (Hesse and others 1996).

Planting of seedlings may be necessary to restore deepwater swamps because natural regeneration is unreliable in such areas (Conner 1988, Conner and others 1986, Hamilton 1984, Hook and others 1967, Kennedy 1982, Smith 1995). Planting 1-year-old baldcypress seedlings at least 1 m tall and larger than 1.25 cm at the root collar improves early survival and growth (Faulkner and others 1986). Planting in the late fall and winter is recommended so that seedlings become established during periods of low water (Mattoon 1915). Even when baldcypress is planted in permanent standing water, its height growth averages 20 to 30 cm/year when there are no herbivory problems (Conner 1988, Conner and Flynn 1989). Tree shelters generally increase the chances of survival of planted seedlings, but they do not prevent all herbivory (McLeod 2000).

A simple technique for planting seedlings in standing water has been tested successfully (Conner 1995, Conner and Flynn 1989, Funderburk 1995, McLeod and others 1996). This technique involves root pruning, or trimming off the lateral roots and cutting the taproot to approximately 20 cm. When this is done, the planter can grasp the seedling at the root collar and push it into the sediment until his or her hand hits the sediment. This method has worked well in trials with baldcypress and water tupelo, but not as well with green ash (*Fraxinus pennsylvanica* Marsh.) and swamp tupelo.

Longleaf Pine Forests

Longleaf pine was once the most prevalent pine type in the South, dominating as much as 25 million ha (Stout and Marion 1993). Burning of understory vegetation by Native Americans augmented the natural understory fire regime of longleaf forests (Abrahamson and Hartnett 1990, Christensen 1981, Robbins and Myers 1992, Ware and others 1993). Longleaf, however, was not well adapted to the forms of disturbance that accompanied European settlement (Frost 1993, Wahlenberg 1946). Logging, wildfires, and conversion to other pines or urban areas reduced longleaf pine to < 5 percent of its original area (Kelly and Bechtold 1990, Outcalt and Sheffield 1996).

Because of past history, an array of potential sites for longleaf restoration is available in various conditions (Outcalt and Sheffield 1996). This includes an estimated 0.5 to 0.8 million ha with intact longleaf overstory and understory (Noss 1989). Other areas with little or no longleaf in the overstory have understories that range from those having most of the native species to those that are devoid of species typical of the longleaf ecosystem (Outcalt 2000). This range of overstory and understory conditions exists across the spectrum of longleaf sites, from dry sandhills to wet savannas. Effective restoration techniques depend on the site type and current condition of the overstory and understory (table 13.1). Generally, techniques include reintroducing growing-season fire and planting longleaf pine seedlings and understory species. Safely reintroducing fire during the growing season, however, may require initial manipulation of other vegetation by mechanical or chemical means to reduce built-up fuels.

Fire suppression has allowed understory shrubs and hardwoods to expand significantly on many longleaf sites. Prescribed burning during the dormant season was introduced on public lands and larger private holdings to reduce fuel buildup, but often had no effect on the well-developed midstory. Reintroducing growing-season fires will adjust structure and relative composition, thereby reestablishing normal function. In the South, growing-season burning of stands with an intact longleaf overstory should be limited to the period from March to July, and late burning (into September) avoided because longleaf pine is then susceptible to fire-caused mortality (Robbins and Myers 1992). Nevertheless, reintroducing growing-season fires into xeric longleaf communities that have not been burned for a long time usually causes some mortality of large trees from 1 to 3 years after the first burn. The exact cause of this is unknown, but mortality seems to be related to smoldering combustion of the excessive litter buildup around the base of larger stems. Several closely spaced dormant season burns should be used to reduce litter buildup prior to any growing-season burning. Caution should be exercised, however, where slopes > 15 percent are burned frequently, because significant erosion can result when mineral soil is exposed in such terrain.

