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A Guide to Bottomland Hardwood Restoration

Information and Technology Report
USGS/BRD/ITR–2000-0011

General Technical Report SRS–40

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J.A. Allen, B.D. Keeland, J.A. Stanturf, A.F. Clewell, and H.E. Kennedy, Jr.

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U.S. Department of the Interior
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Preface

The primary focus of this guide is to provide information for land managers and landowners who want to reestablish bottomland hardwood forest vegetation, particularly the trees, on lands where they formerly occurred. Restoration and reforestation are approached with the realization that hydrology, as the driving force of wetland ecosystems, must be explicitly considered in all projects. Without the proper hydrologic regime for the site conditions and tree species selected for planting, it is unlikely that a project will be a success. It is assumed that the goal of the audience using this guide is at least the reestablishment of bottomland hardwood forest systems and hopefully the restoration of all functions and values associated with these forests (e.g., storage of floodwaters, water quality improvement, provision of wildlife habitat, etc.).

It is unlikely that a publication will ever be produced that contains all the information needed for an untrained person to plan and implement a completely successful restoration project. Certainly, this guide has no such pretensions. We have tried to make the guide as comprehensive as possible but concise, realizing there is probably much that we have missed. In addition, there are currently information needs expressed by practitioners that have not been adequately addressed by researchers.

This guide will provide the reader with a reasonably comprehensive introduction to the wide range of activities and techniques which, taken together, make up the process of bottomland hardwood restoration as it is now understood. Hopefully, this guide will also provide valuable information to experienced, professional ecosystem ecologists, especially those who have worked mainly with other types of wetland systems.

Whenever possible, the novice restorationist should seek opportunities to work with experienced professionals during every phase of their projects, from initial planning, through implementation, to monitoring and reporting. Opportunities to visit ongoing or completed restoration projects should also be sought.

First and foremost, though, understanding the ecology of bottomland hardwood systems is vitally important. Without a fundamental understanding of factors such as the seasonal patterns of flooding and groundwater dynamics, species-site relationships, seed dispersal mechanisms, plant establishment requirements, and plant-animal interactions, a restoration project is unlikely to be fully successful. In many ways, ongoing efforts to reestablish bottomland forest systems is a continuing experiment. As new information is gained, it should be cycled back into the decision-making process and subsequent forest reestablishment efforts.

Contents

Figures

Tables

A Guide to Bottomland Hardwood Restoration

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Abstract: During the last century, a large amount of the original bottomland hardwood forest area in the United States has been lost, with losses greatest in the Lower Mississippi Alluvial Valley and East Texas. With a holistic approach in mind, this manual describes methods to restore bottomland hardwoods in the lower Midwest, including the Lower Mississippi Alluvial Valley and the southeastern United States. Bottomland hardwoods in this guide include not only the hardwood species that predominate in most forested floodplains of the area but also the softwood species such as baldcypress that often co-occur. General restoration planning considerations are discussed as well as more specific elements of bottomland hardwood restoration such as species selection, site preparation, direct seeding, planting of seedlings, and alternative options for revegetation. We recognize that most projects will probably fall more within the realm of reforestation or afforestation rather than a restoration, as some site preparation and the planting of seeds or trees may be the only actions taken. Practical information needed to restore an area is provided in the guide, and it is left up to the restorationist to decide how complete the restoration will be. Postplanting and monitoring considerations are also addressed. Restoration and management of existing forests are included because of the extensive areas of degraded natural forests in need of rehabilitation.

Key words: bottomland hardwood forest, forested wetlands, Lower Mississippi Alluvial Valley, restoration, silviculture

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Chapter 1: Introduction

Definition of Bottomland Hardwoods

The term "bottomland hardwoods" is generally used to describe both the dominant forest tree species and the major forest types that occur on floodplains in the lower Midwest and the southeastern United States. Occasionally, the term is also applied to floodplain forests in other regions. Bottomland hardwoods in much of the scientific literature, and in this guide, include not only the hardwood species that predominate in most forested floodplains but also the softwood species such as baldcypress. The Society of American Foresters' forest cover type classification system (Eyre, 1980) identifies 16 forest cover types found in the southern and central United States (see Appendix A for descriptions) that are considered bottomland hardwoods (table 1.1).

In this guide, bottomland hardwoods are treated as wetlands. Under the wetlands classification system used by the U.S. Fish and Wildlife Service (Cowardin and others, 1979), bottomland hardwoods are in the palustrine system, forested wetland class, and primarily either in the broad-leaved deciduous or needle-leaved deciduous subclasses. It is recognized, however, that not all bottomland hardwoods may be classified as jurisdictional wetlands under the jurisdiction of section 404 of the Clean Water Act (U.S. Army Corps of Engineers, 1987), as there are several methodologies for identifying wetlands. Regardless of whether or not a particular project involves jurisdictional wetlands, the basic principles described in this text will remain the same.

Table 1.1. Bottomland hardwood forest cover types.[1]

Type	SAF Number[1]
River birch-Sycamore	61
Silver maple-American elm	62
Cottonwood	63
Pin oak-Sweetgum	65
Willow oak-Water oak-Laurel (diamondleaf) oak	88
Live oak	89
Swamp chestnut oak-Cherrybark oak	91
Sweetgum-Willow oak	92
Sugarberry-American elm-Green ash	93
Sycamore-Sweetgum-American elm	94
Black willow	95
Overcup oak-Water hickory	96
Baldcypress	101
Baldcypress-Tupelo	102
Water tupelo-Swamp tupelo	103
Sweetbay-Swamp tupelo-Redbay	104

[1] Numbers refer to the classification system used by the Society of American Foresters (SAF). See Eyre (1980) and Appendix A for cover type descriptions.

The common and scientific names, along with information on habitat, flood and shade tolerance, seed ripening and storage requirements, and reproductive characteristics of many tree species common to southern bottomland hardwood forests are given in Chapter 4. Table 13.2 contains the common and scientific names of some wildlife species common in bottomland hardwood forests. In addition, Appendix B lists the common and scientific names of all species mentioned in the text.

Geographic Scope

This guide is designed primarily to provide information for restoration efforts in the lower Midwest, including the Lower Mississippi Alluvial Valley (LMAV; extending from the southern tip of Illinois to the Gulf of Mexico and including portions of Illinois, Missouri, Kentucky, Tennessee, Arkansas, Mississippi, and Louisiana) and the southeastern United States (fig. 1.1). The area with perhaps the greatest forested wetland losses and potential for restoration is the delta portion of Arkansas, Louisiana, and Mississippi. To a lesser degree, the methods described here will be applicable to forested wetlands throughout the United States.

What is Restoration?

Throughout this guide, "restoration" refers to the ultimate goal of bottomland hardwood reestablishment projects. It is therefore necessary to discuss the concept of restoration and contrast it with other commonly used terms, such as "reforestation," "reclamation," "creation," and "enhancement."

Ecological restoration is defined as the return of an ecosystem to a close approximation of its condition prior to disturbance (National Research Council, 1992). This definition, supported by the Society for Ecological Restoration, stresses that restoration is intentional and that it emulates the structure, function, diversity, and dynamics of a previously existing natural ecosystem. The Natural Resources Conservation Service (NRCS) defines a restored wetland as "a rehabilitated degraded wetland where the soils, hydrology, vegetative community, and biological habitat are returned to the original condition to the extent practicable" (NRCS, 1998). The NRCS's definition recognizes that it may not always be possible to completely restore a site to some previous condition, but that it is still desirable to restore it to the greatest extent possible.

These definitions of restoration serve to highlight some of the difficult issues facing restorationists. Although the definitions are seemingly straightforward, questions about what constitutes predisturbance or original forest conditions are ambiguous and need to be considered because they are often open to debate within

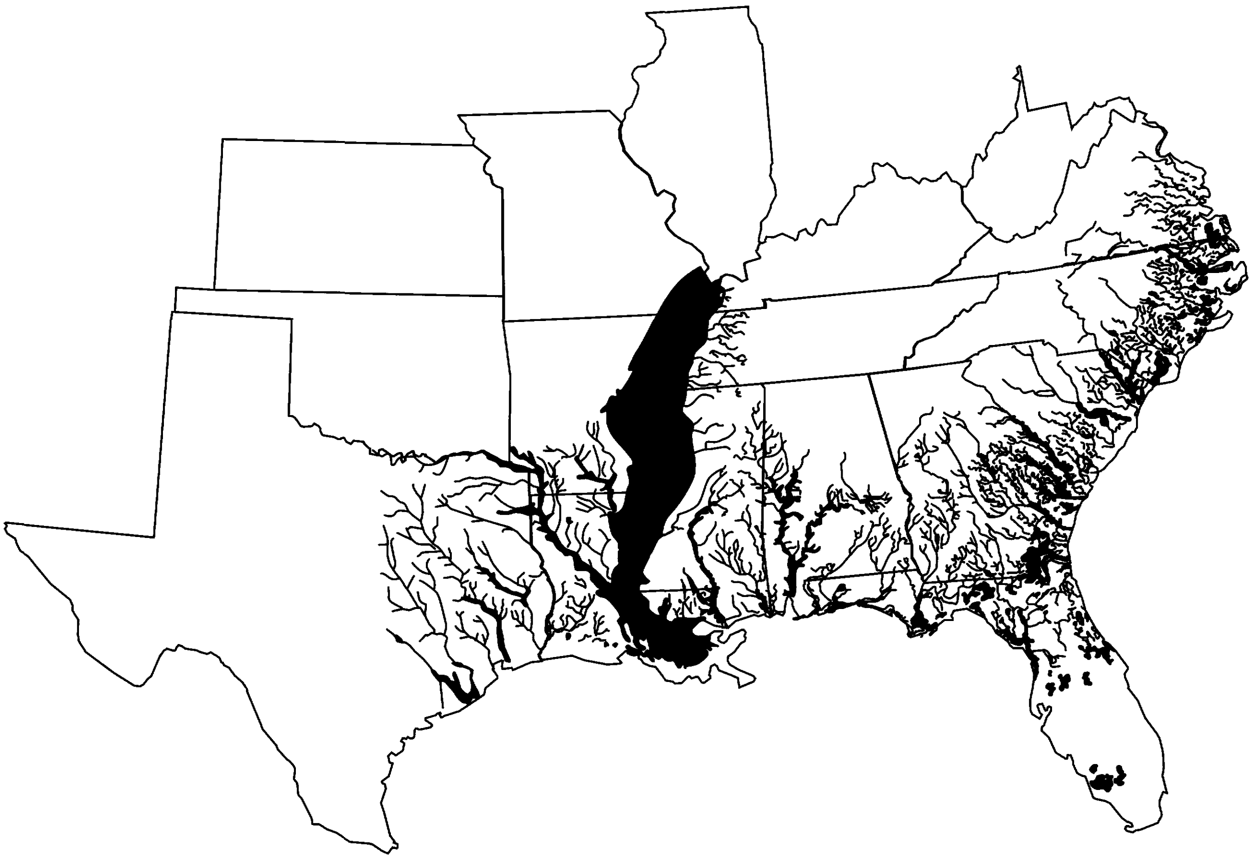

Figure 1.1. Distribution of bottomland hardwood forests along rivers and streams in the lower Midwest and southeastern United States. The dark band shows the extensive area covered by this forest type along the lower Mississippi River (modified from Putnam and others, 1960).

the scientific community. During the height of Pleistocene glacial activity, the forests of the southeastern United States included many boreal forest species such as spruce and fir (Delcourt and Delcourt, 1987). While it may be obvious that we should not try to restore to the Pleistocene community type, it is often not so obvious that forests have been naturally changing for eons and will continue to do so. Factors that have shaped the structure, function, diversity, and dynamics of bottomland hardwood forests over the last 500 years (less than the lifespan of some individual trees in the region) include natural disturbances (e.g., hurricanes, droughts, lightning-caused fires), Native Americans' agricultural practices and use of fire, and the agricultural, silvicultural, drainage, and flood control practices of European settlers. Restorationists need to be aware that, in a sense, they are trying to hit a moving target. Trying to restore to a previously existing natural ecosystem is less important than matching the tree species to be planted with the topographic, soil, and hydrologic conditions that will exist on the site after the project is completed. We must, therefore, use best judgement and any available data to determine the composition and structure of the forests we want to restore.

True ecological restoration may not be possible in many cases because of factors beyond the restorationist's control. For example, Schneider and others (1989) have shown that practically every major stream and hundreds of smaller ones throughout the southeastern United States have been affected by major construction projects. Such projects often affect the timing, magnitude, and duration of flooding as well as groundwater dynamics (i.e., a site's hydrology). Ideally, restorationists would be able to restore the hydrologic regime of their restoration sites, but it is rarely possible to reverse the impacts of major construction projects that affect hundreds or thousands of square kilometers of land. Because hydrology drives wetland ecosystems and determines the type of wetland that will develop, it must be restored if possible. If complete hydrologic restoration cannot be accomplished, then the trees to be planted must be selected based on the expected hydrologic regime. If only the hydrology is restored (a partial restoration), the vegetation and soils will develop naturally over a period of many years (and eventually become a full restoration).

The lack of ability to conduct a full restoration does not eliminate the importance of restoring those functions and values that we understand or restoring an area as close as possible to its previous condition. Restorationists, then, may frequently have to settle for more modest goals than complete ecological restoration, such as partial restoration or one of the terms described below: reclamation, reforestation, creation, or enhancement. Regardless of the level of restoration, the restorationist should maintain a holistic approach to each project and, to the greatest extent possible, establish an ecological community that is not only as close as possible to the original forest but is also well matched to the environmental conditions that will exist on the completed site.

Reclamation is defined by Jordan and others (1988, p. 55) as "any deliberate attempt to return a damaged ecosystem to some kind of productive use or socially acceptable condition short of restoration." Reforestation is defined by the Society of American Foresters (SAF) as the reestablishment of a tree crop on forest land (Ford-Robertson, 1971). With reforestation there is not necessarily any attempt to restore the same species of trees or the same functions that occurred naturally on the site. Establishment is defined as the process of developing a crop to the stage where it can be considered safe from normal adverse influences such as weeds, browsing, or drought (Ford-Robertson, 1971). Without hydrologic restoration, most projects probably fall within the realm of reforestation or reclamation. On any project, the restorationist is faced with the decision to spend a limited budget to completely restore a small amount of land or to reforest a much larger area.

Wetland creation has two meanings. First, it is "the conversion of a persistent non-wetland area into a wetland through some activity of man" (Lewis, 1990, p. 418). This activity generally includes lowering the surface of an upland sufficiently for the seasonal or permanent exposure of the water table. Conversely, wetland creation can be accomplished by filling a deepwater habitat with dredged materials to a sufficiently shallow depth to support wetland plants. The second kind of wetland creation occurs when an entire ecosystem is first destroyed and then re-created on the same site. Creation in this manner takes place, for example, when a wetland is destroyed during the course of surface mining. Following mining, the original ecosystem is re-created on physically reclaimed land, which requires the ecological engineering of new soils and hydrological conditions, as well as the establishment of a biotic community. The term "constructed wetland" is often used interchangeably with "created wetland" and is apparently coming into preferred usage by many practicing restorationists.

Enhancement is defined as "the increase in one or more values of all or a portion of an existing wetland by man's activities, often with the accompanying decline in other wetland values" (Lewis, 1990, p. 418). Examples of forested wetland enhancement include selective removal of some tree species to favor growth of those species that provide greater values to desired wildlife and diking tracts of bottomland forest so that flooding can be controlled (i.e., construction of green-tree reservoirs). In many cases an enhancement for one species or suite of species proves detrimental to many other species. In contrast to enhancement, the process of ecological restoration is holistic and does not favor individual species or particular ecological functions and values to the detriment of other species or functions.

The Need for Restoration

During the last century, a large amount of the original bottomland hardwood forest area in the United States has been lost. Losses have been greatest in the LMAV and East Texas. Of an estimated 9.7 million ha (24 million acres) of bottomland hardwood forest present in the LMAV at the time of European colonization, only 2.1 million ha (5.2 million acres; 22%) remained by 1978 (MacDonald and others, 1979). Approximately 63% of the original bottomland hardwood forest area in East Texas has been lost (Frye, 1987). Proportionally, the most extreme losses of bottomland hardwood forest have occurred in the northern part of the LMAV; in southern Illinois, about 98% of the original bottomland hardwood forest area has been lost (Tiner, 1984).

The primary cause of bottomland hardwood loss has been conversion of the land to agricultural production. Approximately 87% of wetland losses in the United States as a whole has been attributed to agriculture (Tiner, 1984), and the losses of forested wetlands in the LMAV have corresponded very closely to the expansion of agricultural land (MacDonald and others, 1979). Additional losses of bottomland hardwood forests have been caused by construction and operation of flood control structures and reservoirs, drainage and conversion to pine forests, surface mining, petroleum extraction, and urban development.

While many of these alternative uses of bottomland hardwood forest sites are important economically, the functions and values of intact bottomland hardwood forests (storage of floodwaters, water quality improvement, provision of wildlife habitat, etc.) are becoming increasingly appreciated. These functions and values have been described both in technical terms (Wharton and others, 1982; Taylor and others, 1990; Wilkinson and others, 1987) and in terms readily understood by nontechnically oriented readers (Harris and others, 1984).

Growing public concern over the loss of bottomland hardwood forests and wetlands in general has resulted in unprecedented opportunities for protection of this valuable resource. Clearly, preservation of the existing bottomland hardwood resource—through fee title acquisition, easements, or other means—should be the preferred protection strategy. Given the magnitude of the losses that have already occurred, however, restoration of former bottomland hardwood habitats has become a key element in an overall strategy of protection. Over the past 10 years, at least 62,500 ha (154,000 acres) were reforested within the LMAV. Most of this area was planted by the Natural Resources Conservation Service (through the Wetland Reserve Program) or the U.S. Fish and Wildlife Service, although other state and federal agencies have also been involved in planting bottomland hardwood forests (King and Keeland, 1999). The rate of reforestation has been increasing to the point that the amount of LMAV land scheduled for reforestation by all agencies over the next 5 years totals 74,200 ha (183,300 acres). Although the amount of land being restored is commendable, the continuing losses are staggering. From the mid-1970's to the mid-1980's (the most current data available) a total of 364,200 ha (900,000 acres) of forested wetlands were lost in the LMAV region of Arkansas, Louisiana, and Mississippi. Obviously, we are a long way from our national goal of no net loss.

Restoration and Mitigation

The term "mitigation" in this guide refers to the process of rectifying or compensating for the impact on a wetland of a specific development project. In the strict sense, mitigation is a much broader concept than restoration, including avoidance (no impacts to wetlands) and minimization (project modification to reduce the amount of wetlands to be affected) (40 CFR 1508.20 [1998]). Mitigation is usually required as part of the process of obtaining a permit for a development project, such as a "404" permit (Section 404 of the Clean Water Act) for dredge or fill operations in a wetland. Thus, mitigation refers to activities taking place in a regulatory environment. Restoration in this situation can help achieve no net loss of wetlands, but it is not likely to make a significant contribution to making up for past losses.

Because so much of the bottomland hardwood resource has already been lost, the greatest contributions are likely to be made by restoration projects that are not done as mitigation. Voluntary projects to restore agricultural fields, old unreclaimed surface mines, and other such sites on public and private lands are needed if restoration of bottomland hardwood forests is to be achieved on a scale significant enough to achieve a net gain of wetlands.

Restoration, Ecosystems, and Landscape

This guide contains information that is specific to restoration of forested wetlands of the Southeast and lower Midwest. The best approach to restoration is to maintain the overall integrity of ecosystems, including the entire global ecosystem. In practice, however, most restoration projects are conducted in isolation, on a site-specific basis. It is probable that some opportunities to increase the value of an individual restoration project are simply overlooked because not all restorationists are used to thinking of their projects within an ecosystem or landscape context. Therefore, it is worthwhile to consider individual restoration projects within a larger, long-term context.

Where sufficient flexibility exists, restoration sites should be selected to maximize their usefulness within a larger geographic area. One obvious example is to locate the site where it will have the most beneficial impact on water quality (or other desired function) within a watershed. Prime locations are along the edges of existing streams or rivers, especially where the site will act as a buffer between farm fields and other nonpoint sources of pollution and the waterway. Also, by placing a forested wetland near the lower end of a small watershed, it may act as a filter for runoff and floodwaters from the entire area upstream. By shading the water and increasing inputs of plant debris and invertebrates, restoration sites along waterways will also improve habitat values for fish. In some cases, it might be beneficial to choose a restoration site that can act as a screen between an existing site, such as a marsh used by waterfowl, and a road, housing development, or agricultural area.

Opportunities to maximize wildlife habitat values should also be sought. For instance, choosing sites that will increase the size of an existing but isolated tract may improve habitat for forest interior species and reduce nest predation and parasitism. Many of the species in most need of protection require the interior habitat provided by large tracts. On the other hand, sites that will provide a travel corridor between existing tracts of forest might be more valuable than isolated sites in some cases. Corridors, however, may actually have negative or minimal impacts on some wildlife, and any reader contemplating creating a corridor is urged to look at some of the recent literature on this subject (Simberloff and others, 1992; Hobbs, 1992; Rosenberg and others, 1997; Tiebout and Anderson, 1997).

Those involved in land management and restoration should keep abreast of developments in fields such as conservation, biology, and systems and landscape ecology to the greatest extent possible. By developing an increased appreciation of ecosystem and landscape level processes, land-use planners, managers, and restorationists may be able to greatly increase the environmental values of their projects.