On many sites, supplemental treatments can accelerate restoration of red-cockaded woodpecker (*Picoides borealis* Vieillot) colonies or forest cover at the urban interface zone. Mechanical treatments (chain saw felling, girdling, or chipping onsite) can rid stands of midstory hardwoods (Provencher and others 2001). Such treatments can be followed with a prescribed burn to stimulate grasses and forbs and control hardwood sprouts. Midstory material left onsite should be allowed to decay before the first prescribed burn. Fuel is often sparse in areas dominated by scrub oak, so these areas are often

Table 13.1—Longleaf pine restoration prescription depends upon site type and the condition of the overstory and understory

	Overstory and understory condition		
Site type	Longleaf overstory, woody midstory and understory	Other species in overstory, understory intact	Former longleaf site, no overstory or understory
Xeric and sub-xeric sandhills	Reduce fuel loads with dormant season burns, introduce summer burns[a] to invigorate grasses;[b] consider mechanical[c] or chemical[d] treatments	Chop and burn scrub oak; remove slash pine;[e] plant longleaf;[f] no or minimal site preparation; introduce summer burns	Remove other trees; chop and burn;[g] plant longleaf; plant[h] or direct seed wiregrass;[i] roll in; plant wiregrass plugs under longleaf overstory; introduce summer burns
Flatwoods and wet lowlands	Reduce fuel loads with dormant season burns, introduce summer burns on short intervals[j]	Reduce fuel loads, remove other pines; chop, reduce logging slash; plant longleaf; introduce summer burns	Remove other trees; chop and burn; plant longleaf; plant or direct seed wiregrass; introduce summer burns
Uplands	Reduce fuel loads with dormant season burns, remove other pines; introduce summer burns;[k] consider mechanical or chemical treatments[l]	Reduce fuel loads; remove other overstory pine, plant longleaf; introduce summer burns	Remove other trees; chop and burn; plant longleaf; plant or direct seed wiregrass; introduce summer burns

[a] Glitzenstein and others (1995).
[b] Greenberg and Simons (1999).
[c] Provencher and others (2001).
[d] Brockway and Outcalt (2000).
[e] Outcalt and Lewis (1990).
[f] Barnett and others 1990).
[g] Burns and Hebb (1972).
[h] Outcalt and others (1999).
[i] Hattenbach and others (1998).
[j] Waldrop and others (1987).
[k] Boyer (1990).
[l] Boyer (1991).

difficult to burn. Mechanical treatments with a small single-drum chopper with no offset can be used to knock over and compress the oaks into a ground layer that will carry a prescribed burn after curing.

Restoration is more rapid if burning is supplemented by use of an herbicide such as hexazinone (applied at a rate of 2 kg/ha of active ingredient); desired results can be obtained with one herbicide application and one burn (Brockway and Outcalt 2000). This treatment is effective at topkilling midstory hardwoods with only short-term reductions in understory grasses and forbs on sandhills sites (Brockway and others 1998), although cover of desirable woody species may be reduced for a period. However, herbicide need be applied only once; periodic prescribed burns will maintain the understory condition.

Longleaf seedlings can be bare-root or container, and can be planted by hand or by machine (Barnett and McGilvray 1997, Barnett and others 1990). Site preparation, other than that outlined above, should be avoided to preserve the understory. A planter with a small scalper blade attached can boost bare-root seedling survival if grass cover is > 60 percent (Outcalt 1995). Acceptable survival can be obtained with container seedlings and no site preparation other than burning, although survival may be increased by hexazinone application on areas with heavy scrub oak competition.

The understory is best restored simultaneously with replanting of longleaf seedlings to take advantage of the reduced competition and ease of operability. The critical factor is reestablishment of the grass component because of its important role as a fuel source for ecosystem maintenance.

Most work to date has focused on the eastern portion of the range and reestablishment of wiregrass (*Aristida beyrichiana* Trin. & Rupr.) (Means 1997, Outcalt and others 1999, Seamon 1998). Wiregrass also can be established by planting plugs under an existing longleaf overstory in the spring, in strips spaced about 1 m apart. Fertilizer applied only to the wiregrass in the second- or third-growing season will stimulate growth (Outcalt and others 1999). Wiregrass also can be directly seeded between rows of trees in plantations (Hattenbach and others 1998). Other native grasses can be included in seed mixes. Pineywoods dropseed [*Sporobolus junceus* (P. Beauv.) Kunth.], like wiregrass, will produce seed following burning. In addition to selected common species such as dwarf huckleberry [*Gaylussacia dumosa* (Andrews) A. Gray.] that do not reinvade or survive, some rare species will probably have to be reintroduced (Glitzenstein and others 1998, Walker 1998).

Shortleaf Pine Forests

Shortleaf pine in the Ouachita Mountains also evolved with fire (Foti and Glenn 1991). Fire return intervals before European settlement were from 2 to 40 years, but today fire has been severely suppressed in this forest type (Foti and Glenn 1991). Throughout the 1970s and 1980s, efforts to recover the endangered red-cockaded woodpecker in the Ouachita Mountains had been largely unsuccessful, despite evidence that it once inhabited the region. Managers realized that the decline of the bird was related to decline in suitable habitat, and restoration of the shortleaf-bluestem community became a priority. Roughly 63,000 ha of the Ouachita National Forest were allocated to restoration of pine savanna (U.S. Department of Agriculture, Forest Service 1996).

Restoration of shortleaf pine savanna requires several changes in management. First, sawtimber rotation is lengthened from 70 to 80 to 120 years, which allows longer retention of suitable cavity trees for the woodpecker and results in larger and higher quality pine sawtimber at harvest. Second, the pine component is subjected to a low thinning to reduce overstory basal area. This provides more light and promotes herbaceous growth; a side benefit is a lowered susceptibility to southern pine beetle (*Dendroctonus frontalis* Zimmermann) attack. Third, the hardwood midstory component, which developed in the 60-year period of fire exclusion, must be removed. Fourth, periodic prescribed burns are reintroduced on a 3- to 5-year cycle to reestablish the native prairie flora. Rootstocks and seed for these woodland savanna plants are still viable in the area, and no special effort other than reintroduction of burning is needed for their reestablishment. Finally, artificial cavities are installed in some of the pines for immediate use by the red-cockaded woodpecker.

DISCUSSION

Despite the handicap of incomplete knowledge, attempts to restore native forests abound. Spencer (1995) drew three lessons from efforts to create woodlands in the United Kingdom. These accurately portray the state of the art of restoration ecology applied to forests:

- Forests are amazingly resilient, and functioning forest habitat will develop whether or not we intervene, given sufficient time.
- Attempts at re-creating ancient forests are doomed to fail because the conditions under which they developed cannot be replicated.
- We can at best design and implement the proper initial conditions that will foster development of a forest appropriate to the site and present climate.

The economics of private land restoration will increase in importance. Current Federal programs that provide large easement payments, such as the Wetlands Reserve Program, are expensive and probably justified on poor sites. On better sites, restoration might pay its own way, with only cost sharing needed to establish the forest. Landowners could derive periodic income from timber production and other nontimber products, including ecological services such as carbon sequestration.

Restoration forests could sequester vast amounts of carbon. Baldcypress, for example, can live longer than a thousand years and attain net primary productivity values as great as 20 t/ha/year (Conner and Buford 1998). Biofuels produced from cottonwood (*Populus* spp.) or willow (*Salix* spp.) would not only sequester carbon in soil organic matter but would have the further carbon-offset benefit of replacing fossil fuels (Stanturf and Madsen 2002).

Attention to the effects of restoration at landscape scales is highlighting the need to consider how restored forests will be managed, and raises the question of the degree to which natural disturbance regimes can be incorporated into forest management. In the shortleaf pine restoration program, for example, efforts are concentrated on establishing restored conditions over the full extent of the landscape, primarily for the benefit of the red-cockaded woodpecker. But sustainability of this habitat type in the long term requires that some portion of the landscape should be managed in age classes of 30 years and younger, which are not useful as nesting habitat for the endangered woodpecker.

The forest that results from restoration or rehabilitation may never recover to the original state for all functions (Bradshaw 1997, Harrington 1999). We accept as restoration any endpoint within the natural range of managed forests where self-renewal processes operate (Stanturf and Madsen 2002, Stanturf and others 2001). This approach offers a broader context for restoration on private land, and landowners with management objectives other than preservation are able to contribute to ecosystem restoration (Stanturf and Madsen 2002, Stanturf and others 2001).

LITERATURE CITED

Abrahamson, W.G.; Hartnett, D.C. 1990. Pine flatwoods and dry prairies. In: Myers, R.L.; Ewel, J.J., eds. Ecosystems of Florida. Orlando, FL: University of Central Florida Press: 103–149.

Allen, J.A.; Keeland, B.D.; Stanturf, J.A. [and others]. 2001. A guide to bottomland hardwood restoration. U.S. Geol. Surv., Biol. Resour. Div. Inf. and Tech. Rep. USGS/BRD/ITR–2001–0011. Gen. Tech. Rep. SRS–40. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 132 p.

Baker, J.B. 1977. Tolerance of planted hardwoods to spring flooding. Southern Journal of Applied Forestry. 1: 23–25.