The Environmental Impacts of Restoration

The process of restoration can have both positive and negative impacts on the environment. While it is clear that a successfully restored site is healthier and more desirable than a degraded site, there may well be some hidden environmental costs associated with the restoration process that can call the overall value of the project into question.

One of the most obvious negative impacts associated with restoration is when one wetland is degraded to restore another. Plants or topsoil are sometimes removed from intact wetlands and moved to restoration sites. When this causes significant damage to the intact wetland, then the net benefit of the project must be considered to be significantly reduced. Fortunately, this issue is being addressed by professional restorationists, and especially with the ever-increasing availability of commercially produced seed and seedlings, is becoming less of a problem.

The creation of green-tree reservoirs is a common forested wetland management practice that has been shown to degrade bottomland hardwood stands in the Southeast. A green-tree reservoir is typically flooded in the fall to provide waterfowl habitat and then drained during the next spring. This usually changes the timing, duration, extent, and frequency of flooding within these systems. Although flooding during the dormant season is generally not thought to harm most bottomland hardwood tree species, studies have shown that the repeated flooding of green-tree reservoirs can result in the loss of the less water tolerant species. Quite often, the hard mast producing species that the manager wants to maintain, such as Nuttall, cherrybark, and willow oaks, are the very species killed by this management technique. These more desirable species are often replaced by overcup oak, water hickory, swamp red maple, green ash, and baldcypress. In addition, most green-tree reservoirs in the LMAV are not dewatered on schedule each spring (Judy DeLoach, U.S. Army Corps of Engineers Regulatory Functions Branch, Memphis, TN, oral commun.), further impacting the desirable hard mast species.

Another negative impact associated with some projects is the destruction of a healthy upland site to create a wetland. The net benefit of this type of project, which is often required by regulatory agencies, is highly questionable, especially because of the low degree of certainty that a fully functional, sustainable wetland can actually be created on a former upland site. While this kind of project could conceivably have an overall net benefit in some cases, the decision to destroy an upland site to create a wetland should never be taken lightly.

Hydrologic restoration is encouraged to the greatest extent possible; however, full consideration must be given to the landscape context in which the restoration will be developed. Many river processes, such as erosion, sedimentation, etc., are occurring at an accelerated rate. Floodplain wetlands can be overwhelmed and/or severely degraded if unnatural fluctuations in river flow and unnatural loads of sediment, nutrients, and contaminants in the river are not reduced to approximate predisturbance levels (Humburg and others, 1996; Sparks and others, 1998). In this case, the restored vegetation may be destroyed and the site filled in with sediment to the point where it can no longer be considered a (viable) wetland.

Some restoration projects involve extremely high expenditures for the restoration of relatively small areas. It seems reasonable to consider the opportunity costs associated with such projects. For example, is expending $100,000 or more to restore a small, isolated wetland in an industrial area worthwhile, or would it be better to put that money towards some other environmentally oriented project that might have a larger net benefit? There is no simple way to determine the answers to such questions, but they are still worth considering.

Finally, the costs associated with energy-intensive restoration projects should be considered. Use of heavy earthmoving equipment, irrigation, and other operations associated with restoration projects all require energy, primarily from fossil fuels. Even use of nursery-produced planting stock (versus direct seeding or natural regeneration) may involve a moderately high expenditure of energy. Because production and consumption of fossil fuels and most other forms of energy involve negative impacts to the environment, energy efficiency should be considered when planning a restoration project. Although it should certainly not be used as an excuse for skimping on necessary operations such as good site preparation, energy inputs to restoration projects should be reduced where possible.

Sustainability of Restoration Projects

Restored wetlands are no different than other ecological systems in that they are both naturally dynamic and subject to future human-induced perturbations. Examples of natural changes that might be expected to occur include succession and damage caused by storms, animals, insects, or disease. Examples of human-induced perturbations include changes in hydrology as encroaching development increases runoff into the wetland and long-term changes in global climate effects on local weather patterns.

In cases where there is a desire to limit or control natural change (e.g., to maintain a restoration site in a stage dominated by early to midsuccessional species), long-term management of the site needs to be planned. The silvicultural techniques discussed in Chapter 14 will be the primary tools for most forms of long-term management.

The concept of "freeboard" has been suggested as one way of increasing the sustainability of a restoration site in the face of human-induced changes in hydrology (Willard and Hiller, 1990). This concept is that the restoration site should be designed so that there is room for the desired plant community to shift to higher or lower elevations in response to gradual shifts in the site's hydrology. Wetlands with steep transitions to uplands or steep dropoffs to deep water do not have as much freeboard as sites with long, gentle slopes and therefore should be avoided where possible.

The one certainty about a restoration project is that, as time passes, it will be subjected to both natural and man-made agents of change. Restorationists, therefore, need to consider multiple decades when designing projects and not just project time specified in permits or the lifetime of the first generation of trees.

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Chapter 2: General Planning Considerations

A successful restoration project starts with good planning. In general, the plan should define the goals for restoration and subsequent management of the project site and should identify specific procedures to meet the goals. The major steps in the planning process are (1) identify goals; (2) characterize the restoration site; (3) select species to be restored; (4) develop a design for the site; (5) determine site preparation needs; (6) determine best regeneration method(s); (7) determine what postregeneration operations will be carried out; (8) develop a timetable for obtaining planting stock, equipment, and personnel; (9) develop a budget and identify the source of funds; and (10) develop specific performance standards for evaluating project success. Some of these steps are discussed in this chapter while all are covered in more detail throughout the manual.

Project Goals, Objectives, and Success Criteria

Ideally, restorationists should begin their projects by developing a list of general goals or long-term objectives. General goals might include something like (1) establishment of a bottomland forest similar in species composition to the original forest or (2) establishment of a forested wetland that will provide wintering habitat for mallards and wood ducks.

Once general goals have been listed, more specific objectives can be developed. An example of a specific objective is a list of the species to be established and the number of each to be planted per hectare (acre). Another specific objective might be that the site should either flood naturally or have the capability of being flooded artificially during the winter months so that waterfowl can feed within the forest. Much time, effort, and money can be wasted on a project if objectives are not specified in the planning stage, yet simply developing a set of objectives is not sufficient. Specific performance criteria should also be developed to help assess whether the objectives are being met.

Frequently, project objectives are limited to the establishment of vegetation. Success criteria for these projects are often simple, such as the survival rate of all species planted should be at least 50% after one complete growing season, or a minimum of 980 trees per ha (400 per acre) of preferred species should be established on the site; the trees should be at least 2 m (~6 ft) tall and have been growing on the site for at least 24 months.

Therefore, specific goals or objectives and success criteria ideally should be established for all elements of the restoration project. In addition to vegetation, it is desirable to establish criteria for soils, hydrology, water quality, and fish and wildlife habitat. The Mitigation Site Type classification system (MiST; White and others, 1990) provides both general and specific success criteria for bottomland hardwood restoration projects (table 2.1). Although these criteria are directed toward mitigation, they can serve as a starting point for developing more specific success criteria for a given project. The MiST is recommended reading for all restorationists involved with bottomland hardwood and other forested wetland systems. In many ways the planning process from an overall landscape perspective is an artistic process and deserves optimum time and attention to detail before moving forward toward implementation.

Project Site Design

The level of effort put into project site design can vary considerably. For small projects that do not involve extensive earthmoving or are not being carried out for mitigation, the design may simply be what a restorationist envisions. For larger, more complex projects, the process of site design may involve development and review of a series of engineering drawings depicting surface contours, structural specifications, and locations of various forest types to be planted (fig. 2.1). Regardless of the level of detail in the final design, the process of site design should only begin after project objectives have been determined and the site evaluation is completed.

The three-stage design process outlined in the Soil Conservation Service's (now the NRCS) Engineering Field Handbook (Soil Conservation Service, 1992a) is appropriate for the design of restoration projects. Their first step, data collection and evaluation, is analogous to the site evaluation process described in Chapter 3.

The second stage is the development of a preliminary design, which consists of (1) developing a list of the general project features; (2) identifying any structures needed; and (3) developing a preliminary layout of the site (e.g., contours, location of any stream channels, and location/area of vegetation types to be established). The preliminary design may consist of a variety of alternatives and should be sufficiently detailed to allow for a well-informed choice of alternatives based on both ecological and economic grounds.

The third stage is development of the final design, which consists of (1) assessment of the accuracy of the data used in the preliminary design; (2) review of the accuracy of all drawings developed in the preliminary design; (3) selection of alternatives; (4) development of final drawings depicting site layout and any structures; and, ideally, (5) production of a report covering both the

Table 2.1. General definitions of mitigation success used in the Mitigation Site Type classification system (MiST) (see White and others, 1990 for more information).

General definitions of mitigation success
Vegetation Successfully mitigated project sites shall contain: (1) An approved species composition represented by self-sustaining species populations. (2) Adequate tree abundance in terms of overall density and spatial distribution throughout the project site. (3) Well-established trees (e.g., trees should have been growing on site for at least 1 year). (4) An adequate representation of undergrowth species.
Soil A successfully mitigated site will be considered acceptable if it has the physical and chemical properties that are necessary for the successful reestablishment of the desired forest ecosystem. At a minimum, the soil will contain hydric characteristics as listed in the definitions of the current U.S. Army Corps of Engineers Wetland Delineation Manual.
Hydrology Successfully mitigated sites should have conditions similar to an undisturbed reference ecosystem, particularly in the frequency, duration, and seasonality of the flooding or soil saturation and the source of the water.
Water quality Water quality success will be achieved when the frequency distribution of monitored parameter values for the project site overlaps 90% of the frequency distribution of the reference site when graphically represented. Minimally, measured levels of parameters should not violate State or Federal water quality standards.
Fish and wildlife habitat Because of the long-term nature of forested wetland restoration, the habitat for fish and wildlife will be considered restored if the success criteria for vegetation, soils, and hydrology are met.

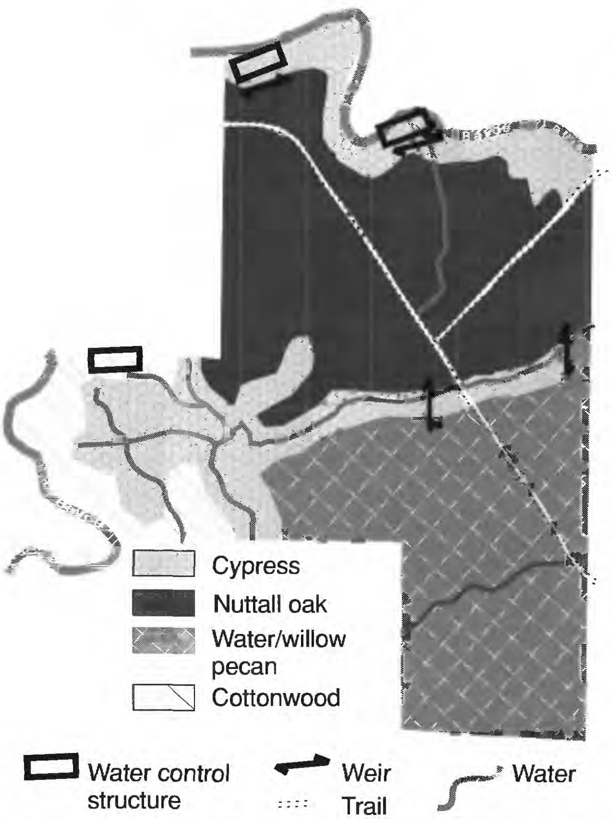

Figure 2.1. Engineering drawings depicting surface contours, structural specifications, and locations of various forest types to be planted can be helpful when designing a restoration project.

final design and a plan for any relevant operation, maintenance, and monitoring.

Review and approval by a licensed civil engineer may be required for designs of structures and surface contours. Local NRCS officials and relevant regulatory agencies should be contacted to determine what regulations apply to restoration project designs.

Regeneration Method

Several regeneration methods have been used effectively to restore bottomland hardwood forests. These methods include direct seeding, planting seedlings, planting cuttings, and transplanting saplings or larger trees. Natural regeneration and topsoiling (the spreading of topsoil from a healthy wetland over a restoration site to introduce seeds and other propagules) are other options that are effective in some cases and should also be considered. Regeneration methods are described in more detail in Chapters 7, 8, 9, and 10.

The final choice of regeneration method should be based on a thorough knowledge of the advantages and disadvantages of each method, characteristics of the species to be planted, condition of the site, availability of planting stock, personnel, equipment requirements, and costs. It is worth noting that, on many restoration projects, combinations of planting methods have been used effectively. For instance, direct seeding might be used as a primary method for regenerating trees, while topsoiling could be employed to introduce understory species, and seedlings of some difficult to establish tree species could be planted.

Decisions about regeneration methods on a given project should be made well in advance of the planting date to ensure the availability of suitable planting stock. If planting is scheduled for late fall through spring, then the choice of planting methods should ideally be made the previous spring or summer for small sites (smaller than about 8 ha [~20 acres]), and even earlier for large sites.

In a survey of federal and state agencies involved in restoring/reforesting bottomland hardwood sites, King and Keeland (1999) found that nearly half of the restorationists experienced problems obtaining sufficient seed of the desired species, and that greater than 80% were unable to obtain the required number of seedlings. In many cases the restorationists were forced to use substitute species. For example, a general shortage of ash seedlings in 1998 forced restorationists to search for seedlings of a variety of other species as replacements.

Obtaining Planting Stock

In most cases, it is best to obtain planting stock from existing suppliers; exceptions will occur most frequently in the cases of large-scale or long-term restoration programs or when using cuttings, transplants from the wild, or direct seeding. A large number of suppliers operate in the region covered by this guide, including state forestry commission nurseries, private nurseries, and both large- and small-scale seed suppliers (see Appendix C for a partial listing of suppliers).

In general, it is best to obtain planting stock as locally as possible. If purchasing planting stock from a local supplier, be sure that their seed was collected from an acceptable (local) source, which will help ensure (but not guarantee) that the stock is adapted to the region where the planting will take place. It may also help reduce damage to planting stock from shipping. Also, nurseries may need lead time greater than 1 year for unusually large orders of seed or seedlings.

Personnel Requirements

Project planning and supervision should be carried out by well-qualified personnel. The project manager should know which specific technical skills are needed to design a project (e.g., forestry, plant ecology, civil engineering, hydrology) and should take the necessary steps to ensure that skilled personnel are available for each task.

It is also important to ensure that personnel who actually implement the project in the field have the requisite skills and are closely supervised. Personnel may be required for skilled (and sometimes dangerous) tasks, such as heavy machinery operation and herbicide application, and for simpler tasks, such as tree planting. The temptation exists to hire an inexpensive, untrained labor force that is poorly supervised, especially for the simpler tasks. The success of some projects has been drastically reduced, however, by the use of poorly trained and inadequately supervised personnel (table 2.2).

Equipment

Some of the equipment needed for restoration projects is described in the following chapters. Actual equipment needs will obviously vary, depending on type of site preparation needed, planting method(s) used, etc. The restorationist should determine in advance what equipment will be needed and take steps to ensure its availability at the appropriate time. Table 2.3 lists some of the equipment that may be required for a restoration project.

Timing of Project Operations

The need to plan in advance for the acquisition of equipment and planting stock has already been mentioned. In addition, careful planning of the overall operations of the project is required.

Forested wetlands typically have periods where the soil is too wet for heavy equipment to operate. Even if the equipment can operate under wet site conditions, this practice should be avoided in order to minimize compaction and soil erosion. Dry seasons, usually in late summer or fall over most of the area covered by this guide, are a good time to do most of the jobs that involve

Table 2.2. Seven "grievous errors" that have been made on restoration projects in the absence of adequate training and supervision (Clewell and Lea, 1990).

1. Vigorous saplings were loaded at a nursery into open trucks and delivered to a project site dead from windburn and desiccation. The unsupervised planting crew planted the dead trees.
2. Potted trees were delivered on a Friday afternoon and allowed to roast in the direct summer sun before being planted dead on Monday.
3. Gallon-sized trees were removed from flat-bottomed pots and planted in holes dug with pointed spades. Air pockets remained beneath their root balls and stressed or killed many saplings.
4. Nurseries shipped trees of the wrong species, the error was either unnoticed or unreported, and the trees were planted.
5. Mesic trees were planted in hydric sites.
6. Cuttings of willows and cottonwoods were planted upside down.
7. Project sites were not fenced or staked, and work crews planted up to 40% of their seedlings on adjacent land.

Table 2.3. Partial list of equipment occasionally used in restoration projects and examples of how they are used.

Equipment	Use(s)
Dragline	Excavation; removal of topsoil
Scraper	Removal, segregation, and transport of soil and/or overburden
Bulldozer	Removal and spreading of soil and/or overburden; surface contouring
Dump truck	Transport of topsoil
Front-end loader	Removal of soil and/or overburden; loading trucks
Tractor	Site preparation; planting; weed control; fire lane construction
Rippers, chisel, plows, offset disks	Reduction of soil compaction; preparation of soil surface for planting
Mechanical seed planter	Direct seeding
Mechanical seedling planter	Planting bare-root seedlings
Gasoline-powered soil auger	Planting containerized seedlings
Tree spade	Transplanting saplings and larger trees
Dibble bar, sharpshooter shovel	Hand planting seedlings
Backpack sprayer	Weed and exotic plant control
Brushhook, machete	Vine control

earthmoving or other site preparation jobs requiring heavy equipment.

In some cases, sufficient time must be allowed between site preparation and planting so that the soil can settle, the hydrology can be double-checked, a green manure crop can be planted and plowed under, and so on. For relatively complex restoration projects, a schedule of operations should be prepared and approved by key personnel involved in project planning and implementation.

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Chapter 3: Evaluation of the Site

Site is a central concept in the practice of forestry and forest restoration. The term "site" is rarely defined precisely but may be interpreted as being synonymous with the term "habitat." It refers to the place in which trees grow and encompasses both the abiotic (nonliving) and biotic (living) factors that may have an impact on the survival and growth of the trees. The size of an area that is considered one site can vary considerably, as long as the critical environmental factors remain relatively the same.

The term "project site" is used occasionally in this guide. In some cases the project site may be homogeneous enough to be considered as one site in the ecological sense of the word. In other cases, variation within the project site, such as different degrees of flooding, different soil types, slope, aspect, existing vegetation, etc., may require that it be treated as a number of smaller sites, each of which may have different site preparation needs, specific levels of suitability for different species, and so on.

In this chapter, it is assumed that the site to be restored has already been chosen. It is expected that the choice of sites will be limited in most cases, either for legal reasons (e.g., permit requirements that a specific area be restored after surface mining) or for management-related objectives (e.g., the desire to provide a travel corridor for wildlife between two large blocks of forest). The principles described in this chapter, however, can also be used to select a site for restoration.

Once the site is identified, the first task is to conduct a site evaluation. Site evaluation can be informal, involving no more than a windshield survey, or it can be much more elaborate (and expensive), involving the development of ecological baseline information by means of prerestoration monitoring (e.g., hydrology) and analytical testing (e.g., soil characteristics). The intensity of the evaluation will depend on factors such as the restorationist's prior experience with similar sites, the degree to which the site has been altered, and available funds. At a minimum, the site should be walked over or traveled by ATV to confirm the restorationist's expectations from various sources (e.g., NRCS soil survey, etc.). Whatever the intensity of the evaluation, the abiotic and biotic factors described in this chapter should be considered.

Abiotic Site Factors

The most important abiotic factors to be considered in bottomland areas are climate, hydrology, and soils. These three factors interact with each other but are treated separately in this section.

Climate

Climate is one of the major factors affecting tree species distribution and the growth of individual trees. The primary climatic factors operating on trees are precipitation (amount and distribution), temperature regime, and evapotranspiration.

Although climate is critical, it is generally not the most important aspect of a site evaluation as long as the species to be established are within their natural range. There is little or no practical need for a detailed climatic assessment if the planting stock is known to be well adapted to the area. Knowledge of the normal variation in local climate could be very important, however, as the success of any plantings could be adversely affected by extremes of temperature and/or precipitation (i.e., drought or flooding) during the first year or two after planting.

The consideration of climate becomes most important when the introduction of a species not indigenous to the area—or a different subspecies or provenance of an indigenous species—is contemplated. In such cases, it is important to know the general climatic characteristics of the site (see table 3.1), but it may be even more important to know the climatic extremes that can occur. Forestry literature is replete with examples of species introductions that were successful until some natural but uncommon event occurred, such as a prolonged drought or flood, an unusually long, deep freeze, or an ice storm. By definition, nonnative species should not be used in restoration projects.

Table 3.1. Abiotic site data that should be obtained if possible.[1]

Climate	Hydrology	Soils
Mean annual rainfall	Mean annual flood duration	*Degree of soil saturation*
Mean monthly rainfall	Mean growing season flood duration	Presence of pans or depressions
Mean monthly temperature	Mean growing season water table depth	Degree of mottling
Evapotranspiration potential	*Hydrologic system*	Percent organic matter
Incidence of droughts, extreme cold, extreme heat, *ice storms, and hurricanes*	Topographic position	Soil type, texture, structure, depth, pH, compaction, and color

[1] Where mean data is specified above, it is also desirable to obtain an indication of variability (e.g., standard deviations).

Occasionally, microclimate can be an important consideration, but this is less often the case on bottomland sites than on upland sites, where slope and aspect may greatly affect the temperature and moisture regime. The exposed nature of most restoration sites, which can result in hotter and drier conditions than in adjacent mature forested wetlands, must be considered. Frost pockets—low, concave areas that tend to trap cold air—are also sometimes a problem within restoration sites at relatively high elevations. Such areas are not likely to occur on large floodplains, but where present, frost pockets may result in direct damage to trees or may literally uproot seedlings by the process of frost heaving.