Baker, J.B.; Blackmon, B.G. 1978. Summer fallowing—a simple technique for improving old-field sites for cottonwood. Res. Pap. SO–142. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 5 p.

Baker, J.B.; Broadfoot, W.M. 1979. A practical field method of site evaluation for commercially important southern hardwoods. Gen. Tech. Rep. SO–26. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 51 p.

Barnett, J.P.; Lauer, D.K.; Brissette, J.C. 1990. Regenerating longleaf pine with artificial methods. In: Farrar, R.M., ed. Proceedings of the symposium on the management of longleaf pine. Gen. Tech. Rep. SO–75. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 72–93.

Barnett, J.P.; McGilvray, J.M. 1997. Practical guidelines for producing longleaf pine seedlings in containers. Gen. Tech. Rep. SRS–14. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 28 p.

Blair, R.M.; Langlinais, M.J. 1960. Nutria and swamp rabbits damage baldcypress plantings. Journal of Forestry. 58: 388–389.

Bonner, F.T.; Vozzo, J.A.; Elam, W.W.; Land, S.B., Jr. 1994. Tree seed technology training course. Gen. Tech. Rep. SO–107. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 81 p.

Boyer, W.D. 1990. Growing season burns for control of hardwoods in longleaf pine stands. Res. Pap. SO–256. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 7 p.

Boyer, W.D. 1991. Effects of a single chemical treatment on long-term hardwood development in a young pine stand. In: Coleman, S.S.; Neary, D.G., eds. Proceedings of the sixth biennial southern silvicultural research conference. Gen. Tech. Rep. SE–70. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 599–606.

Bradshaw, A.D. 1997. What do we mean by restoration? In: Urbanska, K.M.; Webb, N.R.; Edwards, P.J., eds. Restoration ecology and sustainable development. Cambridge, UK: Cambridge University Press: 8–14.

Brantley, C.G.; Platt, S.G. 1992. Experimental evaluation of nutria herbivory on baldcypress. Proceedings of the Louisiana Academy of Science. 55: 21–25.

Broadfoot, W.M. 1976. Hardwood suitability for and properties of important Midsouth soils. Res. Pap. SO–127. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 84 p.

Brockway, D.G.; Outcalt, K.W. 2000. Restoring longleaf pine wiregrass ecosystems: hexazinone application enhances effects of prescribed fire. Forest Ecology and Management. 137: 121–138.

Brockway, D.G.; Outcalt, K.W; Wilkins, R.N. 1998. Restoring longleaf pine wiregrass ecosystems: plant cover, diversity and biomass following low-rate hexazinone application on Florida sandhills. Forest Ecology and Management. 103: 159–175.

Burns, R.M.; Hebb, E.A. 1972. Site preparation and reforestation of droughty, acid sands. Agric. Handb. 426. Washington, DC: U.S. Department of Agriculture. 61 p.

Christensen, N.L. 1981. Fire regimes in southeastern ecosystems. In: Mooney, H.A.; Bonnicksen, T.M.; Christensen, N.L. [and others], tech. coords. Proceedings: fire regimes and ecosystem properties. Gen. Tech. Rep. WO–26. Washington, DC: U.S. Department of Agriculture, Forest Service: 112–135.

Conner, W.H. 1988. Natural and artificial regeneration of baldcypress in the Barataria and Lake Verret Basins of Louisiana. Baton Rouge, LA: Louisiana State University. 148 p. Ph.D. dissertation.

Conner, W.H. 1995. Baldcypress seedlings for planting in flooded sites. In: Edwards, M. Boyd, comp. Proceedings of the eighth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–1. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 430–434.

Conner, W.H.; Buford, M. 1998. Southern deepwater swamps. In: Messina, M.G.; Conner, W.H., eds. Southern forested wetlands: ecology and management. Boca Raton, FL: Lewis Publishers/CRC Press: 261–287.

Conner, W.H.; Flynn, K. 1989. Growth and survival of baldcypress (*Taxodium distichum* (L.) Rich.) planted across a flooding gradient in a Louisiana bottomland forest. Wetlands. 9: 207–217.

Conner, W.H.; Toliver, J.R.; Sklar, F.H. 1986. Natural regeneration of cypress in a Louisiana swamp. Forest Ecology and Management. 14: 305–317.

Dahl, T.E. 2000. Status and trends of wetlands in the conterminous United States, 1986 to 1997. Washington, DC: U.S. Department of the Interior, U.S. Fish and Wildlife Service. [Number of pages unknown].