Hydrology

Hydrology is the most important factor affecting the local distribution of bottomland tree species within their natural ranges. Hydrology as treated in this guide refers to the frequency, duration, depth, seasonality, and source of flooding and/or soil saturation that occur on a site, as well as the depth of the water table.

Detailed hydrologic data, such as the first three items listed in table 3.1, will often not be available for a given site but should be obtained to the greatest extent possible. The U.S. Geological Survey's Water Resources Division provides real-time hydrologic data online at http://water.usgs.gov. In most cases, the restorationist will have to make do with knowing only the hydrologic system type and the topographic position of the site. Fortunately, much can be inferred about a site's hydrologic characteristics from this information.

The main hydrologic systems in the the lower Midwest and southeastern United States are large alluvial rivers, minor stream bottoms, blackwater rivers (those originating in the Coastal Plain), spring-fed streams, isolated basins, backwater swamps, bogs, and seep areas. Different hydrologic systems can have very different flooding patterns (fig. 3.1). Large alluvial rivers tend to have longer periods of high water, with most of the flooding occurring between November and May. Minor stream bottoms and blackwater rivers tend to have more erratic flooding, since these smaller systems are more responsive to local precipitation. Spring-fed streams, bogs, and seeps tend to have much more stable hydrologic patterns, and groundwater table levels assume greater importance than overbank flooding.

Topographic positions within floodplains include sloughs, natural levees, lower floodplain or first bottoms, terraces, and slopes (transitional areas to uplands; fig. 3.2). The depth and seasonality of flooding, as well as numerous other site characteristics, varies substantially with topographic position. Other sites such as cypress domes support forested wetlands somewhat similar in nature to bottomland hardwoods. These wetlands typically occur as isolated basins rather than within a riverine floodplain.

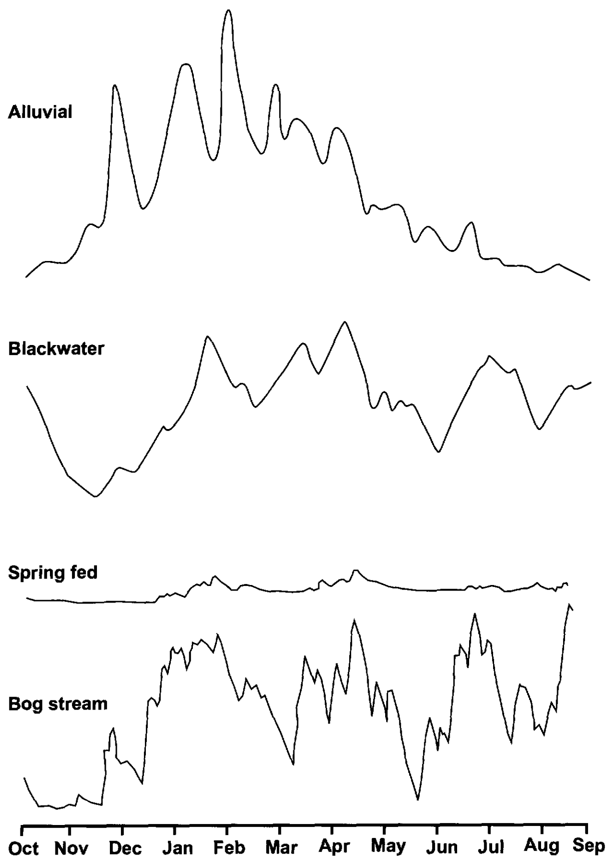

Figure 3.1. Hydrographs of typical bottomland hardwood sites (redrawn from Wharton and others, 1982).

It is important to realize that hydrologic alterations have occurred at most sites. Drainage and flood control projects, diversions of flows, pumping from aquifers, road construction, and numerous other developments are so ubiquitous that nearly every site has a hydrologic regime different than it had 50-100 years ago. A tract of mature forest in the immediate vicinity can be very informative. If the existing overstory trees in the tract look stressed, or the understory trees are mostly either less or more flood tolerant than the overstory trees, then there may have been substantial hydrologic modifications to the site. Hydrologic records, maps, aerial photos, and interviews with people knowledgeable about the site may all be used to determine what types of hydrologic changes have taken place. It may be impossible to restore a site's hydrology back to historic conditions.

In cases where the natural hydrologic pattern of a site has been altered drastically, or for areas that are not naturally bottomland hardwood sites, more specific hydrologic information may be necessary. Along

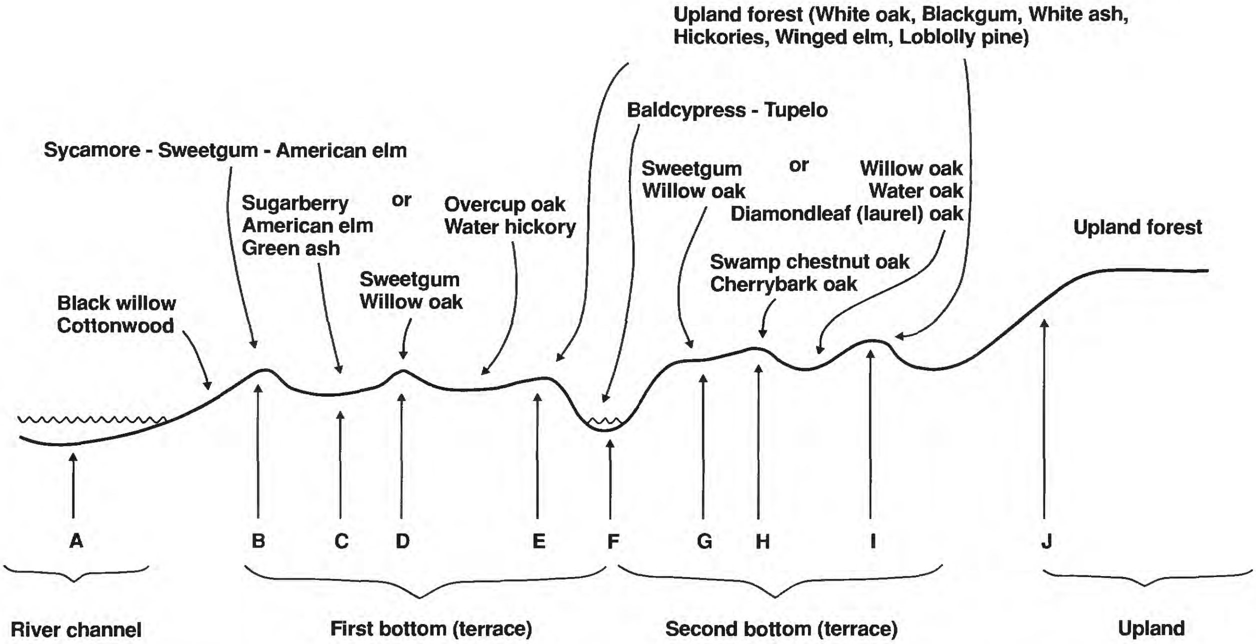

Figure 3.2. Topographic positions and associated forest cover types within a river floodplain (modified from Wharton and others, 1982).

reservoir shorelines, for example, water levels may fluctuate dramatically, and seasonal patterns of flooding and drawdown need to be understood in detail. In areas where heavy machinery has been operated, topsoil has been displaced, or water control structures have been installed, surface flooding and/or water table levels may vary considerably from an undisturbed site. On the most heavily disturbed sites, such as surface-mined areas that have been regraded, it is advisable to collect as much detailed information as is available or even to monitor the hydrologic regime of the site prior to selecting species and initiating planting (see Chapter 13).

Soils

Alluvial bottomland soils generally have more clay and organic matter than upland soils, and therefore they tend to have higher moisture-holding capacity, fertility, and productivity. There are numerous exceptions and potential soil-related problems, however, and an appreciation of soil conditions is important for ensuring the success of a restoration project.

A good place to start evaluating the soils on a site is with the county or parish soil survey. Even if the site has been drastically altered, county or parish soil surveys can provide information on the soil originally found on the site. Soil surveys should be used with caution, however, since the information on forested wetland sites is usually much less detailed than information on adjacent agricultural lands. In many instances, the mapped soil type within a wetland may include one to several areas of a different soil type. Soil surveys are available for most of the counties and parishes covered by this guide and can be obtained from local NRCS offices (also see NRCS National Soil Survey Center data at http://www.statlab.iastate.edu/soils/nssc). The restorationist should know what soil series are present on the project site and be familiar with their basic characteristics. A list of some of the soil characteristics that are often important to know and which are for the most part available in soil surveys is provided in table 3.1.

Soil texture (relative amounts of sand, silt, and clay) is basic information for a restorationist because texture affects other soil characteristics important for tree survival and growth and also because it may greatly affect planting operations. In particular, heavy clay (and organic soils) can present difficulties for planting operations.

Soil moisture characteristics are also critical (see hydrology section, this chapter). In addition to the hydrology data listed in table 3.1, soil color and mottling can provide good indications of the degree of soil saturation. Dark, dull soils (i.e., those with low chroma values) indicate prolonged soil saturation. Soils that are somewhat less saturated may contain brightly colored mottles.

Although soil surveys can provide much information, they are not a substitute for an on-site examination or for soil testing, especially if the site has been heavily disturbed. If there is evidence of soil compaction (e.g., signs of overgrazing, ruts caused by heavy machinery, lots of puddles), it would be worthwhile to determine the bulk density of the soil. Most bottomland hardwood trees will not grow well if bulk density exceeds 1.4 g/cm^3, and they may not survive if the bulk density exceeds 1.7 g/cm^3. Soil penetrometers (fig. 3.3), or simple soil probes, can be used as a quick means to assess the degree of compaction.

On some sites, in particular areas that have been surface-mined for coal, soil pH assumes great importance. Soil pH on these sites may be below 4.0 to 4.5, which is the lower limit that most bottomland species apparently tolerate. Soil can also be too alkaline. Some riverfront soils along the Mississippi and Red Rivers have pH values of 7.5-8, and this degree of alkalinity has probably been responsible for the failure of planting trials with oak species such as Nuttall and cherrybark.

Figure 3.3. Soil penetrometer being used to assess soil compaction.

Sites mined for phosphate may also have a pH in excess of 7, which is high enough to affect the survival and growth of some bottomland hardwood species.

Nutrient deficiencies are generally not a problem on bottomland sites, except where soils have been drastically disturbed (e.g., by surface mining or topsoil removal) or have been in agricultural production over long time periods. In such cases, nitrogen is likely to be deficient. Nutrient deficiencies may be detected by soil tests. Guidelines for soil sampling, testing, analysis, and interpretation can be found in some of the references at the end of this chapter.

Biotic Site Factors

Four biotic factors may affect the success of a restoration project: plant competition (including competition from exotic species), animals, insects, and disease.

Plant Competition and Exotic Species

Competition from other plants for light, water, or nutrients may reduce the survival and growth of planted trees. Although there have been cases where the partial shade caused by competing vegetation actually increased survival of planted trees—and planted trees will usually win out over weeds given enough time—competition generally reduces both overall survival and initial growth. In addition, a heavy plant cover can (1) interfere with tree planting operations, (2) provide habitat for small rodents and other animals that can consume planted seeds or seedlings, and (3) serve as fuel for wildfire. It is therefore important to evaluate the current plant cover on the restoration site and also attempt to determine what type of plant competition may occur after planting.

Certain types of plants can be particularly harmful to planted trees. A heavy growth of vines, for example, can shade tree seedlings and their weight can cause bending or physical damage. Some exotic weeds, such as Johnson grass, Vasey grass, and cogongrass grow so tall and thick that they can reduce growth and significantly increase mortality of planted trees. Fescue, bahia grass, and other turf-forming grasses that are commonly planted for pasturage and erosion control often compete successfully against young planted trees for water during times of drought.

The amount and type of weeds that can be tolerated on a site before or after planting depends on the objectives of the project and the planting methods being considered. There is rarely a need to quantify the weed cover precisely, but it is useful to know if weeds cover much of the site, how tall the weedy vegetation is, and what dominant species are present.

An attempt should be made to determine in advance what type of plant competition may arise after planting. This determination will aid in the planning and budgeting of postplanting operations and can be accomplished by examining similar restoration sites, reviewing available literature, the NRCS Plants Database (http://plants.usda.gov/), or talking to people with knowledge of the area (such as county foresters or agricultural extension agents).

In many restoration projects done as mitigation, there is a requirement that no more than a certain percentage of the total plant cover (typically 5-10%) consists of exotic species. Therefore, a special effort needs to be made to determine in advance what types of exotic plants are likely to become established and what control measures will be necessary. Exotic species of particular concern include melaleuca, Brazilian pepper, and cogongrass in peninsular Florida. Elsewhere, nuisance exotic species may include Chinese tallow, Japanese honeysuckle, kudzu, multiflora rose, wild grapes, and various turf grasses.

Animals

Both domestic animals and various wildlife species may damage or destroy planted trees. The animals most likely to cause damage to planted seeds or seedlings include deer, raccoons, beaver, nutria, small rodents, cattle, and hogs. The restorationist should therefore find out if any of these animals are present in numbers large enough to affect tree species selection or to make specialized protection measures necessary. An accurate appraisal of deer damage may best be obtained by requesting the assistance of a wildlife biologist from the state wildlife agency.

Field personnel need to be trained to look for and recognize animal damage in potential restoration sites (Larry Savage, Louisiana Department of Wildlife and Fisheries, oral commun.; Waller and Alverson, 1997) because grazing can affect the long-term species composition of the site. In the bottomland hardwoods of southern Illinois, deer browsing on planted oaks and natural sugarberry have resulted in an overabundant advanced regeneration of the less palatable sweetgum and boxelder (Larry Savage, Louisiana Department of Wildlife and Fisheries, oral commun.). Boerner and Brinkman (1996, p. 309) reported that "deer browsing was more important than environmental gradients or climate factors in determining seedling longevity and mortality." Seedlings that are fertilized and irrigated in nurseries are especially preferred by browsing deer.

Rodents have caused extensive mortality to restoration projects that have used direct seeding. Savage and others (1996) reported successful seedling establishment by seeding willow oak acorns at rates 62% higher than normal (5,982 per ha [2,420 per acre]) in spite of extensive damage caused by rice and cotton rats. In areas subject to long-term flooding, nutria and beaver have been especially damaging. Nutria can decimate baldcypress regeneration and are a major factor limiting baldcypress regeneration in swamp forests of Louisiana (Conner and others, 1986). Damage to baldcypress usually consists of pulling up the seedling and eating the bark from the taproot. Although seedling protectors have proven successful in some studies, they have not been universally successful and add substantially to the cost of planting.

Insects and Disease

Numerous injurious insects and diseases affect bottomland hardwood tree species. Many of these agents can drastically lower the value of trees for timber production, but seldom will they cause the total failure of a restoration project. Most cases where insects or disease destroyed large numbers of planted seeds or seedlings occurred when the trees planted were not well suited to the site and were therefore heavily stressed. Although it will generally not be a problem, the potential for insect or disease outbreaks should be investigated any time the restorationist is working in an unfamiliar area.

Human Influences

In addition to abiotic and biotic factors, restorationists should assess the potential for human impacts on the restoration site. Among other things, people may use the site as a play area, drive over it in off-road recreational vehicles or farm machinery, accidentally douse it with herbicides from nearby farm or forestry operations, burn it with a carelessly thrown cigarette, or intentionally vandalize it.

Some indirect human influences are much less obvious but can still cause the total failure of a restoration project. For example, residual herbicides applied to previous agricultural crops can stunt or kill many tree species. Some tree planting failures in the Lower Mississippi Alluvial Valley have repeatedly occurred on fields where milo was grown the previous year, and the effect of residual herbicides was a prime suspect. Although the effect of residual herbicides has not been demonstrated experimentally, it cannot be ruled out as a possible influence on restoration success.

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Chapter 4: Species Selection

Tree species selection is one of the more critical phases of a restoration project. An inappropriate choice can result in a total planting failure, an inadequately stocked and underproductive forest, or a forest of minimal value for wildlife.

The choice of species to be planted depends on the project goals, the characteristics of the site, and the availability of planting stock, equipment, and personnel. An informed choice also requires knowledge of the silvical characteristics (see Burns and Honkala, 1990a,b, "Silvics of North America, Volumes 1 and 2") and uses of bottomland hardwood tree species (Putnam and others, 1960).

There is no standard or widely recommended procedure for selecting the species to be planted. Assuming the goal of the project is full restoration and the site has not been irreversibly modified, information about the original forest composition of the site, or of a nearby forest with similar site characteristics (see reference sites section, this chapter), should be used as the basis from which to begin the selection process. Once the restorationist has an idea of the original forest composition (keeping in mind that forest composition is continually changing), then he or she can begin to narrow the number of species to be planted. Species selected must be tolerant of the soils and hydrological conditions on the project site. Flood tolerant tree species (e.g., Nuttall oak or green ash) can be planted in areas that rarely flood, but less flood tolerant species cannot survive in flood prone areas.

Tree species that are likely to colonize the restoration project site by natural dissemination of seeds or other propagules need not be planted, or at least not in great numbers. Assuming a nearby seed source exists, such species generally include sweetgum, sycamore, and the common species of maple, elm, and ash. These species fruit prolifically almost every year and produce fruits that are carried great distances from parent trees by the wind. In contrast, heavy fruited species such as most oaks and hickories should be planted. Such species may produce mast prolifically only once in several years, and their dispersal mechanisms are weak or unreliable.

If the primary purpose of the restoration is for wildlife habitat, fast growing species such as cottonwood or sycamore can be planted to provide some vertical structure within a few years. These species can attain heights of 10 m or more within 3 to 4 years and could provide Neotropical migratory bird habitat during the early developmental stage of the restoration. As these fast growing trees begin to provide vertical structure, their use by birds will assist in increasing biodiversity through the introduction of numerous seeds (Twedt and Portwood, 1997). An additional consideration, especially on private land, might be the market value of cottonwood or sycamore for pulp within 10 years. Schweitzer and others (1999) reported on an experimental cottonwood plantation that was used to provide a financial return to the landowner within 10 years while acting as a nurse crop to Nuttall oak seedlings. Such innovative plantings can provide multiple benefits, including the development of improved soil structure and increased organic matter, while the long-term target vegetation (the underplanted seedlings such as oak) are developing. Upon harvest, some of the cottonwood trees can be retained to provide future sawlogs or den trees.

To assist with the process of species selection, several types of information are provided here. Selected silvical characteristics and wildlife-related uses of 69 bottomland hardwood species are listed in table 4.1. Supplemental information on species associations and ecological relationships, based on the Society of American Foresters cover types listed in table 1.1, is provided in Appendix A. Additional information on matching species and soil types in the Midsouth is supplied in Appendix D, and for the Southern Atlantic Coastal Plain, information is in Appendix E. Also, several references to more detailed treatments of individual species or other aspects of species selection are provided at the end of this chapter (page 34).

Reference Sites

The concept of a "reference wetland" has been used for several years by professionals involved in wetland restoration and creation for mitigation purposes. Using the reference wetland approach, data are collected on the plant community, hydrology, and other characteristics of a natural, relatively undisturbed wetland on a site similar to and in the vicinity of the proposed mitigation site. These data are then used as a basis for designing the mitigation project and judging its success.

Because of the high degree of variability within natural bottomland hardwood forests, the use of a "reference forest ecosystem" has been proposed. A reference forest ecosystem has been defined as a conceptual forest selected for creation or restoration. It is based on forested wetlands represented locally (in the same or a nearby watershed) in terms of species composition and physiognomy. The key difference between a reference forest ecosystem and a reference wetland is that a reference wetland is a specific wetland, whereas a reference forest ecosystem is a composite description from several similar forested wetlands.

Table 4.1. Characteristics of selected tree and shrub species suitable for reforestation in bottomland hardwood forests of the southeastern United States: typical habitat; flood and shade tolerance; seed ripening and storage requirements; reproductive characteristics; and suitability for direct seeding, wildlife food and habitat, and wood products.

Key to Flood Tolerance:

T (tolerant) —Species are able to survive and grow on sites where soil is saturated or flooded for long periods during the growing season. Species have special adaptations for flood tolerance.

MT (moderately tolerant) —Species are able to survive saturated or flooded soils for several months during the growing season, but mortality is high if flooding persists or reoccurs for several consecutive years. These species may develop some adaptations for flood tolerance.

WT (weakly tolerant) —Species are able to survive saturated or flooded soils for relatively short periods of a few days to a few weeks during the growing season; mortality is high if flooding persists longer. Species do not appear to have special adaptations for flood tolerance.

I (intolerant) —Species are not able to survive even short periods of soil saturation or flooding during the growing season. Species do not show special adaptations for flood tolerance.

Species Name	Habitat	Tolerance		Seed ripening	Seed storage requirements[1]
		Flood	Shade		
Ash, green *Fraxinus pennsylvanica*	First bottoms and newly deposited sediments except in deep swamps. Most common on flats or shallow sloughs.	MT	Adult = I; Seedling = MT to T	Sept.- Oct.	Sealed container at 41°F (5°C) and 7-10% seed moisture.
Ash, pumpkin *Fraxinus profunda*	Widely distributed on new sediments, in first bottoms, and edges of swamps. Similar to green ash.	T	Adult = I to MT; Seedling = MT	Oct. - Dec.	Sealed container at 41°F (5°C) and 7-10% seed moisture.
Ash, white *Fraxinus americana*	Widely distributed; however, limited to ridges and high hummocky flats of older alluvium, outwashes from uplands, and creek bottoms.	WT	Adult = I; Seedling = MT	Sept. - Dec.	Sealed container at 41°F (5°C) and 7-10% seed moisture.
Bay, loblolly *Gordonia lasianthus*	Swamps, bays, and wet sites in pine barrens of Coastal Plain.	MT	T to I	Sept. - Dec.	Unknown.
Bay, red *Persea borbonia*	Borders of swamps in rich, moist, mucky soil and wet pine and hardwood flats and bays. Not on alluvial sites.	MT	T	Sept. - Oct.	Unknown.
Bay, swamp *Persea palustris*	Pine barrens, swamp margins, and river bottoms.	MT	T	Unknown	Unknown.
Bay, sweet *Magnolia virginiana*	Edges of headwater and muck swamps and pocosins.	MT	MT	July - Oct.	Store in sealed container at 32-41°F (0-5°C). Seeds stored at higher temperatures should not be cleaned.
Beech, American *Fagus grandifolia*	Mostly creek bottoms and occasionally in minor river bottoms and on ridges of old alluvium or terraces.	I	VT	Sept. - Nov.	Store loosely in sealed polyethlyene bags from fall until February of the following winter at 20-30% moisture and 33-41 °F (1-5 °C).

Key to Shade Tolerance:
In some cases a range of tolerance is given depending on the source of the information. Shade tolerance information has been taken from a variety of sources but predominately from Putnam and others, 1960 and Burns and Honkala, 1990.
Adult —Refers to the shade tolerance of adult individuals. This information is given when it is known that adult and seedlings respond differently to shade.
Seedling —Refers to the shade tolerance of seedlings.
VT (very tolerant) —Species are able to survive and thrive in the deep shade of a closed canopy forest.
T (tolerant) —Species are able to survive and grow in shade, but growth and productivity rates may be slowed somewhat if shade is deep.
MT (moderately tolerant) —Species will survive in moderate shade, but growth rates and seed production may be reduced if shading continues over a period of many years.
WT (weakly tolerant) —Species will grow with partial shading for a portion of each day but require some direct sunlight for normal growth. These species will survive codominant but not overtopping competition.
I (Intolerant) —Species require open conditions and full sunlight for normal growth and development.
Key to Suitability:
H = high
M = medium
L = low
I = insufficient data to determine suitability or unsuitability

Reproductive characteristics	Direct seeding	Waterfowl food	Deer/turkey food	Neotropical migrant	Wood products
Germination best on bare, moist soil in openings. Excellent natural seed dispersal. Sprouts well.	I	L	L	I	M
Seedlings establish on bare, moist soil after water has drained off. Sprouts well from stumps.	I	L	L	I	M
Seedlings establish best in openings on bare, moist soil after water has drained off. Sprouts prolifically from stumps.	I	L	L	I	H
Seedlings establish best in relatively open areas with exposed soil.	I	L	L	I	I
Seedlings establish in both understory and openings. Fire stimulates germination. Sprouts well from stumps.	I	L	L	I	L
Seedlings establish both in understory and openings. Sprouts well from stumps.	I	I	I	I	L
Seedlings establish both in shade and especially in openings and heavy thinnings.	I	L	L	I	L
Regeneration is generally sparse but persistent. Seedlings establish best in shade on moist, well-drained soil. Sprouts well from roots and stumps.	I	L	M	I	L-M

Species Name	Habitat	Tolerance: Flood	Tolerance: Shade	Seed ripening	Seed storage requirements[1]
Birch, river *Betula nigra*	Near river fronts and banks of minor streams. Not below Memphis in the Delta but extends to the coast on secondary streams.	MT	I	May - June	Store at 1-3% moisture content and 36-38 °F (2-3 °C).
Blackgum *Nyssa sylvatica*	Throughout bottoms on ridges and high flats of older silty alluvium. Well drained, silty and loamy soils.	WT	I to WT	Sept. - Oct.	Store over winter in cold, moist sand or in cold storage.
Boxelder *Acer negundo*	Scattered throughout riverfronts of major streams, bottomlands, ridges, and high flats.	MT	MT to T	Aug. - Oct.	Air dry to a moisture content of about 10-15% before storage.
Buttonbush *Cephalanthus occidentalis*	Mostly in Gulf of Mexico coastal plains and Delta. Also in swamps along streams and margins of ponds.	T	T	Sept. - Oct.	Unknown.
Cherry, black *Prunus serotina*	Sparsely scattered throughout on oldest alluvium and outwash from uplands. Often in hammocks.	I	I to MT	Late Aug.- Sept.	Unknown.
Cottonwood, eastern *Populus deltoides*	Mostly on newly deposited soil along major streams, recently abandoned fields, right-of-ways, clean burns, wet spots in pastures, and banks of small drainages and ditches.	WT - MT	VI	May - Aug.	Air dry 4 days at room temperature. Store in stopper vials at 36-40°F (2-4 °C).
Cottonwood, swamp *Populus heterophylla*	Scattered in shallow swamps, in deep sloughs, along often flooded creek bottoms, and on wet spots on low hammocks on the east coast.	MT	I to WT	Apr. - July	Cold storage of 41°F (5 °C) and 5-8% moisture content.
Cypress, bald (baldcypress) *Taxodium distichum*	Very poorly drained organic or clay soils. Swamps, deep sloughs, borders of old lake beds, very wet areas with up to 3 m (10 ft) of flooding. Commonly originates as dense, even-aged stands.	VT	I to WT	Oct. - Dec.	Seeds keep well in dry storage of 41 °F (5 °C) for at least one winter.
Cypress, pond (pondcypress) *Taxodium distichum* var. *nutans*	Shallow piney woods, headwater and/or back swamps, perched ponds, sloughs, and wet flats on lower Coastal Plain, mostly east of the Mississippi River.	T	I	Oct. - Dec.	Seeds keep well in dry storage of 41 °F (5 °C) for at least one winter.
Dogwood, flowering *Cornus florida*	Common in bottoms of minor streams and on well-drained sites.	I	VT	Sept. - Oct.	Store cleaned seeds in sealed containers at 38- 41 °F (3-5 °C) for 2-4 years.

Reproductive characteristics	Direct seeding	Waterfowl food	Deer/turkey food	Neotropical migrant	Wood products
Seedlings establish on moist, well-drained soils. Rapid early growth from seed.	I	L	L	I	L
Sparse regeneration. Germination and establishment only on dry soil. Stumps to 30 cm (12 inches) sprout well.	I	M	M	I	L
Germinates best on moist, bare, mineral soil in shade or openings. Sprouts well from stumps.	I	L	H	I	L
Very moist seed bed is optimum. Stumps of all sizes sprout.	I	M	L	I	L
Seeds establish in bare mineral soil or in leaf litter. Sprouts from stumps.	I	L	M	I	H
Germination best on wet mineral soil. Continued moisture and top light imperative. Sprouts well from stumps up to 30 cm (12 inches).	I	L	M	I	H
Reproduction is erratic and sparse. Germination best on bare, moist, mineral soil. Rapid early growth. Sprouts from stumps up to 30 cm (12 inches).	I	L	M	I	L
Generally poor regeneration but occasionally excellent in openings. Best germination on very moist muck substrate. Sprouting inconsistent from stumps up to 50 cm (20 inches).	I	L	L	I	H
Similar to baldcypress.	I	L	L	I	M
Germination best on bare mineral soil in understory or openings. Stumps of all sizes sprout well.	I	L	H	H	L

Species Name	Habitat	Tolerance Flood	Tolerance Shade	Seed ripening	Seed storage requirements[1]
Dogwood, rough-leafed *Cornus drummondii*	Dry to very wet sites and on soils that range from sand to clay.	T	T	Aug. - Oct.	Store cleaned seeds in sealed containers at 38- 41 °F (3-5 °C) for 2-4 years.
Elm, American *Ulmus americana*	Common on flats in newer alluvium.	MT	MT to T	Late Feb. - June	Store at 3-4% moisture content in sealed containers at 25°F (-4 °C).
Elm, cedar *Ulmus crassifolia*	High flats, poorly drained ridges, usually on impervious silty clay soils.	MT	MT to T	Sept. - Oct.	Air dry and store at 39 °F (4 °C) in sealed containers.
Elm, slippery *Ulmus rubra*	Occasionally on banks of secondary streams.	I	T	Apr. - June	Sealed containers.
Elm, water *Planera aquatica*	Swamps, deep sloughs or low, poorly drained flats. Usually found on clay soils covered with water for part of the year.	T	T	Early spring	Unknown.
Elm, winged *Ulmus alata*	Ridges and high flats of older alluvial soils and terraces. Generally in creek bottoms and hammocks.	WT - I	T	April	Air dry and store at 39°F (4 °C) in sealed containers.
Hackberry *Celtis occidentalis*	Common on flats and river fronts of new alluvium but not in deep swamps.	MT	MT to VT	Sept. - Oct.	Store in sealed container at 41°F (5 °C) for up to 5 ½ years without losing viability.
Hawthorn *Crataegus* spp.	Dry, sandy, stony ridges to moist river bottoms and in margins of swamps.	MT	I	July - Nov.	Unknown.
Hickory, shagbark *Carya ovata*	Moderately well-drained loams.	WT	MT	Sept. - Oct.	Same as for water hickory.
Hickory, shellbark *Carya laciniosa*	On river terraces and on loamy flats in second bottoms. Also grows well on clay and silt loams, dry and sandy soils.	WT	VT	Sept. - Nov.	Same as for water hickory.
Hickory, water (bitter pecan) *Carya aquatica*	Common to flats, sloughs, and margins of swamps of major alluvial streams. Poorly to moderately well-drained clays and loams.	MT	MT	Sept. - Nov.	Store at 41 °F (5 °C) in closed containers for 3 to 5 years. Storage for one winter is achieved by stratification.
Pecan, sweet *Carya illinoinensis*	Current or recent river fronts on moderately well-drained loams.	WT	I to MT	Sept. - Oct.	Store at 41 °F (5 °C) in closed containers for 3 to 5 years. Storage for one winter is achieved by stratification.

Reproductive characteristics	Direct seeding	Waterfowl food	Deer/turkey food	Neotropical migrant	Wood products
Seedlings establish best on moist soil under partial shade. Sprouts well from stumps.	I	L	H	H	L
Germination and establishment on surface of moist mineral soil or on undisturbed humus; seldom on bare areas. Stumps up to 33 cm (13 inches) sprout well. Seeds remain viable submerged for a month.	I	M	M	M	L-M
Seedlings establish in shade or in openings on moist, bare mineral soil. Stumps up to 30 cm (12 inches) sprout well.	I	M	M	M	L
Seedlings establish in shade or in openings on moist, usually well-drained soil. Stumps up to 30 cm (12 inches) sprout well.	I	M	M	M	L
Seedlings establish after water recedes. Sprouts well from stumps.	I	M	L	M	L
Seedling establishment prolific in new openings but sparse in understory. Stumps up to 30 cm (12 inches) sprout well.	I	M	M	M	L
Seedlings often become established in full shade but cannot withstand submergence. Sprouts well from stumps up to 30 cm (12 inches).	I	L	L-M	H	M
Does not readily establish seedlings. Trees are good sprouters.	I	L	M-H	M-H	I
Seedlings require moderately moist seedbed. Sprouts well from stumps.	L	I	M	I	L
Needs moist soil for germination and establishment in understory and openings. Sprouts well from stumps.	I	L	M	I	L
Prolific regeneration in full sunlight. Seedlings are more common in new openings but also occur in understory. Sprouts well from stumps to 50 cm (20 inches).	L	L-M	L	I	L
Adequate regeneration in small or partial openings. Seedlings establish best under about an inch of loamy soil.	M	H	H	I	H

Species Name	Habitat	Tolerance		Seed ripening	Seed storage requirements[1]
		Flood	Shade		
Holly, American *Ilex opaca*	Minor stream bottoms and on high ridges of oldest alluvium.	WT	VT	Sept. - Oct.	Store in sealed container.
Honeylocust *Gleditsia triacanthos*	Scattered in large bottoms on all sites except swamps and sloughs. Grows best on the better ridges of new alluvium.	MT	I	Sept. - Oct.	Seeds will retain viability for several years when stored in sealed containers at 32-45 °F (0-7 °C).
Hophornbeam, eastern *Ostrya virginiana*	Slopes and ridges, occasionally in bottoms.	I	T to VT	Late Aug. - Oct.	Unknown.
Hornbeam, American *Carpinus caroliniana*	Rich, moist loams.	MT	VT	Aug. - Oct.	Store at 35-49°F (7-9 °C) in moist sand, sand and peat, or soil for up to 2 years.
Magnolia, southern *Magnolia grandiflora*	On old alluvium and outwash areas. More common in minor or secondary stream bottoms, hummocks, and wet flats.	WT	T	July - Oct.	Store in sealed containers at 32-41°F (0-5 °C). Seeds stored at higher temperatures should not be cleaned.
Maple, Florida *Acer barbatum*	Drained sites in secondary bottoms.	WT	T	March - April	Unknown.
Maple, silver *Acer saccharinum*	On riverfronts and stream-banks on moderately well-drained loams.	MT	I to T	April - June	Air dry to 30% moisture content before storage.
Maple, swamp red *Acer rubrum*	Common on low, wet flats and edges of headwater swamps.	MT	T	April - June	Air dry to a moisture content of about 10-15% before storage.
Mulberry, red *Morus rubra*	Common on heavy, moist but well-drained soils in first bottoms.	WT - I	T to VT	June - Aug.	Store dry seeds at subfreezing temperature of about -10 to 0 °F (-23 to -17 °C).
Oak, bur *Quercus macrocarpa*	On better flats and low ridges of older alluvium and tributary bottoms north of latitude of Memphis. Commonly found on limestone ridges.	I	WT	Aug. - late Nov.	White oak group
Oak, cherrybark *Quercus pagoda*	Widely distributed on the best loamy sites on all river-bottom ridges and all better drained creek bottoms and hammocks. Predominantly on older alluvium.	WT - I	I	Sept. - Nov.	Red oak group
Oak, delta post *Quercus stellata* var. *mississippiensis*	Large bottoms of the lower Mississippi River. Well-drained, silty clay and loam sites on older alluvium.	WT - I	WT	Sept. - Nov.	White oak group

Reproductive characteristics	Direct seeding	Waterfowl food	Deer/turkey food	Neotropical migrant	Wood products
Seedlings occur in understory and openings. Sprouts well from stumps.	I	L	L	I	L
New seedlings are usually found in openings and rarely in the understory. Sprouts well from stumps.	I	L	L	H	L
Seedlings establish best on moist mineral soil in understory and in openings. Sprouts well from stumps of all sizes.	I	L	L	I	L
Seedlings establish best on moist mineral soil in understory and in openings. Sprouts well from stumps of all sizes.	I	L	L	I	L
Usually good seed crops but low germination. Sprouts well from stumps.	I	L	L	M-H	L-M
Germinates best on moist mineral soil in shade or openings. Sprouts well from stumps.	I	L	I	I	L
Seedlings occur on bare mineral soil in shade or especially in openings. Sprouts well from stumps.	I	L	H	I	M
Germinates best on moist mineral soil in shade or openings, often after water recedes. Sprouts well from stumps.	I	L	M	I	L
Seedlings occur in shade or openings. Sprouts well from stumps.	I	L	M-H	H	M
Germination may be prolific in open bottomland areas. Seedlings are often killed if flooded during the growing season. Sprouts well from stumps and following burning of small trees, but the quality of sprouts is usually poor.	I	L	H	I	H
Good regeneration with full light but never prolific. Poor quality stump sprouts.	H	H	H	I	H
Good regeneration with light but seldom prolific. Seedlings most common in openings. Not a good stump sprouter.	I	I	H	I	H

Species Name	Habitat	Tolerance		Seed ripening	Seed storage requirements[1]
		Flood	Shade		
Oak, laurel (diamondleaf) *Quercus laurifolia*	Near the coast on wet flats, margin of swamps, low clay ridges, or even low sandy loam ridges of blackwater streams.	WT - MT	I - T	Sept. - Oct.	Red oak group
Oak, live *Quercus virginiana*	Usually in well-drained loams and sandy soils along the coast but also may occur in heavier clays.	WT - T	I	Sept. - Dec.	White oak group
Oak, Nuttall *Quercus nuttallii*	Flats, low ridges, shallow sloughs, and margins of swamps in recent alluvial sites, and heavy, poorly drained clays and clay loams. Strictly limited to bottoms of major streams entering the gulf and their larger tributaries.	MT	I	Sept. - Oct.	Red oak group
Oak, overcup *Quercus lyrata*	Widely distributed on poorly drained, heavy soils of major alluvial bottoms. Prevalent in sloughs, on margins of swamps, and in backwater areas.	MT	WT	Sept. - Nov.	White oak group
Oak, pin *Quercus palustris*	In first bottoms and terraces on wet flats with heavy, poorly drained to moderately well-drained clays or clay loams.	MT	I	Sept. - Dec.	Red oak group
Oak, Shumard *Quercus shumardii*	Restricted to well-drained ridge soils in older alluvium and outwash from uplands and to well-drained creek bottoms and hammocks.	WT	I	Sept. - Oct.	Red oak group
Oak, swamp chestnut *Quercus michauxii*	Common in large creek bottoms and hammocks on best, well-drained loamy ridges. Occasionally on a wet, silty clay, high flat.	WT	I to WT	Sept. - Oct.	White oak group
Oak, swamp white *Quercus bicolor*	Extreme northern part of the lower Mississippi Valley, mainly in smaller bottoms on sites with pervious but poorly drained mineral soils.	MT	WT	Sept. - Oct.	White oak group
Oak, water *Quercus nigra*	Widely distributed on loam ridges in first bottoms and on any ridge and silty clay flats in second bottoms or terraces. Moderately well-drained silty clays and loams.	WT - MT	I	Sept. - Nov.	Red oak group

Reproductive characteristics	Direct seeding	Waterfowl food	Deer/turkey food	Neotropical migrant	Wood products
Regeneration erratic but plentiful with light. Seedlings establish in shade or openings but require release. Sprouts when cut or burned.	I	H	H	I	L
Germination best on moist, warm soil. Sprouts well from roots.	M	H	H	I	L
Acorns remain viable in water for up to 311 days. Seedlings establish in openings or shade but die soon under shade. Seedlings are killed by flooding during the growing season. Stumps of young trees sprout readily.	H	H	H	I	M
Germination is best on moist mineral soil in open or shade but dies under continued shade. Seedlings may be killed by high water during first growing season. Sprouts from small stumps only.	M	M	H	I	L
Seedlings become established in understory openings, but many are killed by flooding during the growing season. Seedlings among most tolerant of oaks. Sprouts well from stumps of small trees.	H	H	H	I	L
Seedlings establish best in full light. Overall poor quality of sprouts but better on young trees.	H	M-H	H	I	H
Germination best on moist, well-drained soils with light cover of leaves. Seedlings require full sunlight for best development. Seedlings are intolerant of flooding. Sprouts from small stumps.	M	M	H	I	H
Regeneration is adequate to sparse, never prolific. Sprouts well from stumps.	I	I	M	I	M
Seedlings establish best on moist, well-aerated soil under leaf litter. Prolonged submergence of seedlings during the growing season is fatal. Sprouts readily from young stumps.	H	H	H	I	M

Species Name	Habitat	Tolerance		Seed ripening	Seed storage requirements[1]
		Flood	Shade		
Oak, white *Quercus alba*	Widely distributed on well-drained loams of the oldest alluvium. Common in better drained creek bottoms above the lower Coastal Plain.	I - WT	WT	Sept. - Nov.	White oak group
Oak, willow *Quercus phellos*	Widely distributed on ridges and high flats of major streams. Less common in creek bottoms. Moderately well-drained silty clays and loams.	WT - MT	I	Aug. - Oct.	Red oak group
Pawpaw *Asimina triloba*	Rich soils along streams and in bottoms.	I	VT	Aug. - Sept.	Unknown.
Persimmon, common *Diospyros virginiana*	Scattered widely on wet flats, shallow sloughs, and swamp margins on poorly drained clays and heavy loams. Rare in creek bottoms.	MT	VT	Sept. - Nov.	Clean, dry seeds should be stored in sealed containers at 41 °F (5 °C).
Poplar, yellow *Liriodendron tulipifera*	Mainly on high quality, well-drained terrace site and outwashes of minor streams. Not primarily a bottomland species.	I	I to VI	Aug. - Oct.	Store dried seeds in sealed cans or plastic bags at 36-40°F (2-4°C) for 3 to 4 years. Moist storage in outdoor soil pits or drums of moist sand in cold storage at 36°F (2°C).
Possumhaw *Ilex decidua*	Margins of swamps, streams, and in rich upland soils.	MT	VT	Early autumn	Unknown.
Sassafras *Sassafras albidum*	Scattered widely on any well-drained site, especially moist but well-drained sandy loam soils.	I	I	Aug. - Sept.	Store in sealed containers at 35-41° (2-5 °C).
Sugarberry *Celtis laevigata*	Common on flats and river fronts of new alluvium but not in deep swamps.	MT	T to VT	Sept. - Oct.	Store in sealed container at 41°F (5°C) for up to 5 ½ years without losing viability.
Swampprivet *Forestiera accuminata*	Swamps, wet flats, and other low lying areas.	T	T	Summer	Unknown.
Sweetgum *Liquidambar styraciflua*	On almost all but the wettest sites. Best developed on clay loam ridges of newer alluvium.	MT	I	Sept. - Nov.	Store at a moisture content of about 10-15% in sealed bags at 35-40 °F (2-4 °C) for up to 4 years.