Davis, D.W. 1975. Logging canals: a distinct pattern of the swamp in south Louisiana. Forests and People. 25: 14–17, 33–35.

DeBell, D.S.; Askew, G.R.; Hook, D.D. [and others]. 1982. Species suitability on a lowland site altered by drainage. Southern Journal of Applied Forestry. 6: 2–9.

Dicke, S.G.; Toliver, J.R. 1987. Response of cherrybark oak families to different soil-site conditions. In: Phillips, D.R., comp. Proceedings of the fourth biennial southern silvicultural research conference. Gen. Tech. Rep. SE–42. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 260–263.

Ezell, A.W.; Catchot, A.L., Jr. 1998. Competition control for hardwood plantation establishment. In: Waldrop, T.A., ed. Proceedings of the ninth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–20. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 42–43.

Faulkner, P.L.; Zeringue, F.; Toliver, J.R. 1986. Genetic variation among open-pollinated families of baldcypress seedlings planted on two different sites. In: Proceedings of the 18th southern forest tree improvement conference. Sponsored Publ. 40. [Place of publication unknown]: Southern Forest Tree Improvement Committee: 267–272.

Food and Agriculture Organization of the United Nations. 2001. Global forest resources assessment 2000. For. Pap. 140. Rome. http://www.fao.org/forestry/fo/fra/main/index.jsp. [Date accessed: July 25, 2002].

Foti, T.L.; Glenn, S.M. 1991. The Ouachita Mountains landscape at the time of settlement. In: Henderson, D.; Hedrick, L.D., eds. Restoration of old-growth forests in the interior highlands of Arkansas and Oklahoma. Morrilton, AR: Ouachita National Forest and Winrock International Institute for Agricultural Development. [Number of pages unknown].

Frost, C.C. 1987. Historical overview of Atlantic white cedar in the Carolinas. In: Laderman, A.D., ed. Atlantic white cedar wetlands. Boulder, CO: Westview Press: 257–264.

Frost, C.C. 1993. Four centuries of changing landscape patterns in the longleaf pine ecosystem. In: Hermann, S.H., ed. The longleaf pine ecosystem: ecology, restoration and management. Proceedings of the 18th Tall Timbers fire ecology conference. Tallahassee, FL: Tall Timbers Research Station. 18: 17–44.

Funderburk, E.L. 1995. Growth and survival of four forested wetland species planted on Pen Branch Delta, Savannah River Site, SC. Clemson, SC: Clemson University. 91 p. M.S. thesis.

Gardiner, E.S.; Russell, D.R.; Oliver, M.; Dorris, L.C., Jr. 2002. Bottomland hardwood afforestation: state of the art. In: Holland, M.J.; Warren, M.L., Jr.; Stanturf, J.A., eds. Proceedings of a conference on sustainability of wetlands and water resources. Gen. Tech. Rep. SRS–50. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 75–86.

Glitzenstein, J.S.; Platt, W.J.; Streng, D.R. 1995. Effects of fire regime and habitat on tree dynamics in north Florida longleaf pine savannas. Ecological Monographs. 65: 441–476.

Glitzenstein, J.S.; Streng, D.R.; Wade, D.D. 1998. A promising start for a new population of *Parnassia caroliniana* Michx. Rep. 3. Auburn, AL: Longleaf Alliance: 44–58.

Greenberg, C.H.; Simons, R.W. 1999. Age, composition, and stand structure of old-growth oak sites in the Florida high pine landscape: implications for ecosystem management and restoration. Natural Areas Journal. 19: 30–40.

Greene, T.A.; Lowe, W.J.; Stine, M. 1991. Volume production of six cherrybark oak provenances in the western gulf region. In: Coleman, S.S.; Neary, D.G., eds. Proceedings of the sixth biennial southern silvicultural research conference. Gen. Tech. Rep. SE–70. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 736–743.

Groninger, J.W.; Aust, W.M.; Miwa, M.; Stanturf, J.A. 2000. Growth predictions for tree species planted on marginal soybean lands in the Lower Mississippi Valley. Journal of Soil and Water Conservation. 55: 91–95.

Hamilton, D.B. 1984. Plant succession and the influence of disturbance in Okefenokee Swamp. In: Cohen, A.D.; Casagrande, D.J.; Andrejko, M.J.; Best, G.R., eds. The Okefenokee Swamp: its natural history, geology, and geochemistry. Los Alamos, NM: Wetland Surveys: 86–111.