Reproductive characteristics	Direct seeding	Waterfowl food	Deer/turkey food	Neotropical migrant	Wood products
Germination best on moist, well-drained soil under direct light. Seedlings intolerant of flooding. Sprouts well from stumps and following fire damage.	M	H	H	I	H
Germination best in full light on moist, well-aerated soil with light leaf litter. Sprouts from young stumps.	H	H	H	I	M
Seedlings establish well in shade or openings. Sprouts well from stumps.	I	L	I	I	L
Seedlings establish mainly in the understory but also in openings. Sprouts readily from stumps and roots.	I	L	H	I	M
Seedlings establish best on moist seedbeds of exposed mineral soil and survive only in full sunlight. Seedlings cannot tolerate flooding. Sprouts readily from stumps.	I	L	L	I	H
Seedlings occur in understory and especially in partial openings. Sprouts well from stumps.	I	L	L	H	L
Germination sparse but is best on moist, loamy soil with litter. Grows well in openings. Sprouts well from roots and stumps.	I	L	L	M-H	L
Seedlings often become established in full shade but cannot withstand submergence. Sprouts well from stumps up to 30 cm (12 inches).	I	L	L-M	H	M
Germination is best in moist mineral soil. Sprouts well from stumps.	I	L	L	I	L
Germination is best on mineral soil in the open. Sprouts well from roots and stumps.	I	M	L	H	M

Species Name	Habitat	Tolerance		Seed ripening	Seed storage requirements[1]
		Flood	Shade		
Sycamore *Platanus occidentalis*	Widely distributed on fronts of major streams and on banks of minor streams, generally on moderately well-drained loams.	MT	WT to I	Sept. - Oct.	Short-term storage in ventilated open-mesh bags. For longer storage, dry to 10-15% moisture content and store in sealed containers at 20-38°F (-7 to 3°C).
Tupelo, Ogeechee *Nyssa ogeche*	Limited to backwater streams and coastal swamps.	T	I	July - Aug.	Store over winter in cold, moist sand or in cold storage.
Tupelo, swamp *Nyssa sylvatica* var. *biflora*	Nonalluvial muck and coastal swamps, seepage areas of upland, and on edges of secondary and minor bottoms.	T	I to WT	Aug. - Oct.	Store over winter in cold, moist sand or in cold storage.
Tupelo, water *Nyssa aquatica*	Swamps and floodplains of alluvial streams.	VT	I to WT	Sept. - Oct.	Store over winter in cold, moist sand or in cold storage.
Walnut, black *Juglans nigra*	Scattered on well-drained loamy sites, typically a creek bottom species.	WT	I	Sept. - Oct.	Clean seed, 20-40% moisture content at 37°F (3 °C) for 1 year in plastic bags or 50% moisture content in screen container buried in pits for up to 5 years.
Waterlocust *Gleditsia aquatica*	Swamps, sloughs, and wet flats.	MT	I	Aug. - Oct.	Seeds will retain viability for several years when stored in sealed containers at 32-45 °F (0-7 °C).
Willow, black *Salix nigra*	Margins and batture of sloughs of principal rivers, also on ditch banks and swamp margins.	T	VI	June - July	Wet seeds may be stored up to a month if refrigerated in a sealed container.
Willow, sandbar *Salix exigua*	Along river margins, on newly formed, low bars and towheads.	MT	VI	Apr. - May	Wet seeds may be stored up to a month if refrigerated in a sealed container.

[1] See seed handling section, Chapter 6, for information on seed drying. Seeds from the white oak group generally should not be stored due to loss of viability. Seeds from the red oak group can be stored for up to about 6 months. Seed storage for longer than 6 months should be dry, in sealed containers at 32-36 °F (0-2 °C), but viability loss will be significant.

Reproductive characteristics	Direct seeding	Waterfowl food	Deer/turkey food	Neotropical migrant	Wood products
Seedlings establish best on moist mudflats or other exposed mineral soils, never in shade. Seedlings remain viable in water for 1 month. Sprouts well from stumps.	I	L	L	I	M
Germination and establishment occurs in openings on bare mud when the water recedes.	I	M	M	I	L
Germination best in openings on moist seedbed. Seeds remain viable for months in water. Sprouts well from stumps. Sprouts produce viable seed within 2 years.	I	L-M	L-M	I	L-M
Need full sunlight for germination. Seeds remain viable for months in water. Stump sprouts produce viable seeds within 2 years.	I	L-M	L	I	L-M
Seedlings are mainly found in forest openings but are intolerant of flooding. Sprouts well from small stumps.	I	L	L	I	H
New seedlings are usually found in openings and rarely in the understory. Sprouts well from stumps.	I	L	M	I	L
Germination best on very moist, exposed mineral soil. Seeds will germinate in water. Sprouts well from stumps of small trees. Intolerant of competition.	I	L	H	M-H	M
Germination best on very moist, exposed mineral soil. Seeds will germinate in water. Seedlings more flood tolerant than mature trees. Sprouts well from stumps of small trees. Intolerant of competition.	I	L	H	I	L

An inherent difficulty with using either reference wetlands or reference forest ecosystems is that forested wetland restoration projects are long-term efforts. Thus, many years will pass before the restoration project can be compared to the reference. Still, the process of characterizing similar natural wetlands in the vicinity of the restoration site is useful for species selection and for developing success criteria (see Chapter 2).

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Chapter 5: Site Preparation

The main purpose of site preparation is to create suitable growing conditions for tree seeds or seedlings. On sites with minimal disturbance, preparation may consist solely of improving soil structure and reducing the existing plant cover and debris by disking, mowing, or burning. Site preparation may also involve other treatments, such as fertilization, modifications of the site's hydrology, replacing topsoil, or large-scale earthmoving.

Another function of site preparation is to create improved conditions for the use of mechanical planting equipment, which is often necessary following logging (because of all the logging slash, fallen snags, etc.) and is sometimes important in other cases, such as on surface mine sites, where grading may be required.

Site preparation is not always necessary and in some cases may hinder the invasion of woody species. In a study of natural invasion of woody seedlings onto abandoned agricultural fields, Allen and others (1998) found significantly more seedlings in areas that had not been disked. The effects of disking on the long-term survival of seedlings that did become established, however, was not examined in that study, and most studies have shown that site preparation will improve the survival and growth of planted seeds or seedlings. Even though site preparation can add a considerable amount to the costs of restoration, it should never be ignored if the site evaluation indicates it is needed.

Site Preparation on Old-Field Sites

A common type of restoration site is abandoned agricultural land. Since old-field sites are generally well suited for growing agricultural plants, they often require only minimal site preparation to grow trees and other forest vegetation. Trees have often been planted successfully on old fields with virtually no site preparation. The method of regeneration is a key factor in determining the level and type of site preparation on old fields. For example, if seedlings are to be mechanically planted, then the site should not be disturbed unless there is substantial soil compaction (see Restoring Soil section, this chapter). Crop stubble and/or standing weeds should be left alone because they tend to provide better support for the tractor. If seedlings are to be hand planted, then crop stubble should be left standing, but standing weeds in fallow fields should be mowed. For machine planting of acorns on heavy clay soils, the site should be double disked the fall prior to planting to prevent cracking of the soil along the furrow lines during dry weather. If acorns are planted on silty or lighter soils not prone to cracking, the site can be planted without tilling.

Restoring Hydrology

Before any restoration project can be considered complete, the hydrology must be restored to approximate some historic pattern of flooding. As mentioned previously, hydrological records, maps, aerial photos and personal interviews can provide information about hydrologic changes that have taken place. The hydrologic regimes of many old-field sites in the southern United States have been altered either by localized drainage efforts such as ditching or tiling or by larger scale drainage or flood control projects. Some fields are still subject to frequent flooding, although the flooding may not be as deep or as long in duration as it was originally. Other fields flood much less frequently or not at all. In some cases, flooding has been increased by large-scale projects. For example, the Atchafalaya Basin of southern Louisiana is now used as a floodway for a portion of the Mississippi River flow. As such, the bottomland hardwood forests in this area are subjected to increased frequency, duration, and depth of flooding, and they are further subjected to greatly increased sedimentation. The restorationist must also remember that the hydrologic regime refers to groundwater dynamics, soil saturation, and periods of low flow, not just to overbank flooding.

When localized drainage is the primary factor, it may be possible to restore hydrology to its original or an otherwise suitable condition by plugging ditches, removing tiles, building or removing dikes, or some similar manipulation. In many cases, only a portion or portions of a levee or dike will have to be removed, rather than spending the time, effort, and money to remove the entire structure. The remaining portions of the levee will provide topographic relief and increase biodiversity by supporting a different forest community type. In areas where land-leveling has removed ridge and swale topography, a complete restoration will require use of earthmoving equipment to restore surface microtopography and hydrology. Interpretation of historic aerial photography can often provide locations of natural swales and other topographic high and low areas, as well as connections to natural aquatic systems as they existed before land-use conversions, land leveling, and other human-induced modifications.

Ideally, hydrology should be restored by methods that require little, if any, long-term maintenance. Flashboard risers and other water control structures requiring occasional maintenance are acceptable if the area to be restored is under permanent management (e.g., a wildlife refuge) but will become problematic in projects that receive little postplanting attention. If long-term maintenance is required, it is likely that nature will eventually take over, and the area may not remain a wetland. Wetland restoration projects that rely on pumped water, for example, are suspect because of the long-term maintenance and expense required.

Where hydrologic modifications are the result of larger scale drainage, it may not be feasible to restore the natural hydrology. Flood control projects on major rivers or channel modifications that have resulted in a dropping of the water table, for example, may put hydrologic restoration beyond the capability of the restorationist. It may still be possible to partially restore the hydrology with the realization that under some conditions, such as large-scale flood events, an unnatural hydrology may still dominate. In these situations, the best that can be done is to make sure the species planted are appropriate for the expected hydrology.

Whenever a modification of the existing hydrology of a field site is contemplated, every effort should be made to ensure that adjacent landowners will not be affected. Increasing the flooding on a field to be restored, for example, may also increase the flooding of adjacent fields that are still in crop production or possibly on roads or residential areas. Any modification to the local hydrology will likely have some effect outside of the project area. A reduction of flooding in one area almost always results in increased flooding somewhere else. The possibility of these unwanted effects should be investigated before project initiation.

Restoring Soil

Most old fields have at least a moderate degree of soil compaction, mainly because of repeated use of heavy farm equipment. Soil compaction can usually be easily overcome by disking (fig. 5.1). Ideally, fields should be disked no more than 2 months before planting. However, disking may need to be done earlier if mid- to late-winter planting is planned and if flooding is a possibility. Two passes with the disk plow or harrow should be made, and disking should be to a depth of at least 15 cm (6 inches) but preferably 20-35 cm (8-14 inches). Disking to these recommended depths may be difficult or impractical on some heavy clay sites, although it can sometimes be accomplished by waiting until soils are moist throughout the desired depth.

In cases where compaction is especially severe, the field should be subsoiled by using a chisel plow or ripper (fig. 5.2). Subsoiling is most effective when the soil is dry and should be done far enough in advance of planting to allow rainfall to close up and firm the soil. Normally, the soil should be ripped to a depth of 45-60 cm (18-24 inches). On most soils, the tractor should have at least 40 horsepower per shank, but more power may be required on heavy clays. Ripped furrows should be oriented with the landform contour in areas with potential for erosion. Where trees are to be planted in rows, spacing between furrows should correspond to the desired spacing.

Although the soils on most bottomland old-field sites are naturally fertile, their fertility has often been reduced over time by repeated cropping or poor management. In general, nitrogen is the most limiting nutrient, followed by phosphorus and potassium. If the early growth rate of the planted trees is critical, a soil test should be carried out before planting, and the field should be fertilized as needed.

Since fertilization may cause a lush growth of weedy species, it may be necessary to plan for some postplanting weed control if fertilization is planned. If no postplanting weed control is carried out, fertilization may indirectly reduce survival of planted trees by increasing the population of small rodents, which are attracted to the increased weed cover.

Control of Plant Competition

On old fields that have been fallow through one or more growing seasons, weed cover may need to be reduced or eliminated before planting. Eliminating weeds will reduce plant competition and temporarily reduce the number of small mammals that may destroy planted seeds or seedlings. A particularly effective way to do this is by disking because not only does it reduce soil compaction but it increases soil organic matter (by turning the weeds into the soil). A variety of other types of farm or construction machinery can also be used for weed control if necessary (e.g., bushhog, mowers, scrapers, bulldozers), but disking is generally preferable.

Prescribed fire is another tool that can be used to reduce weed cover effectively. Late spring burns, for example, are generally very effective in reducing the cover of highly competitive pasture grasses such as fescue. Fire does, however, have some potentially serious disadvantages. There is always the danger of the fire escaping and causing damage to nearby property, smoke can reduce visibility on adjacent roads, and the time when burning can be done effectively (and safely) is relatively limited. Prescribed fire for weed control should be carried out only by trained personnel with adequate fire control equipment. Also, permits to conduct prescribed burns are required in some areas.

Herbicides are frequently used for weed control in commercial forestry applications but are not recommended for site preparation on old fields except as a last resort. Examples of situations where use of herbicides may be justified include sites where weed cover is too heavy to use a disk, where use of heavier equipment or prescribed fire is not feasible, and on sites with a

Figure 5.1. Old field being disked to alleviate soil compaction before planting. Disking can also be used to create a fire break around a restoration site.

Figure 5.2. Subsoiling for severe cases of soil compaction.

significant cover of exotic or particularly noxious native weed species.

Site Preparation on Heavily Disturbed Sites

Surface-mining and other activities that drastically alter a site have caused much less loss of bottomland hardwood forests than clearing for agriculture. Coal mining, however, has affected some bottomland hardwood areas, most notably in the lower Midwest, and phosphate mining has caused extensive losses in Florida and smaller losses in North Carolina and Tennessee. Peat mining has damaged pocosins in the Carolinas, and localized sand and gravel mining has affected sites throughout the lower Midwest and southeastern United States.

While the losses of forested wetlands due to mines are relatively small, areas affected are much more dramatically altered than agricultural fields (fig. 5.3). Restoration of these sites is costly and complex and should be attempted only by experienced restorationists working closely with mine managers and reclamation engineers.

Throughout this discussion about site preparation on heavily disturbed sites, the term "restoration" is used. The terms "created" or "constructed," however, are often more appropriate for such discussions because an entire ecosystem must be established, including soils, hydrology, and biotic communities. Also, the newly established ecosystems may either be the same types of ecosystems originally on the project site but in different locations than the original systems, or they may be entirely new types of ecosystems.

Surface Contouring

The first consideration for site preparation on heavily disturbed sites is to establish an appropriate surface contour. Because the landscape has been so drastically altered, the restorationist first needs to decide what kind of ecosystems are to be created on the reclaimed land, how they should be placed in relation to each other, and how they should interact with existing ecosystems on adjacent unmined lands. The guiding principle is to integrate the new contour into the regional drainage system.

A restored bottomland forest should function ecologically within the regional drainage system in a manner comparable to bottomland forests on undisturbed lands. Therefore, the restored forest must be positioned where

Figure 5.3. Phosphate mine site showing the degree of habitat alteration.

it receives adequate surface runoff and groundwater baseflow to maintain a desirable hydroperiod. Prediction of the hydrologic regime that will occur after contouring is probably the most technically difficult challenge involved in restoration. Such predictions require that surface and groundwater flows be determined, with full consideration given to seasonal hydrologic patterns and expected flows during extreme events (such as 100-yr storms and unusually dry periods). Ideally, the restorationist should work closely with a hydrologist when designing the surface contour for a project site.

The restorationist should know the types of materials that are available for use as fill for the site and how they will influence hydroperiod, surface and subsurface flow, groundwater quality, and soil development. Clayey materials, for example, may swell upon hydration, possibly affecting water table depths and zones of soil saturation. In other cases, much of the fill material might be nearly pure sand, which will cause entirely different groundwater dynamics and tree survival.

The construction of a stream channel poses special challenges. Extensive gullying and downstream sedimentation can happen during a single heavy rainstorm, requiring difficult repairs and disrupting other project activities. Stream channels are less prone to gullying if they are relatively broad, shallow, and have a gently rounded bottom configuration. They should also have a low gradient and be meandering, rather than straight, because this will act to retard erosive flows in storm events. The bottom should either consist of indurated materials or should be vegetated with densely rooted wetland plants. Grading techniques, soil treatments, and cover crops that encourage the rapid infiltration of surface runoff upslope will also diminish the potential for channel erosion.

It is difficult to create a natural-appearing yet completely stable channel, so it is likely that the shape of the channel will change somewhat over time. Natural stream channels also change over time, thus some change in the course of the created stream channel should be expected, tolerated, and even planned. One way to introduce a dynamic element is to place barriers made of logs at intervals along the created channel. The logs will help reduce stream velocities and initiate meandering. Logs are present in natural streams, and in addition to affecting stream morphology, play a major role in the stream ecosystem by acting as a substrate for invertebrate and algal production and as a site for feeding by fish and wading birds.

Restoring Soil Characteristics

Restoring soils on heavily disturbed sites is a much more difficult and expensive proposition than it is on old fields. Among other things, the soils on heavily disturbed sites may have the original soil horizons mixed together, may be more (or less) acidic, may be highly compacted, and typically have much less organic matter.

Where possible, the impacts of projects that drastically alter soils can be minimized by stockpiling the topsoil (organic material and surface mineral horizons) separately from the underlying horizons. Once the surface is contoured, the topsoil can be placed back on the surface.

The postproject soil conditions will not be identical to preproject conditions, of course, but stockpiled topsoil is still generally preferable to a more thoroughly mixed soil. An exception is heavy clay topsoil, which may impede infiltration of water when spread over mined and reclaimed land. Also, it should be recognized that many bottomland soils are Inceptisols or Entisols (soils with relatively little profile development). This makes identification of topsoil rather difficult, but it is generally safer to mix surface and subsurface soil horizons of young soils than it is to mix more developed soils.

When using stockpiled topsoil, every effort should be made to minimize the time that soil is stored because organic matter and numbers of desirable soil organisms usually decline rapidly. Also, stockpiles should be kept as low as possible because the quality of stockpiled topsoil declines substantially when the depth exceeds 1 m.

The surface soil of a recontoured site will often be nearly devoid of organic matter. Cover crops and volunteering weeds contribute humus, but additional organic matter will accelerate forest establishment and soil maturation. If possible, organic matter should be added to the surface soil at the conclusion of final grading. Composted sludge has shown promise in experimental plots as a source of both organic matter and nutrients. Yard trimmings, which municipalities may provide without charge, are another source of organic matter. Experimental plantings conducted by the Florida Institute of Phosphate Research have shown that hay cover significantly increases tree survival and growth. Hay, if applied in a deep enough layer, conserves soil moisture, prevents the establishment of competitive weeds, retards erosion, and reduces the daily changes of soil temperatures in the root zone. If applied in a thin layer that allows sunlight through to the soil surface, though, seeds carried in the hay can foster pernicious growth of weeds and turf grasses. Pine straw (needles) have also been used effectively as a mulch.

Establishment of Ground Cover

In an effort to reduce soil erosion, many regulatory agencies require that surface mined and other highly disturbed sites be planted with a cover of grass immediately after surface contouring. Usually, a rapidly growing and spreading species such as fescue, Bahia grass, or Bermuda grass is required. Unfortunately, the same characteristics that make these ground cover species good for erosion control make them strong competitors with planted tree seeds or seedlings. Tree survival and growth are almost always diminished when the planting site is covered by these species.

While planting a ground cover species may reduce erosion in some cases, the nearly flat soil surface typical of forested wetland restoration sites and the rapid natural invasion of herbaceous species on these sites already reduce the potential for erosion. Such plantings, which are sometimes required in mitigation plans, are therefore of questionable value on wetland sites.

An alternative to planting aggressive grass species is to plant nitrogen-fixing species (such as clovers, alfalfas, or many other legumes) that can be disked under after one growing season as green manure. Green manuring can reduce erosion and at the same time improve soil structure and fertility. The main drawback to this practice, however, is that the desired tree species cannot be planted during the first growing season after contouring.

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Chapter 6: Seed Collection, Handling, and Storage

Quality seed must be obtained regardless of whether the method of reforestation will be direct seeding or by planting seedlings. It is assumed for the purposes of this guide that the restorationist is not planning to grow his or her own seedlings; rather, it is expected that the seed will either be sown directly on the site to be restored or given to a nursery for seedling production. Guides to the production of seedlings in nurseries are provided in the references at the end of this chapter, but nursery management is too large in scope to be covered in this guide.

Seed Collection

Regardless of the type of seed to be collected, five principles will always apply. First, the restorationist must know when the seed of the species of concern ripens (see table 4.1) and should scout the seed crop as it nears maturity. If adequate storage facilities are available, it is advisable to take full advantage of years with good seed production because collection is easier, usually more of the seed is viable, and it ensures an adequate supply of seed during years with poor seed crops.

Second, collection should take place as soon as the seeds are mature. If seeds are collected too early they may not germinate, or high moisture content may lead to handling and storage problems. If collection begins too late, much of the crop may have been eaten or otherwise made inviable.

Seed maturity is often indicated by color. For instance, the fruits of ashes, sweetgum, yellow poplar, and sycamore all should have turned from green to greenish-yellow or yellow by the time they are collected. Maturity of acorns can be recognized by the color of the nut (pericarp), which is green when immature, brown or black for mature acorns in the red oak group (e.g., cherrybark oak, laurel oak, Nuttall oak, pin oak, Shumard oak, water oak, and willow oak), and brown or a mottled-looking, yellow-brown for mature acorns in the white oak group (e.g., bur oak, Delta post oak, live oak, overcup oak, swamp chesnut oak, white oak, and swamp white oak). Another good criterion for acorn maturity is easy release from the cups; immature acorns are more difficult to separate from their cups.