Harrington, C.A. 1999. Forests planted for ecosystem restoration or conservation. New Forests. 17: 175–190.

Hattenbach, M.J.; Gordon, D.R.; Seamon, G.S.; Studenmund, R.G. 1998. Development of direct-seeding techniques to restore native groundcover in a sandhill ecosystem. Rep. 3. Auburn, AL: Longleaf Alliance: 64–70.

Haynes, R.J.; Bridges, R.J.; Gard, S.W. [and others]. 1995. Bottomland hardwood reestablishment efforts of the U.S. Fish and Wildlife Service: southeast region. In: Fischenich, J.C.; Lloyd, C.M.; Palermo, M.R., eds. Proceedings: national wetlands engineering workshop. Vicksburg, MS: U.S. Army Corps of Engineers, Waterways Experiment Station: 322–334.

Hesse, I.D.; Conner, W.H.; Day, J.W., Jr. 1996. Herbivory impacts on the regeneration of forested wetlands. In: Flynn, K.M., ed. Proceedings of the southern forested wetlands ecology and management conference. Clemson, SC: Clemson University: 23–28.

Hook, D.D.; LeGrande, W.W.; Langdon, O.G. 1967. Stump sprouts on water tupelo. Southern Lumberman. 215(2680): 111–112.

Johnson, R.L. 1990. *Nyssa aquatica* L.–water tupelo. In: Burns, R.M.; Honkala, B.H., tech. coords. Silvics of North America: 2. Hardwoods. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture: 474–478.

Jokela, J.J.; Mohn, C.A. 1976. Geographic variation in eastern cottonwood. In: Thielges, B.A.; Land, S.B., Jr., eds. Proceedings of the symposium on eastern cottonwood and related species. Baton Rouge, LA: Louisiana State University, Division of Continuing Education: 109–125.

Kelly, J.F.; Bechtold, W.A. 1990. The longleaf pine resource. In: Farrar, R.M., ed. Proceedings of the symposium on the management of longleaf pine. Gen. Tech. Rep. SO–75. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 11–22.

Kennedy, H.E., Jr. 1981. Bottomland hardwoods research on site preparation, plantation establishment, and cultural treatments, at the Southern Hardwoods Laboratory. In: Barnett, J.P., ed. Proceedings of the first biennial southern silvicultural research conference. Gen. Tech. Rep. SO–34. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 75–78.

Kennedy, H.E., Jr. 1982. Growth and survival of water tupelo coppice regeneration after six growing seasons. Southern Journal of Applied Forestry. 6: 133–135.

Kennedy, H.E., Jr. 1993. Artificial regeneration of bottomland hardwoods. In: Loftis, D.; McGee, C.E., eds. Oak regeneration: serious problems, practical recommendations. Gen. Tech. Rep. SE–84. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 241–249.

King, S.L.; Keeland, B.D. 1999. Evaluation of reforestation in the Lower Mississippi River Alluvial Valley. Restoration Ecology. 7: 348–359.

Krinard, R.M.; Johnson, R.L. 1985. Eighteen-year development of sweetgum (*Liquidambar styraciflua* L.) plantings on two sites. Tree Planters' Notes. 36: 6–8.

Krishnaswamy, A.; Hanson, A., eds. 1999. Our forests, our future: summary report, World commission on forests and sustainable development. Cambridge, UK: Cambridge University Press. 37 p.

Land, S.B., Jr. 1983. Performance and G-E interactions of sycamore established from cuttings and seedlings. In: Jones, E.P., Jr., ed. Proceedings of the second biennial southern silvicultural research conference. Gen. Tech. Rep. SE–24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 431–440.

Little, S., Jr. 1950. Ecology and silviculture of white cedar and associated hardwoods in southern New Jersey. Bull. 56. New Haven, CT: Yale University, School of Forestry. 103 p.

Little, S.; Garrett, P.W. 1990. *Chamaecyparis thyoides* (L.) B.S.P. Atlantic white cedar. In: Burns, R.M.; Honkala, B.H., tech. coords. Silvics of North America: 1. Conifers. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture: 103–108.

MacDonald, P.O.; Frayer, W.E.; Clauser, J.K. 1979. Documentation, chronology, and future projections of bottomland hardwood habitat losses in the Lower Mississippi Alluvial Plain. Washington, DC: U.S. Department of the Interior, U.S. Fish and Wildlife Service. 2 vols.

Mattoon, W.R. 1915. The southern cypress. Agric. Bull. 272. Washington, DC: U.S. Department of Agriculture. 74 p.

McCoy, J.W.; Keeland, B.D.; Allen, J.A. 1999. Atlantic white-cedar plantings in St. Tammany Parish, Louisiana, and the Bogue Chitto National Wildlife Refuge, Mississippi. In: Shear, T.H.; Summerville, K.O., eds. Atlantic white-cedar: ecology and management symposium. Gen. Tech. Rep. SRS–27. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 36–41.

McLeod, K.W. 2000. Species selection trials and silvicultural techniques for the restoration of bottomland hardwood forests. Ecological Engineering. 15: S35–S46.

McLeod, K.W.; Reed, M.R.; Ciravolo, T.G. 1996. Reforesting a damaged stream delta. Land and Water. 40: 11–13.

Means, D.B. 1997. Wiregrass restoration: probable shading effects in a slash pine plantation. Restoration & Management Notes. 15: 52–55.

Michelak, A.J.; Lockhart, B.R.; Dean, T.J. [and others]. 2002. Hand planting versus machine planting of bottomland red oaks on former agricultural fields in Louisiana's Mississippi Alluvial Plain: sixth-year results. In: Outcalt, K.W., ed. Proceedings of the 11th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–48. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 352–357.

Mitsch, W.J.; Gosselink, J.G. 1993. Wetlands. 3d ed. New York: John Wiley. 920 p.

Myers, R.S.; Shaffer, G.P.; Llewellyn, D.W. 1995. Baldcypress (*Taxodium distichum* (L.) Rich.) restoration in southeast Louisiana: the relative effects of herbivory, flooding, competition, and macronutrients. Wetlands. 15: 141–148.

Newling, C.J. 1990. Restoration of the bottomland hardwood forest in the Lower Mississippi Valley. Restoration and Management Notes. 8: 23–28.

Noss, R.F. 1989. Longleaf pine and wiregrass: keystone components of an endangered ecosystem. Natural Areas Journal. 9: 211–213.

Outcalt, K.W. 1995. Maintaining the native plant community during longleaf pine establishment. FRI Bull. 192. Rotorua, New Zealand: New Zealand Research Institute: 283–285.

Outcalt, K.W. 2000. Occurrence of fire in longleaf pine stands in the Southeastern United States. In: Proceedings of the 21st Tall Timbers fire ecology conference. Tallahassee, FL: Tall Timbers Research Station. 21: 178–182.

Outcalt, K.W.; Lewis, C.E. 1990. Response of wiregrass (*Aristida stricta*) to mechanical site preparation. In: Duever, L.C.; Noss, R.F., eds. Wiregrass biology and management. Gainesville, FL: KBN Engineering & Applied Sciences. 12 p.

Outcalt, K.W.; Sheffield, R.M. 1996. The longleaf pine forest: trends and current conditions. Resour. Bull. SRS–9. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 23 p.

Outcalt, K.W.; Williams, M.E.; Onokpise, O. 1999. Restoring *Aristida stricta* to *Pinus palustris* ecosystems on the Atlantic Coastal Plain, U.S.A. Restoration Ecology. 7: 262–270.

Parrotta, J.A. 1992. The role of plantation forests in rehabilitating tropical ecosystems. Agricultural Ecosystems Environment. 41: 115–133.

Peters, M.A.; Holcombe, E. 1951. Bottomland cypress planting recommended for flooded areas by soil conservationists. Forests and People. 1(2): 18, 32–33.

Phillips, R.; Gardner, W.E.; Summerville, K.O. 1993. Plantability of Atlantic white-cedar rooted cuttings and bare-root seedlings. In: Brissette, J.C., ed. Proceedings of the seventh biennial southern silvicultural research conference. Gen. Tech. Rep. SO–93. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 97–104.

Provencher, L.B.; Herring, J.; Gordon, D.R. [and others]. 2001. Effects of hardwood reduction techniques on longleaf pine sandhill vegetation in northwest Florida. Restoration Ecology. 9: 13–27.

Rathborne, J.C. 1951. Cypress reforestation. Southern Lumberman. 183(2297): 239–240.