Third, if possible, seeds should be collected from trees in the same general area as the site to be restored. The abiotic factors of the site where the seeds are collected (see Chapter 3) should resemble those of the restoration site as closely as possible to help insure that the seedlings will be adapted to the local environment.

Fourth, to enhance genetic diversity, seeds should be collected from numerous trees, preferably at least ten. To help maximize genetic diversity, seed trees should be at least 100 m apart. If timber production is an objective, collection should be from mature trees of good form, even though this may make collection more difficult. Likewise, if production for wildlife is the main objective, collection should be from the heaviest seedbearers.

Fifth, records should be kept on each batch of seed collected and include at a minimum the species, the date, and the specific location (provenance) of collection. Subsequent seedling performance for each lot can then be checked, and the best seed sources can be used in future restoration projects.

Most collection of bottomland hardwood seed is done in forests rather than in seed orchards. Seeds are typically collected manually, either by collecting freshly fallen seed from the ground, by using pruning poles, by climbing trees, or by collecting from logging slash (fig. 6.1). When possible, it is worth taking advantage of logging operations, because seed collection directly from felled trees can be easy, and many other seeds will fall on the ground during felling. Mechanized seed collection techniques exist (see references at the end of this chapter).

Inevitably, nonviable seed will be collected along with viable seed, but this can be minimized by learning to recognize indicators of seed quality. If there is evidence of insect depredation, decay, or physical damage, or if the seed feels exceptionally light, it should be discarded. Cutting open a small number of seeds to look for signs of insect infestation, decay, or other problems is advisable.

In the field, freshly collected seed should NOT be kept in plastic or other containers providing low aeration (fig. 6.1), especially if large batches of seed are being collected at one time and it will be a day or more before the seed is processed. The combination of heat buildup due to cellular respiration and the high moisture content of fresh seed can damage seed and promote the growth of molds.

Seed Handling

Seed handling steps include seed extraction and drying, separation of chaff and nonviable seed from sound seed, and in some cases, prestorage treatments. Depending on the type of seed and the type of planting operation planned, not all of these steps may be necessary.

Most seeds, other than heavy-seeded species such as oaks and hickories, require some type of drying and/or extraction process. The first step is usually air-drying. Screens or trays can be set up outdoors (and protected

Figure 6.1. Fresh acorns being collected in an appropriate container in the field.

Figure 6.2. Processing acorns using the float test to determine viability. Nonviable acorns float to the top and are discarded.

from rain, dew, and excessive direct sunlight) in a greenhouse or in a building. Fruits and cones should be air-dried only until the point where extraction is possible (e.g., the cones or pods open up); longer drying may reduce viability. Solar driers, kilns, and other mechanized means of drying are recommended when large batches of seed will be handled annually.

Seeds within fleshy coverings should be extracted before drying to avoid fermentation or spoilage. The fleshy material can be removed first by macerating the fruit by hand (perhaps by rubbing the fruits across hardware cloth) or with a machine such as a feed grinder or commercial seed macerator and separator. The seed of some small stony-seed species (e.g., the hollies) can be extracted using an ordinary blender with a little water added. Following maceration of the fruits, seed can be separated from the fleshy material and other debris by swirling in a bucket of water. Once the seed is completely separated, it will sink if viable.

Because viable acorns of most oak species sink in water, a float test is highly recommended (fig. 6.2). The float test will work for all oak species except overcup oak, which floats when viable because it retains its cup after the acorns are mature. In addition to separating viable acorns from unsound acorns and other chaff, the float test can also serve to rehydrate desiccated acorns.

Acorns should be floated on the day of collection but can be placed in cold storage for several days before floating if necessary. If conditions are dry at the time of collection, acorns should be left in the water for 16-24 h because many viable acorns will float at first if a little dry. The acorns should be stirred once or twice to allow all unsound acorns to float up to the surface. After flotation, the unsound acorns and chaff should be skimmed off the surface and the water drained away. Complete surface drying of the acorns is not necessary, but there should not be enough water remaining to form a pool in the bottom of the container.

Seed Storage

Seeds of many species can be stored for several years (at least five) if dried to a moisture content of 5-10%, placed in airtight containers, and kept at temperatures slightly below freezing (-1 to -18 °C [34-64 °F]). Storage for shorter periods can often be successful at normal refrigerator operating temperatures of around 2-3 °C (36-37 °F) (table 4.1).

Acorns, however, are a special case. Even with the best of care, acorns of white oaks generally cannot be stored longer than a few months, and the percentage of viable red oak acorns drops substantially after 3 years. Following guidelines provided by the U.S. Forest Service's Southern Hardwoods Laboratory (Johnson, 1979; Bonner and Vozzo, 1985), the Louisiana Department of Wildlife and Fisheries has been able to store overcup oak acorns for up to 2 years and Nuttall oak acorns for up to 6 years (Larry Savage, Louisiana State Department of Wildlife and Fisheries, personal communication).

To store acorns successfully, high moisture content must be maintained: about 35% for red oaks and 50% for white oaks (wet weight; see table 4.1). High moisture content is best accomplished by placing the acorns in storage immediately after completing the float test (fig. 6.3). Occasional testing of moisture content is recommended during storage. If the moisture content drops below 30% for red oaks or 40% for white oaks, the acorns should be immersed in water for at least half a day. Actual measurements are not always required; when acorns are stored in clear plastic, condensed moisture on inside bag walls indicates that acorns are still moist.

Figure 6.3. Sacks of acorns in a large cold storage unit.

It is important to keep acorns cool but at temperatures above freezing (1-3 °C [34-37 °F]). Bags or other containers used to store acorns should not be completely airtight but should be loosely fastened. Containers should be separated within the cold storage unit to allow for air circulation. If bags are used, they should be placed on wire racks rather than on solid shelves (fig. 6.3). Turning the bags frequently is also recommended. Polyethylene bags 0.1-0.15 mm (4-6 mils) thick holding up to about 11 kg of acorns work very well because they hold in moisture but allow exchange of oxygen and carbon dioxide, which is necessary because cellular respiration still occurs. Drums or boxes with polyethylene liners are also satisfactory. There is some evidence that because white oak acorns tend to respire more rapidly than red oak acorns, they may store better in cloth bags or polyethylene bags (or liners) as thin as 0.04 mm (1.5 mils) thick. If facilities for refrigeration are not available, acorns can be stored successfully over a winter by burying them 30-60 cm (12-24 inches) underground.

Nuttall oak acorns have also been stored successfully over one winter in refrigerated tap water and wet sand. Storage in water apparently also reduces the number of acorns that germinate in storage.

A 4-8 week period of cold stratification is recommended for most southern oaks. A somewhat longer period (8-12 weeks) is recommended for Shumard oak and water oak. In general, the needs for stratification are met by proper cold storage.

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Chapter 7: Direct Seeding

Direct seeding is an important bottomland hardwood forest restoration technique, particularly for establishing oaks on old-field sites and sites surface-mined for coal. In situations where it can be applied successfully, direct seeding is very appealing because it is relatively inexpensive compared with planting tree seedlings (table 7.1). Direct seeding may cost as little as half of what planting seedlings costs on a per area basis, although the cost depends on factors such as the price of seed and labor, the availability of suitable equipment, and the success of the first direct seeding effort.

Direct seeding is also appealing because of its flexibility. The planting window for direct seeding is much longer than for planting seedlings (see the seasonal timing section, this chapter, and Chapter 8); therefore there is greater freedom in scheduling site preparation and planting operations.

Another advantage of direct seeding is that it allows the tree's roots to develop naturally. In contrast, seedlings taken from a nursery or the wild usually have had their roots pruned, balled up, or twisted. Also, it is very difficult to plant a seedling so that its roots are as spread out as they would be naturally, even if seedlings arrived from the nursery in perfect condition. To do so requires digging a wider planting hole and taking much more care placing soil around the roots than is typically done. This extra attention to planting slows the planting operation and ultimately costs more money. Roots that develop unnaturally may cause the tree to be more susceptible to drought stress and windthrow.

On the other hand, many direct seeding projects have failed, sometimes because newly germinated seedlings lack sufficient energy reserves to survive stresses caused by events such as dry periods. It is likely, however, that most failures have been caused by lack of attention to one of eight controllable factors described by Toumey and Korstian (1942): (1) seed quality; (2) species selection; (3) competing vegetation present on planting site; (4) soil condition; (5) presence of seed predators; (6) seeding rate; (7) timing of seeding; and (8) depth of sowing. The Louisiana Department of Wildlife and Fisheries suggests that proper handling of seeds from cold storage to actual planting be explicitly considered in item (1) above because seed quality can diminish very rapidly if the seed is not protected from heat and sun before planting.

Recent successes, such as those obtained by Louisiana Department of Wildlife and Fisheries personnel in northern Louisiana (fig. 7.1), demonstrate that direct seeding can be effective. In addition, recent evidence suggests that some sites planted by direct seeding of acorns that were considered failures were later determined to meet density requirements. The lack of apparent early success may have been a result of delayed germination, rodents clipping the stem (but not killing the roots), or the difficulty of locating small seedlings in dense herbaceous vegetation. Most practitioners recommend that sites planted by direct seeding should not be abandoned until they have been evaluated at least 5 years after planting.

A major limitation of direct seeding as currently practiced is that its use is restricted mostly to oaks and other large-seeded species. The few efforts that have been made with light-seeded species (such as ashes, sweetgum, and elms) have almost all failed, although some successes with green ash have been reported in West Virginia and eastern Kentucky. The failures were primarily due to depredation by birds and rodents or to drought stress shortly after germination. Because small-seeded species have low energy and moisture reserves they are particularly susceptible to drought. It is probable that these light-seeded species, which must be sown on or near the soil surface, will require some sort of protection in order to become established. Use of rodent and bird repellents may eventually prove successful, but none have been demonstrated to work on bottomland hardwood species at this time. Mulches, slurries, and other techniques may also work, but no evidence exists that these have been tried in bottomland projects. Limited trials in Florida suggest that direct seeding of light-seeded species requires exposed, moist mineral soil and regularly distributed rainfall for several months after seeding.

Seasonal Timing

Most direct seeding is done in late fall, spring, or early summer. Research with red oak acorns indicates that direct seeding may also be successful at all other times of the year; however, Wood (1998) showed that cumulative germination of Nuttall and willow oaks was greatest with December planting (~70%), less with March planting (~50%), and least with June planting (~15%). The period of June through October is not recommended in most of the Deep South.

Species such as the white oaks, which are difficult to store successfully, are most likely to do well when planted immediately after seed collection (i.e., in late fall). Other types of seed can be stored and planted when labor and equipment are not engaged in other activities or when planting conditions on the site are most favorable for the type of equipment being used. At least some red oaks (Nuttall and willow) perform best when planted in December, regardless of flood conditions (Wood, 1998).

Table 7.1. Pros and cons of direct seeding and planting seedlings (from Haynes and others, 1995).

Pros	Cons
Direct Seeding	
Typically about half to one-third as expensive as planting seedlings.	Proven reliable only for oaks and some other large seeded species.
Roots develop naturally without problems caused by disturbing roots and removing seedlings from nursery.	Slower initial establishment and development, although long-term growth and survival may not be significantly different from seedlings.
Acorns may remain in a dormant state for a period of time under adverse site conditions (drought or too wet), thereby increasing survival potential.	Local acorn supply for one or more species may be scarce or difficult to obtain from commercial sources.
Can plant twice as fast, normally using a two-row planter versus a one-row with a seedling planter (however, there are some two-row seedling planters now being used).	Rodents can sometimes be a problem by digging up and eating the acorns; however, planting in large open fields typically results in little damage.
Proven method of reforestation when site is properly prepared using viable seed that has been properly stored.	Cold storage of acorns is generally limited to red oaks (see table 4) and sweet pecan. White oaks do not usually store well for periods greater than 3 months.
Window for planting is longer than for seedlings (acorns can usually be planted successfully from October through April or May).	Acorn-adapted planters (i.e., J.D. Max-Emerge 7100, converted) have more working parts, thus more potential for breakdowns than seedling planters.
	More difficult to monitor success, since it takes several years for germinated seedlings to become large enough to find easily.
Planting Seedlings	
Planting tree seedlings is a reliable and well established method of reforestation.	About two or three times as expensive as direct seeding of acorns.
Usually a good selection of reliable commercial suppliers of seedlings; seedlings available for many species.	Seedlings subjected to adverse site conditions (drought or severe flooding) will perish quickly.
Initial seedling development is faster than for planting acorns, although long-term growth and survival may not be significantly different.	Seedlings must be planted during the dormant period (January through March) when many bottomland forest sites may be flooded. Planting in extreme wet conditions must be done by hand.
Taller seedlings may be able to survive flooding events during the growing season if water does not top the seedling for extended periods.	Seedlings that have been fertilized in the nursery are a preferred food for rodents and deer.
For monitoring compliance and determination of planting success, planted seedlings are easier to locate than newly germinated seedlings from acorns or other seed.	

Depth of Sowing and Spacing

Acorns and other large seeds can be sown successfully at depths between 5-15 cm (2-6 inches). Sowing 5-10 cm (2-4 inches) deep usually results in better germination and survival than sowing between 10-15 cm (4-6 inches), and is easier (and faster) than sowing deeper. Wood (1998) observed significantly greater germination for seeds sowed at 7-10 cm (3-4 inches) than sowed at 3-5 cm (1-2 inches) in the absence of herbivory. Sowing deeper than 10 cm (4 inches) may pay off, however, in situations where there are a lot of rodents or the soil surface is subject to freezing or drying out completely.

Experience has shown that as many as 25% of acorns sown in relatively weed-free old fields, and about 10% of acorns sown in cleared forests, will produce trees still growing well after 10 years. Initial germination and establishment success may be as high as 80%, but usually it is closer to 35 or 40%. Based on these initial germination and longer term survival estimates, sowing of acorns should range from 1,700-3,700 acorns per ha (700-1,500 per acre). On old fields with good site preparation, 1,700-2,500 acorns per ha (700-1,000 per

Figure 7.1. Restoration site where oaks have been successfully established by direct seeding (Ouachita Wildlife Management Area, Louisiana).

Table 7.2. Number of seed or seedlings required per hectare (acre) at various spacings.[1]

Spacing		Number	
Meters	Feet	per ha	(acre)
0.75 × 3.65	2.5 × 12	3,586	(1,452)
0.9 × 1.80	3 × 6	5,977	(2,420)
0.9 × 2.75	3 × 9	3,984	(1,613)
0.9 × 3.65	3 × 12	2,989	(1,210)
0.9 × 4.57	3 × 15	2,391	(968)
1.8 × 1.80	6 × 6	2,989	(1,210)
1.8 × 2.75	6 × 9	1,993	(807)
1.8 × 3.65	6 × 12	1,494	(605)
1.8 × 4.57	6 × 15	1,195	(484)
2.44 × 3.05	8 × 10	1,346	(545)
2.75 × 2.75	9 × 9	1,331	(539)
2.75 × 3.65	9 × 12	995	(403)
2.75 × 4.57	9 × 15	798	(323)
3.05 × 3.05	10 × 10	1,077	(436)
3.05 × 3.65	10 × 12	897	(363)
3.65 × 3.65	12 × 12	746	(302)
3.65 × 4.57	12 × 15	598	(242)
3.65 × 6.10	12 × 20	450	(182)
4.57 × 4.57	15 × 15	479	(194)
4.57 × 6.10	15 × 20	358	(145)
6.10 × 6.10	20 × 20	269	(109)

[1] Assuming a 25% survival rate for direct seeding of acorns, reduce number per area by 75% to estimate the number of surviving trees per area (ha or acre) (Haynes and others, 1995).

acre) should be adequate. Sowing rates of 3,000-3,700 acorns per ha (1,200-1,500 per acre) are recommended for sites where seedling survival is questionable, including mine spoils and areas with a dense vegetative cover. Savage et al. (1996) reported that seeding rates of 5,900 acorns per ha (2,400 per acre) were necessary in a field with a particularly high population of rice and cotton rats. Because acorns are a relatively inexpensive part of the overall direct seedling operation, higher seeding rates should be seriously considered where appropriate.

Direct seeding is generally done in rows, which are most often spaced between 2.5-4.5 m (8-15 ft) apart. Spacing within rows will depend on the distance between rows and the number of seeds sown per acre; a range of possible spacings is depicted in table 7.2. If the aesthetics of the reforested site are an important consideration, the restorationist can avoid the appearance of a plantation, with its neat rows of trees, by planting in wavy lines or even at random. The main thing to keep in mind is to allow adequate growing space around each seed.

Hand Sowing

Direct seeding by hand can be accomplished using very simple and inexpensive equipment. The simplest approach is to use a metal bar, broomstick, or even a stick found in the woods, to make a planting hole. The seed is then dropped in the hole, after which the planter closes the hole with his or her foot. A hand tool, such as the one developed by the U.S. Forest Service (fig. 7.2), can make the job easier because the seed is dropped down the tube to a preset depth in the ground, thereby avoiding the need to bend over to put the seed in the hole. The hole is then closed by foot.

On a relatively clean site with favorable soil moisture conditions, a single planter with the Forest Service's hand planter can sow 2.8-3.2 ha (7-8 acres) per day at a rate of 3,000-3,700 seeds per ha (1,200-1,500 per acre). A planter using just a stick or bar probably will plant no more than 2.0-2.5 ha (5-6 acres) per day. These rates can decline considerably depending upon the experience and physical condition of the planter, the depth of sowing, the distance the planter has to hand carry seed before being able to start planting, and the actual site conditions.

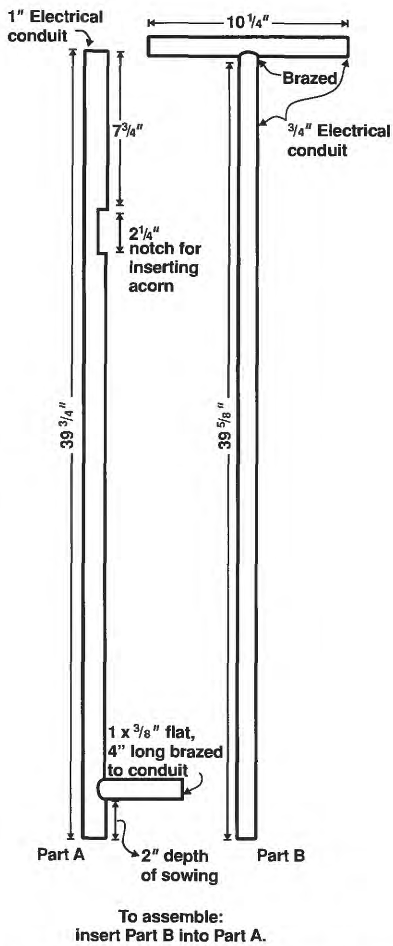

Figure 7.2. This hand tool, developed by the U.S. Forest Service, can make hand sowing of acorns much easier.

Machine Sowing

On clean sites with slopes of 10% or less, sowing seeds with a mechanical planter may work very well. Almost all of the planters that have been used on bottomland hardwood sites in the past are modified agricultural planters.

Two main types of modifications to agricultural planters have been made to date. One modification involves placing seats behind the drop tubes and requires personnel to ride on the planter and drop seeds in by hand (fig. 7.3a). The second modification involves adapting a no-till planter so that it can handle both the deeper planting depths and larger seeds that are necessary when direct seeding acorns, while still dropping the seeds automatically (fig. 7.3b). Specifically, use of agricultural (no-till) planters requires modification of the hopper bottoms and drop tubes to handle acorns (especially the larger species, such as Nuttall oak) and installation of heavy-duty coulters, down pressure springs, closing wheels, and other equipment that allows the planter to dig deep enough into the soil, cut through a heavy weed cover, and drop in large seeds.

Although not essential, an electronic seed monitor is desirable when using modified no-till planters. Seed monitors let the tractor operator know if the hoppers become jammed and seeds are not being planted properly, which is a frequently encountered problem. Jammed hoppers are common because tree seeds tend to be more irregular in size, and more foreign matter is likely to be present than in agricultural seed lots.

Electronic seed monitors are expensive, yet they can be very cost effective. They eliminate the need for constant checking of the hoppers (and replanting rows that were "planted" with a jammed hopper). They can also reduce the size of the planting crew needed, since one person can both drive the tractor and continually ensure that seed is actually being planted.

Use of modified agricultural seed planters can greatly increase the rate of planting. Three people can sow at least 16-24 ha (40-60 acres) per day with the first type of modified planter, and one person can sow up to 8 ha (20 acres) per hour with the second type of planter equipped with a seed monitor.

At least two recently developed planters designed specifically for acorns or other large, irregular seeds appear to have real potential: the Truax large seed planter (fig. 7.4), and a planter designed by the U.S. Forest Service's Missoula Technology and Development Center for sowing multiple rows of acorns in nursery seedbeds (fig. 7.5a,b). The basic design of the U.S. Forest Service planter (fig. 7.5a,b) could probably be adapted for use on restoration sites.

To date, very little direct seeding has been done using broadcast seeders, but this would appear to be quite possible and may become a viable method when there is a desire to avoid the look of a tree farm (i.e., with the trees in neat rows). One trial on the Ouachita Wildlife Management Area in Louisiana showed that the technique is feasible, but another trial showed that the method is less efficient than direct seeding by hand or machine, mostly because of rodent damage (Tom Dean, Louisiana State University, School of Forestry, Wildlife, and Fisheries, unpub. data). A few attempts at broadcast seeding have been made in Florida, but most have resulted in failure. The few successes were on freshly disked sites. More research and development work is needed before any specific guidelines on this approach can be published.

a.

b.

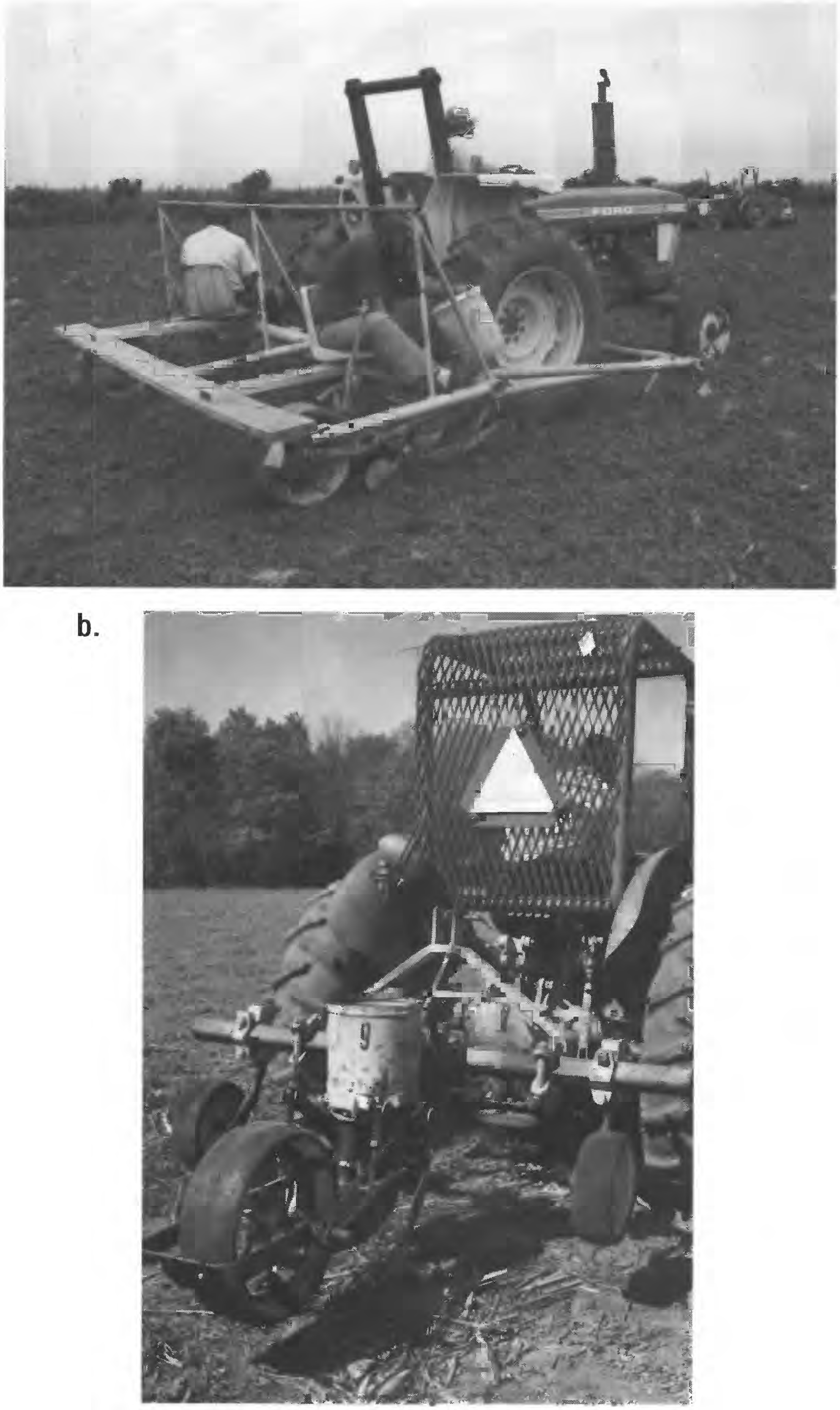

Figure 7.3. Two types of modified agricultural planters used for direct seeding: (a) planter requiring personnel to drop seeds in manually and (b) planter that drops seeds in automatically.

Figure 7.4. The Truax large seed planter.

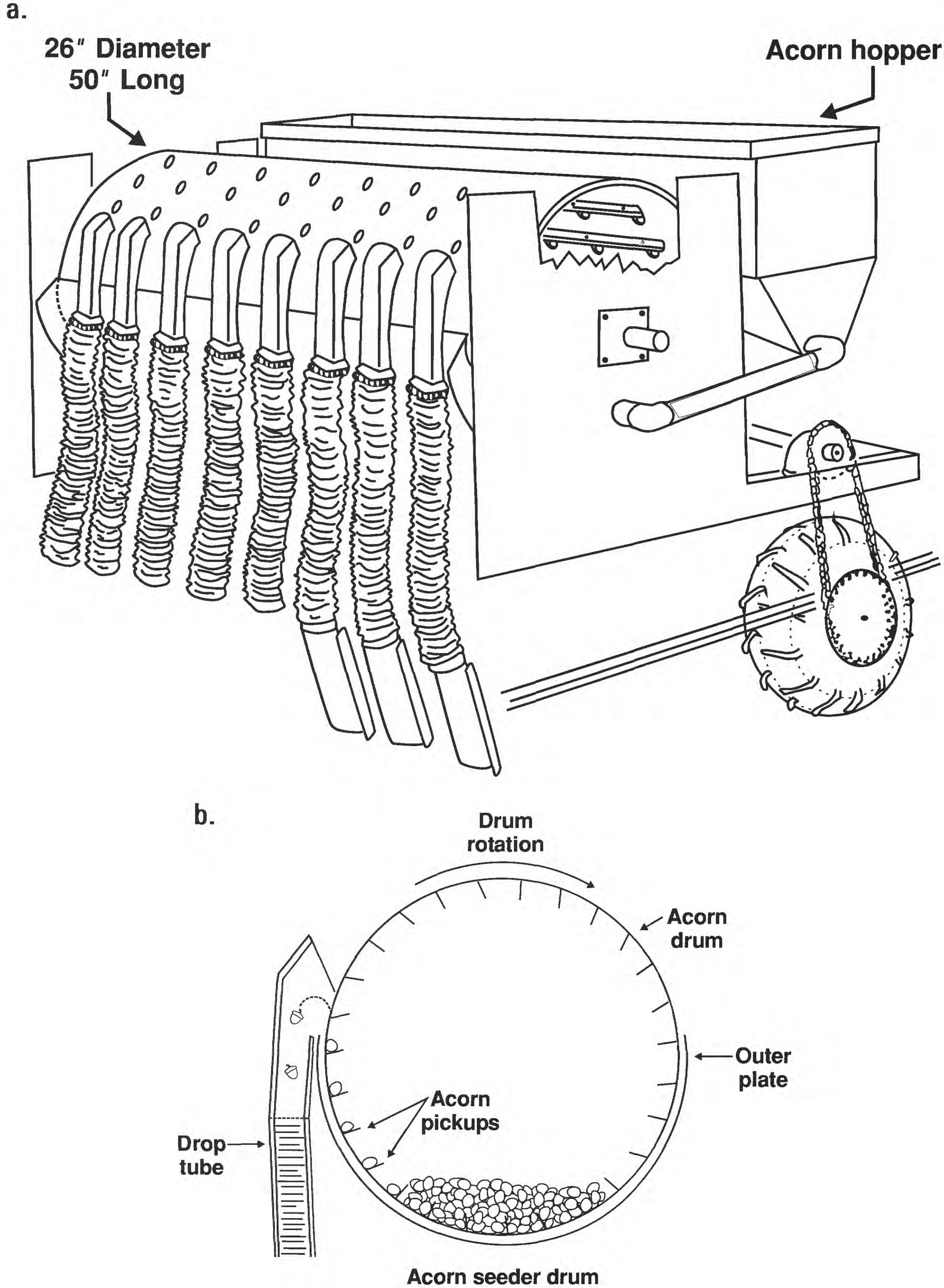

Figure 7.5. Machine developed by U.S. Forest Service for sowing acorns in nursery seedbeds: (a) machine sowing acorns and (b) schematic drawing of hopper mechanism.

Aerial Seeding

Aerial seeding has been widely used in the southern United States to sow pine seed, but it has rarely been used for direct seeding of hardwood species. The primary advantages of aerial seeding are that seeding rates are increased dramatically over manual and mechanical seeding; it can be more cost effective on large projects; it can be employed on sites too wet or unstable for mechanical seeders; and, because it is much faster than machine planting, more area can be planted during the sometimes brief window of suitable site conditions that exist on heavy clay soils. Also, in much of the area covered by this guide, aircraft normally used for crop dusting can be hired for direct seeding. Crop dusters often are not busy at the time of year direct seeding is carried out and may welcome the additional business.

Several small trials carried out between 1989 and 1992 in southern Arkansas, and more recently in the Mississippi delta by U.S. Fish and Wildlife Service, Division of Refuges (Larry Threet, Felsenthal National Wildlife Refuge, oral commun.), have shown that aerial seeding has potential on bottomland sites. In these trials, fields were disked in the fall prior to seeding so that large clods were produced. Then, a crop duster was loaded with acorns (fig. 7.6), and the seeds were broadcast over the field either in the fall or the following spring.

Several methods of burying the seeds after aerial seeding have been tried by the various refuge staffs. The simplest method was aerial seeding immediately before predicted rains with the hope that acorns would be buried as soil clods were broken up by raindrops. In other cases, the soil surface was rebroken in the spring just before seeding using a cutting disk or a field cultivator. All fields in the latter trial were also disked or cultivated after seeding, and some of the area was compacted using a roller drum.

These trials, although promising, showed that several aspects of the process need to be resolved before aerial seeding of bottomland hardwoods is considered a truly

Figure 7.6. Crop duster used for sowing acorns.

effective technique. One problem with aerial seeding is that the standard hopper and gate system on cropdusters cannot handle more than one size class of acorns at a time. Unless a more flexible system is developed that allows several sizes of acorns to be sown simultaneously, multiple passes over a field will be required.

Applied research on calibration of hoppers, gates, and air speeds is needed to ensure desired sowing rates are achieved. Also, definitive guidelines need to be developed on the best ways to ensure that seed is buried deeply enough. For example, the field cultivator worked better than disking when the soil moisture was high. In short, testing of aerial seeding methods needs to be expanded and replicated over a variety of site and soil types.

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Chapter 8: Planting Seedlings

Planting tree seedlings is an old, well-established method of reforestation. The primary advantage of using seedlings is that, overall, the chances for success appear to be higher than with direct seeding. Also, the initial development of the trees is usually somewhat faster. The main disadvantage is the higher cost, since seedlings must first be raised in a nursery (or dug up from under existing stands; see Chapter 9).

Although chances for success are high when planting seedlings, incorrect or careless handling or planting of seedlings can easily result in an expensive failure. In addition to selection of the appropriate species for the site, the keys to successful establishment of tree seedlings are obtaining good quality seedlings, taking proper preplanting care of the seedlings, and using proper planting techniques.

Choice of Seedling Type

There are two major types of seedlings used in planting operations, bare-root and containerized. Bare-root seedlings have been separated from the soil in which they were growing at the nursery by a process known as "lifting," which usually involves cutting the tap root 15-30 cm (6-12 inches) below the soil surface and mechanically loosening the soil around the roots. Containerized seedlings come in a variety of forms, ranging from very small seedlings in small tubes to larger seedlings (or saplings) in gallon-sized or larger pots or bags (fig. 8.1). The choice of seedling type depends to a large degree on the conditions at the restoration site. In some situations bare-root seedlings will be preferred, and in other situations containerized stock will be preferred.

Bare-Root Seedlings

Bare-root seedlings can be expected to survive and grow well as long as the planting site is not too drought-prone and the soil conditions are not otherwise unfavorable. They are less expensive, lighter, easier to transport, and generally easier to plant than containerized seedlings. Bare-root seedlings must be planted during the dormant season, December through mid-March. Some species, such as baldcypress, can be planted along water bodies in flood prone areas later in the season as the water recedes.

Bare-root hardwood and cypress seedlings should have a top height of at least 46 cm (18 inches). The root collar (the part of the root just below ground level) should be at least 0.6 cm (1/4 inch) thick. When possible, though, selected seedlings should have a minimum top height of 60 cm (24 inches) and a minimum root collar diameter of 0.9-1.3 cm (3/8 to 1/2 inch). The use of larger seedlings may be especially important for projects where no site preparation or weed control will be carried out. Although larger seedlings may be more expensive, their use will still generally be cost-effective because mortality will be lower, meaning that less seedlings need to be planted. The cost of planting is usually considerably more than the cost of seedlings; therefore, the higher cost of large, good-quality seedlings may be more than offset by the reduced expense of planting a large number of seedlings. On the other hand, seedlings that are much larger than about 90 cm (36 inches) in top height are difficult to handle and plant. Seedlings in the 60-90 cm (24-36 inches) range are ideal for most applications.

In addition to their large size, bare-root seedlings should have a good balance between shoot size and root volume. The roots should be healthy looking, well-developed (i.e., have several lateral roots greater than about 1 mm [1/25 inch] in diameter), and pruned to a length of about 20 cm (8 inches) (fig. 8.2). Seedlings that have too much top growth for the roots to support will often die back and resprout from the root collar. It is preferable to top prune the seedlings back to a favorable size.

Figure 8.1. Selection of larger sized containers for growing seedlings.

Figure 8.2. Good quality bare-root oak seedlings.

In some cases, it might be desirable to obtain top-pruned, bare-root seedlings. Top-pruned seedlings are cheaper to ship and easier to plant, and they may have better survival or less dieback on sites prone to drought stress. Seedlings can be top-pruned after purchase using simple equipment such as a machete. In general, though, few differences in long-term performance have been found, so the primary advantages of top-pruning may be in lower shipping costs and easier planting.

Containerized Seedlings

When planting on harsher sites and/or outside of the dormant season, containerized seedlings are preferable because their roots are protected by the same soil they were grown in at the nursery. This can lessen the initial shock of transplanting and ensures that the roots of the seedlings remain moist for a longer period after planting.

Containerized seedlings are used most extensively in peninsular Florida, where prolonged dry, hot seasons occur in late spring and again in late autumn. Small containers are also gaining in popularity in the Lower Mississippi Alluvial Valley. The U.S. Army Corps of Engineers has planted over 800 ha (2,000 acres) with containerized stock. Most containerized seedlings are grown in gallon-sized pots, and the seedlings are outplanted upon attaining heights of 45-125 cm (18-48 inches); however, a wide variety of small containers have been recently developed for seedling propagation. Containerized seedlings offer the advantage of reducing transplant shock and have a wider planting window. Burkett (1996) suggested that the more extensively developed root system of containerized stock may offer potential advantages when seedlings are planted at sites prone to drought. Also, inoculation of the containerized seedlings with mycorrhizae slightly but significantly enhanced root fibrosity (Burkett, 1996). If grown in too small of a container, however, containerized seedlings can often be root bound with the roots curled around the inside of the pot (fig. 8.3). Root-bound seedlings tend not to form vigorous root systems when planted. They may grow for several years as vigorous saplings and then suddenly die, their roots apparently unable to supply adequate water during especially dry periods. Quality is hard to summarize for containerized seedlings

Figure 8.3. Root-bound seedling grown in a 1-gallon container.

because of the variety of container types. In general, seedlings should have good root development but should not be root bound. There should be a good balance between root mass and size of the shoot.

Recently, restorationists in Florida have been planting sack-grown trees with much better success. The thin plastic sacks are 0.3 m (12 inches) long cylinders with drain holes at the bottom (fig. 8.4). Roots of sack-grown trees grow downward without curling. After the roots have reached the sack bottom, the seedling is approximately 60 cm (24 inches) tall and ready for planting. Gasoline-powered soil augers drill holes into which the root ball fits snugly. The roots are deep enough when planted to reach moist soil layers during dry seasons. Experimental plot studies by the Florida Institute of Phosphate Research are corroborating the generally superior results of restorationists who have tried sack trees. Costs of growing and planting sack trees are lower than for gallon-sized seedlings, but start-up costs are much higher. The substitution of fabric containers for sacks is still more promising because aeration and root development are more uniform than in plastic sacks. No large-scale trials with fabric containers, however, have been tried.

Another seedling type, used in Florida, is the tubeling or "plug." Plugs have features of both bare-root seedlings and containerized stock. Their densely compacted roots enclose only a very small amount of soil (fig. 8.5). They are grown in specially designed flats, called "liners," from which they are removed before delivery at a project site. Planting of plugs can be accomplished with a bulb planter that extracts a plug of soil, leaving a cylindrical hole (fig. 8.6). They combine the convenience and low cost of bare-root seedlings with a somewhat higher probability of survival on harsh sites. They are less likely to survive during prolonged dry seasons, however, than seedlings grown in larger containers. For this reason, most restorationists opt for

Figure 8.4. Carolina ash seedlings grown in plastic sacks.

Figure 8.5. Dahoon tubelings removed from their pots and ready for planting.

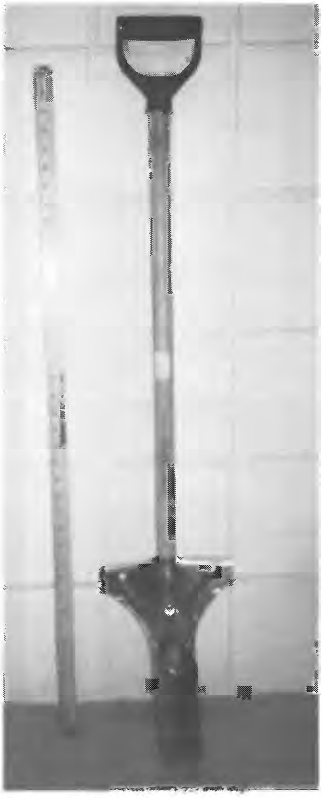

Figure 8.6. A bulb planter is a commonly used hand tool for planting seedlings.

more traditional types of containerized stock. No matter what type is used, only good quality seedlings should be planted. The importance of this cannot be overemphasized. Even if everything else is done right on a restoration project, the project will still be a failure if poor quality seedlings are used.

Handling Seedlings

As discussed, bare-root seedlings have important advantages, but they require especially careful handling. Because their roots are exposed, care must be taken to prevent them from drying out. The seedlings will typically come from the nursery in bundles of about 50 to 200 (up to 400), ideally with their roots packed together and wrapped in sphagnum moss or some type of water-retaining material and the whole bundle wrapped in waterproof paper bags or cardboard boxes.

If the seedlings are not planted immediately, they should be stored at a temperature slightly above freezing, preferably in a cold storage unit. Storage in a barn, shed, or dense shade will be adequate for a few days to a few weeks, as long as the seedlings stay reasonably cool and the roots are not allowed to freeze or dry out.

Another method of temporary storage is "heeling-in." Using this method, seedlings are spread out in a V-shaped trench (dug in a shaded location), and their roots covered with loose soil. The soil is then watered and gently packed down to remove any air pockets, and the roots are kept moist throughout the storage period.

Only as many seedlings as can be planted in one day should be taken to the field. The seedlings should either be taken out of the nursery-supplied bundles and planted immediately or transferred in small groups to a bucket or a planting bag (fig. 8.7). A group of seedlings should never be carried by hand while planting. Smith (1986, p. 296) wrote, "In any step in handling bare-rooted seedlings it is vital that the roots always remain visibly moist. They should not be uncovered for more than 2-3 minutes at any time whether it is just after lifting, in the packing shed, or when it is finally planted. Even briefer exposure is preferable . . . Tree roots are so easily killed

Figure 8.7. A good field method to protect the roots of seedlings is to carry them in a planting bag.

that it is remarkable indeed that many millions of bare-rooted seedlings survive planting."

Although containerized seedlings are less susceptible to freezing or drying out, they can also be damaged or destroyed by careless handling. If containerized seedlings are transported in a closed truck, they can become overheated, especially when planting in late spring or summer. On the other hand, if seedlings are transported in an open vehicle they can become desiccated or damaged by having their stems and leaves blown about in the wind. Seedlings should be transported in ways that provide good ventilation (especially on hot days so that they do not overheat), although too much wind directly on the leaves causes desiccation.

Timing of Planting

The best time to plant bare-root seedlings is when they are dormant and the soil is moist. Generally, planting conditions in the South are most suitable from January through March. Planting can usually be done in November and December, especially for species which have lost their leaves, such as green ash and sycamore, but planting earlier than November is not usually recommended. Planting can also be done later than March if the seedlings are kept in cold storage and the roots kept moist until planting. Planting bare-root seedlings that have broken dormancy is not recommended.

The most frequent limitations on planting are excessive cold and flooding. Bare-root seedlings should not be planted in subfreezing temperatures. The more flood-tolerant species can be planted in shallow water, up to about 15 cm. Disked soils should be moist but not flooded.

An advantage of containerized seedlings is that they can be planted safely once they have broken dormancy. It is still advisable to plant in the winter or early in the growing season while the temperatures are cool and the soil is moist, but as long as conditions are not excessively hot and dry, later plantings will usually be successful. In Florida, containerized seedlings are also successfully planted at the beginning of the summer rainy season, which usually starts in June.