Robbins, L.E.; Myers, R.L. 1992. Seasonal effects of prescribed burning in Florida: a review. Misc. Publ. 8. Tallahassee, FL: Tall Timbers Research Inc. 96 p.

Russell, D.R., Jr.; Hodges, J.D.; Ezell, A.W. 1998. An evaluation of hardwood reforestation methods on previously farmed lands in central Alabama. In: Waldrop, T.A., ed. Proceedings of the ninth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–20. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 272–276.

Seamon, G. 1998. A longleaf pine sandhill restoration in northwest Florida. Restoration and Management Notes. 16: 46–50.

Sharitz, R.R. 1992. Bottomland hardwood wetland restoration in the Mississippi drainage. In: Restoration of aquatic ecosystems: science, technology, and public policy. Washington, DC: National Academy Press: 496–505.

Smith, L.E., II. 1995. Regeneration of Atlantic white-cedar at the Alligator River National Wildlife Refuge and Dare County Air Force bombing range. Raleigh, NC: North Carolina State University. [Number of pages unknown]. M.S. thesis.

Spencer, J.W. 1995. To what extent can we recreate woodland? In: Ferris-Kahn, R., ed. The ecology of woodland creation. London: John Wiley: 1–16.

Stanturf, J.A.; Gardiner, E.S.; Hamel, P.B. [and others]. 2000. Restoring bottomland hardwood ecosystems in the Lower Mississippi Alluvial Valley. Journal of Forestry. 98(8): 10–16.

Stanturf, J.A.; Madsen, P. 2002. Restoration concepts for temperate and boreal forests of North America and Western Europe. Plant Biosystems. 136(2): 143–158.

Stanturf, J.A.; Schoenholtz, S.H.; Schweitzer, C.J.; Shepard, J.P. 2001. Achieving restoration success: myths in bottomland hardwood forests. Restoration Ecology. 9: 189–200.

Stanturf, J.A.; Schweitzer, C.J.; Gardiner, E.S. 1998. Afforestation of marginal agricultural land in the Lower Mississippi River Alluvial Valley, U.S.A. Silva Fennica. 32: 281–297.

Stine, M.; Chambers, J.L.; Wilson, M.; Ribbeck, K. 1995. Twenty-year survival and growth of six bottomland hardwood species. In: Edwards, M.B., ed. Proceedings of the eighth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–1. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 500–502.

Stout, I.J.; Marion, W.R. 1993. Pine flatwoods and xeric pine forest of the southern (lower) Coastal Plain. In: Martin, W.H.; Boyce, S.G.; Echternacht, A.C., eds. Biodiversity of the Southeastern United States, lowland terrestrial communities. New York: John Wiley: 373–446.

U.S. Department of Agriculture, Forest Service. 1996. Renewal of the shortleaf pine/bluestem grass ecosystem and recovery of the red-cockaded woodpecker: final environmental impact statement for an amendment to the land and resource management plan, Ouachita National Forest. Hot Springs, AR. 94 p.

U.S. Department of the Interior. 1988. The impact of Federal programs on wetlands. In: The Lower Mississippi Alluvial Floodplain and the prairie pothole region. A report to Congress by the Secretary of the Interior. Washington, DC. 114 p. Vol. 1.

Wahlenberg, W.G. 1946. Longleaf pine: its use, ecology, regeneration, protection, growth, and management. Washington, DC: C.L. Pack Forestry Foundation and U.S. Department of Agriculture, Forest Service. 429 p.

Waldrop, T.N.; Van Lear, D.H.; Lloyd, F.T.; Harms, W.R. 1987. Long-term studies of prescribed burning in loblolly pine forests of the southeastern Coastal Plain. Gen. Tech. Rep. SE–45. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 23 p.

Walker, J.L. 1998. Ground layer vegetation in longleaf pine landscapes: an overview for restoration and management. Rep. 3. Auburn, AL: Longleaf Alliance: 2–13.

Ware, S.; Frost, C.C.; Doerr, P.D. 1993. Southern mixed hardwood forest: the former longleaf pine forest. In: Martin, W.H.; Boyce, S.G.; Echternacht, A.C., eds. Biodiversity of the Southeastern United States, lowland terrestrial communities. New York: John Wiley: 447–493.

Wilhite, L.P.; Toliver, J.R. 1990. *Taxodium distichum* (L.) Rich.–baldcypress. In: Burns, R.M.; Honkala, B.H., tech. coords. Silvics of North America: 1. Conifers. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture: 563–572.