Spacing

Spacings of planted seedlings will depend on objectives. Spacings of 3 × 3 m (10 × 10 ft) or closer are often used for wood production and may be required to ensure the number of surviving seedlings stipulated in some permits. In other cases, wider spacings can be used, such as 3.6 × 3.6 m (12 × 12 ft), 4.5 × 4.5 m (15 × 15 ft), or 6 × 6 m (20 × 20 ft). The standard spacing for the Natural Resources Conservation Service and the U.S. Fish and Wildlife Service is 3.6 × 3.6 m (12 × 12 ft). Because fewer seedlings are required per hectare (see table 7.2), wider spacings are more economical and may be just as effective in meeting the project objectives. Also, using a wider spacing will allow openings for the natural invasion of light-seeded tree species. Wide spacing of the seedlings is one potential, but not always reliable, method for increasing species diversity on the restoration site.

As mentioned previously, making the spacing very precise is undesirable unless timber production is the primary goal or weed control by mowing or disking is planned. A tree farm appearance should be avoided if wildlife, aesthetics, or a more natural appearing forest are the primary goals.

Planting with Hand Tools

Bare-root seedlings can be planted using a dibble bar or sharpshooter shovel (fig. 8.8). The proper technique for use of these tools is shown in fig. 8.9. Occasionally, other tools are used, such as grub hoes, mattocks, and hoedads. Regardless of what type of tool is used, roots should be placed in the hole so they can spread out

Figure 8.8. Bare-root seedlings can be planted using a sharpshooter shovel, dibble bar, or bulb planter.

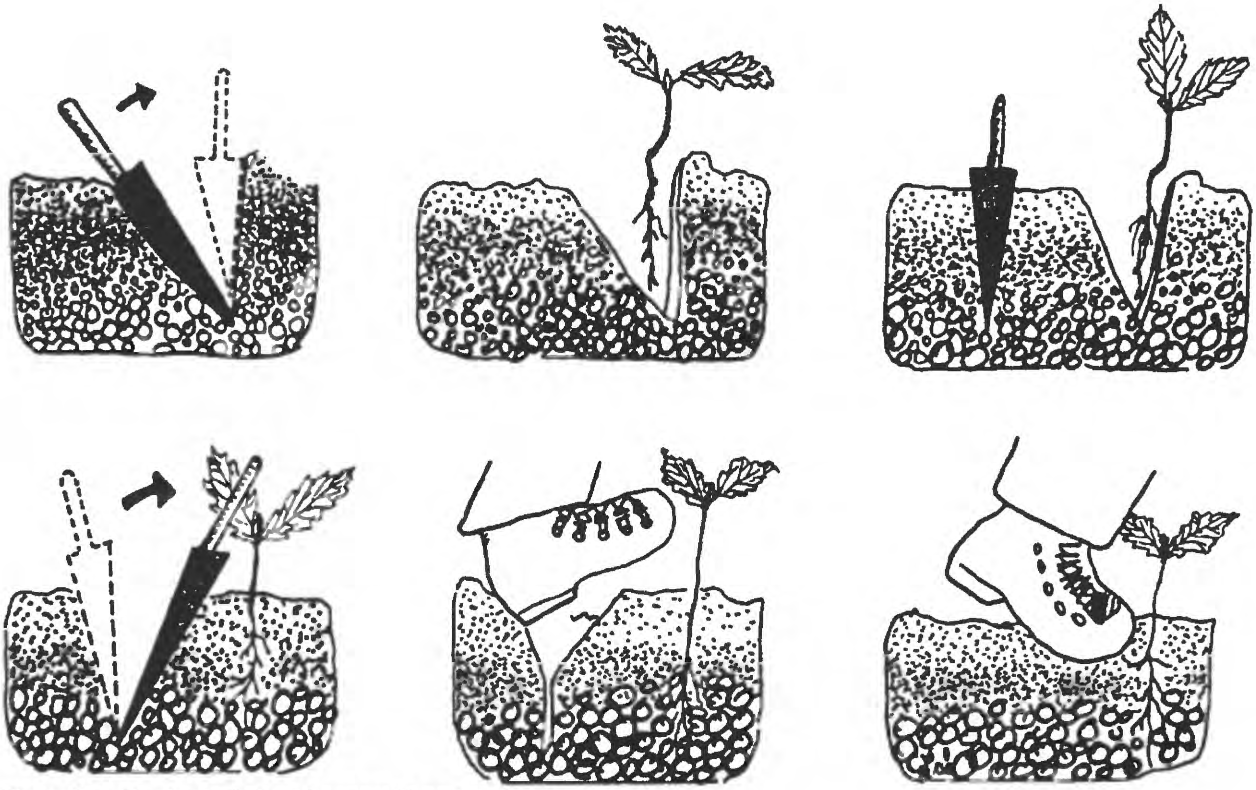

Figure 8.9. Planting technique for use with hand tools.

naturally; they should not be twisted, balled up, or bent. Moist soil should then be firmly packed around the roots. Hand planting of most types of containerized seedlings is done with a shovel, although specialized hand tools have been developed for some of the smallest types of containers.

Planting a tree by hand is a simple task but nevertheless is often done incorrectly. If a crew of inexperienced tree planters is used, it is essential to demonstrate clearly to them the proper way to plant. The crew should be supervised closely, especially the first time they plant and late in the day after they have become tired and perhaps careless.

Seedlings should be planted with their root collars just below the soil surface (fig. 8.10a). One of the most common planting mistakes is planting seedlings either too deep (fig. 8.10b) or not deep enough (fig. 8.10c). Another common mistake is digging a hole too shallow for proper root placement. If this occurs, roots may be bent upwards, or "J-rooted" (fig. 8.10d), which results in roots not penetrating deeply enough into the soil to protect the tree from windthrow or drought. Additional mistakes are planting so that settling soil leaves the root-collar exposed and leaving an air pocket near the roots after closing the hole (fig. 8.10e), which allows the roots to dry out.

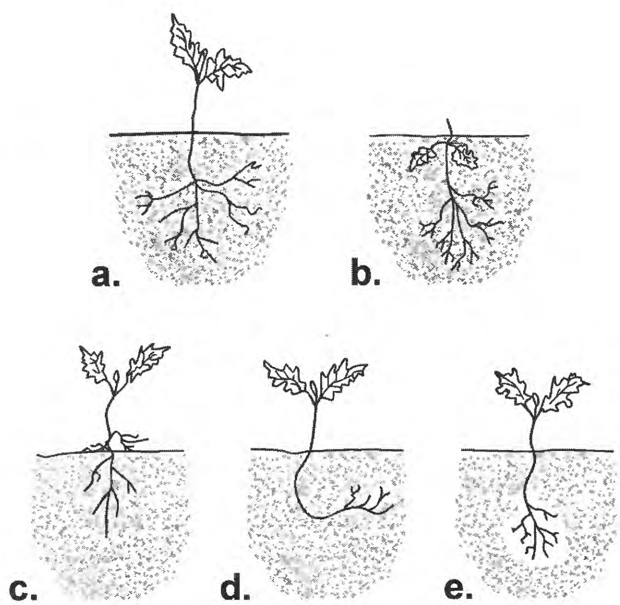

Figure 8.10. It is critical that tree seedlings be (a) planted properly; they should not be planted (b) too deep, (c) too shallow, (d) with roots bent upwards, or (e) with air pockets.

When planting containerized seedlings, the container should be removed first, although this may not be as critical if the container is biodegradable. If a biodegradable container is not removed, it should be trimmed so as not to protrude above the ground, since this can cause drying of the soil through a process known as "wicking." When seedlings are removed from their containers, any roots encircling the outside of the root ball should be loosened up and pointed outwards and downwards or removed. Otherwise, these roots will not spread out properly and could even girdle the stem. The seedlings should be planted in a hole deep enough so that the tops of the root balls are slightly below ground level. The final step in planting a containerized seedling is to fill the hole and pack the soil firmly around the root ball to remove any air pockets and keep the seedling pointed straight up.

Just like the number of seeds a single person can plant in a day will vary widely, the number of seedlings that can be planted will also vary, depending on factors such as the size and type of seedling, degree of site preparation, spacing, soil type, soil condition, weather, experience and physical condition of the planter, and distance the planter has to carry seedlings before being able to start planting. On a clean, level site, a planter should be able to plant at least 500 to 800 bare-root seedlings per day or sometimes up to 1,000 seedlings per day for planters with more experience. Because planting quality can diminish through the day as the crew becomes tired, planting quality should be monitored more closely after several hours of work. The number of seedlings planted per day will be much less if containerized seedlings are being planted, the locations of individual seedlings must first be marked, or if planting conditions are suboptimal.

Planting with Machines

When site conditions are favorable, machine planters can speed up the planting of bare-root seedlings dramatically on soils other than heavy clays. An experienced crew of two or three may plant from 4,000 to 10,000 seedlings a day with a machine planter. Also, survival will often be better than that achieved by a large, relatively inexperienced crew of hand planters. Some of the newer planting machines perform well in heavy clays, planting 5,000 to 8,000 seedlings per day with an experienced crew.

One disadvantage of machine planters is that intensive site preparation may be required. Machines cannot readily operate where there are stumps or heavy debris. On heavy clays, planters may become clogged or be unable to penetrate deeply enough to ensure that the roots are completely covered. Also, the furrows dug by the planter may reopen in the summer when the clay dries out, thereby exposing the roots. On abandoned

Figure 8.11. Mechanical seedling planter.

agricultural fields, no site preparation may be needed for mechanically planting seedlings. Machine planting is becoming a more extensively used reforestation method and, as new tools are being developed, may become preferred even on heavy clay soils as long as soil conditions (e.g., moisture) remain favorable.

Another disadvantage of mechanical planters is their high cost, which is prohibitive for most small planting projects. It is possible in some areas to rent or borrow a planter; a good source of information on the local availability of planters is the county, parish, or district forester.

An example of one type of mechanical planter is shown in fig. 8.11. Other types of planters, including some that are considerably less expensive, are available through sources such as forestry supply companies.

The planting rate for containerized seedlings may also be increased by using machines to dig the planting holes. Machines that have been used for this purpose range from augers to backhoes, depending on the size of the planting stock.

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Chapter 9: Other Options for Revegetation

Although direct seeding and planting seedlings are the two most widely used techniques for reestablishing bottomland hardwood trees, there are several other regeneration methods available. In this chapter, four methods of revegetation are covered: use of cuttings, transplanting, topsoiling, and natural regeneration.

Cuttings

Several species of bottomland hardwoods can be readily propagated with cuttings, or short lengths of young shoots. Cuttings can be rooted first in a nursery and then planted as seedlings, or they can be directly planted on the restoration site. Cuttings of black willow, cottonwood (fig. 9.1), green ash, and sycamore have been successfully planted as unrooted cuttings. For most other species, using rooted cuttings is likely to be more successful.

Cuttings should be obtained in the dormant season and can either be stored until spring or planted right away. Effective temporary storage methods include placing the cuttings in cool water or covering them with wet burlap or similar material. Long-term storage can be achieved by bundling cuttings and refrigerating them in moist sand or plastic bags.

Success has been obtained with cuttings ranging in size from 10-15 cm (4-6 inches) “slips” to poles of 2.5-3 m (8-10 ft) in length, depending on the species. In general, cuttings 40-50 cm (16-20 inches) long and no less than about 0.6 cm (1/4 inch) in diameter at the top end should be used. Larger cuttings may be necessary on sandy or drought-prone soils.

Cuttings are usually planted vertically with the buds pointing upwards and the tops of the cuttings projecting 5-10 cm (2-4 inches) above the soil surface. Cuttings of cottonwood, green ash (fig. 9.2), sycamore, and black willow have also been planted horizontally, in slits about 2.5-5 cm (1-2 inches) deep.

Cuttings should be planted when dormant because survival generally decreases substantially if they are planted once the buds have begun to open. Ideal planting sites are moist but not flooded for long periods. Seedlings usually survive better than cuttings in areas with extensive flooding in the growing season.

Transplants

Seedlings or saplings transplanted from natural forests (also known as “wildlings”) are sometimes used in restoration projects. Depending on size, the planting material can be transplanted by using hand tools or heavy equipment such as tree spades (fig. 9.3) or backhoes. Unless the transplanting is done very carefully, mortality will be high, and surviving transplants will suffer so much shock that they will not begin to grow for a year or more after transplanting.

Figure 9.1. Bundle of cottonwood cuttings.

Figure 9.2. One-year-old green ash seedling grown from a horizontally planted cutting.

Figure 9.3. Tree spade used for planting large saplings or small trees. Photo courtesy of Dr. Schilling, Louisiana State University School of Forestry.

Transplanting is most successful when done in the dormant season. The roots of large transplants (those with basal diameters larger than about 5 cm) should be balled and bagged before transporting to the restoration site. Smaller transplants can be transported without being placed in bags, as long as their roots are protected from drying out. If possible, transplants should be taken from open sites, rather than from under dense forest canopies, since the chances of shock caused by exposure to full sunlight and high temperatures will be somewhat reduced.

Transplanting has been most frequently employed on restoration projects in Florida (Clewell, 1981; Posey and others, 1984). Clewell (1981) suggests that about 200 saplings can be transplanted in a week using a tree spade.

Some restorationists working in Florida observed that transplanting can also introduce desirable understory plants (Clewell, 1999). A few species appear to become successfully established by transplanting yet not by topsoiling, perhaps because the soil surrounding the seedling's or sapling's roots is kept more intact than it is with topsoiling. Of course, undesirable species may also be introduced by transplanting, depending on the species composition of the donor site. Another advantage of transplanting is that the larger size stock provides perches for birds and therefore provides vertical structure and enhances natural seed dispersal of some plant species.

Topsoiling

Topsoiling involves the transfer of topsoil from a natural wetland site to a restoration site. With this method, topsoil is spread out over a restoration site in the hopes that the seeds, stumps, rhizomes, and other plant parts contained within it will produce new plants. Topsoiling is commonly employed in marsh restoration but has been used much less frequently to restore forested wetlands.

A major advantage of topsoiling is that it has the potential to introduce many of the native understory tree, shrub, and herbaceous species that ordinarily are not planted. Also, it may result in successful introduction of mycorrhizal fungi or soil biota that enhance soil conditions.

There are several possible disadvantages, however, of topsoiling. A potentially serious drawback is that topsoiling requires disturbance of an intact wetland. Unless the topsoil can be taken from a wetland about to be destroyed, it means that one wetland has to be damaged to restore another. A second disadvantage is that species composition is difficult to predict and control. In some cases, topsoiling may also introduce exotic or otherwise undesirable species.

A variety of methods have been employed to remove topsoil from the donor site, transport it, and spread it on the restoration site. If tree cover exists on the donor site, the first step is usually removal of the trees. The topsoil can then be removed using equipment such as draglines, scrapers, or bulldozers. Only the top 20-30 cm (8-12 inches) of topsoil should be removed because below that depth the number of viable seeds drops off significantly.

Transportation methods for moving topsoil will depend on the distance between the donor and the restoration sites. Dump trucks are generally used for transportation distances in excess of 1.6 km (1 mile). Scrapers (fig. 9.4) can be cost effective for shorter hauls, although they do not work well in very wet situations or with heavy clay soils that may require additional heavy equipment to push or pull them. For very small distances, simply pushing the topsoil to the restoration site with a bulldozer or transporting it with a front end loader may be effective. Light, crawler-mounted bulldozers (fig.

Figure 9.4. Scrapers are useful for short-distance transport of topsoil.

9.5) are recommended for spreading the topsoil on the restoration site because they minimize soil compaction.

Topsoil should be spread on the restoration site to a depth of about 10-20 cm (4-8 inches). Depths shallower than about 7 cm (3 inches) may not contain enough seeds and other plant material to ensure adequate plant establishment. Spreading topsoil to depths much greater than 20 cm (8 inches) may actually be counterproductive because costs become excessive, and many seeds will be buried too deep for germination.

In general, topsoiling will be most successful on sites where the topsoil will remain moist. In most of the Southeast, spring is the best time of year for topsoiling. On exposed sites where the soil surface is likely to dry out, irrigation will be required. In most situations, topsoiling should be viewed as a useful secondary means of revegetation with one of the other methods used as the primary means of reestablishing trees.

The term "mulching" is often used when referring to topsoiling, but mulching is technically a broader term that describes the process of applying any organic or inorganic material to the soil surface. Examples of other materials occasionally used as mulches include agricultural residues such as straw, hay, or bagasse and wood residues such as bark, sawdust, or wood chips.

Natural Regeneration

Natural regeneration—allowing vegetation to become established from natural sources—is an attractive alternative for restoration because the cost of planting is avoided. Also, any plants that become established on the restoration site should be well adapted to the site. If conditions are suitable, natural regeneration can be quite rapid, but highly degraded sites or sites far from a seed source will take much longer to naturally revegetate.

Many restoration projects rely on natural regeneration for all or part of vegetation establishment. In the Lower Mississippi Alluvial Valley and on some western Kentucky coal-mined sites, for example, only hard mast producing tree species are planted on most old-field restoration projects, and natural regeneration is relied upon for establishment of light-seeded tree species, understory tree species, and herbaceous vegetation.

Sites where use of natural regeneration is most appropriate include small or narrow sites where most of the site is no farther than about 70-90 m (75-100 yds) from an existing forest and sites that are subject to frequent flooding. A general rule of thumb is that natural regeneration will succeed without intervention in areas that are within a distance from an existing forest no

Figure 9.5. Bulldozer spreading topsoil at Hall's Branch restoration site.

greater than twice the height of the dominant canopy trees. Although disking is often used to reduce competition for the newly planted seedlings, Allen and others (1998) showed that disking of old-field sites reduced the number of invading woody seedlings that became established. They proposed that the added soil drying and elimination of microrelief (old bedding rows) resulted in reduced opportunity for seedling establishment.

Seedlings of species not dispersed by wind are often missing from naturally regenerated stands, or stands show a clumped distribution related to bird roosting and/or animal eating habits. Providing perches, planting of a few large trees, and even placing snags on a restoration site can encourage the natural regeneration of plant species dispersed by birds.

The major disadvantage of natural regeneration is that species composition is difficult to control. Light-seeded or undesirable species may need to be thinned out to allow the higher value heavy-seeded species time and space to become established and grow.

Another potentially serious disadvantage is the longer time period required for establishment of tree cover. A naturally regenerated site is likely to go through a successional process where the site is first dominated by annual plants, then perennial herbaceous plants, then shrubs and light-seeded, shade-intolerant tree species, and finally heavy-seeded and shade-tolerant tree species. On large old-field sites, the herbaceous plants may dominate a site for 10 years or more. On other types of sites (e.g., clay settling basins), willows, boxelder, swamp red maple, river birch, or other species that provide less wildlife value (compared with hard mast species) may dominant for many years (see table 4.1).

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Chapter 10: Establishing Native Undergrowth Vegetation

Most species of plants occurring in forests are not trees. For example, a bottomland hardwood forest in western Kentucky contained 143 species, of which 80 (56%) were terrestrial herbs, and only 38 (27%) were overstory trees; the remainder were shrubs and woody vines. In hardwood forests along the upper reaches of the Alafia River near Tampa, Florida, 71% of the 409 plant species were terrestrial herbs (292 species), consisting largely of ferns, sedges, grasses, and wildflowers (Clewell and others, 1982). Only 36 plant species were overstory trees. The remaining 81 species were small understory trees, shrubs, woody vines, and epiphytes.

These and similar observations elsewhere demonstrate that bottomland hardwood forest restoration is incomplete until a representative contingent of undergrowth species is established. This conclusion complicates revegetation activities, which, in the past, have focused on tree planting. Four basic questions are immediately raised: (1) are understory species so important ecologically that we should be concerned about them? (2) will undergrowth species colonize a newly restored forest by means of natural regeneration? (3) how many undergrowth species should be established to restore a forest adequately? and (4) how can undergrowth species be intentionally established at restoration project sites? This chapter attempts to answer these questions.

Although the importance of understory species is widely recognized by virtually all involved with bottomland hardwood restoration, some are of the opinion that, over time, the overstory plantings will develop conditions conducive to the natural establishment of understory species from an existing seedbank or from species brought into the area by wind, wildlife, or floodwater. Such natural invasion of understory species has not been conclusively demonstrated, but most restoration projects are still relatively young. The restorationist must determine if the time and resources spent on physically establishing understory species are well spent or if they may be better spent on other projects.

Ecological Importance of Understory Plants

Biodiversity

The aforementioned 292 species of terrestrial herbs occurring along Florida's Alafia River were tallied in sample areas totaling only 4.6 ha (11.3 acres). In spite of this small sample size, these herbs represented 8% of all vascular plant species known from the entire state of Florida. This floristic wealth vividly demonstrates the importance of forest undergrowth with respect to regional biodiversity. If ample biodiversity is a goal of restoration, then undergrowth cannot be ignored. Undergrowth vegetation that would likely overtop newly planted tree seedlings may best be planted one to several years later to allow the tree seedlings time to attain sufficient height to be above the undergrowth.

Ecological Functions

When considered by forest ecologists, the numerous undergrowth species are generally treated collectively by stratum or by life form. The functional roles of individual species are poorly known because the autecology (relationship between an individual species and its environment) of very few have been investigated. Perhaps the best known functional roles of undergrowth are those pertaining to wildlife habitat in terms of providing cover, forage, and nesting sites. Another obvious benefit provided by undergrowth is anchorage of the soil, which counters the erosive forces of runoff and overbank flooding. Undergrowth vegetation also contributes friction (roughness) to the forest surface, thereby retarding the velocity of floodwater. Anchorage and reduction of flood velocities both contribute to substrate stability and encourage sedimentation on floodplains. Sedimentation, in turn, increases the reservoir of nutrients available to vegetation.

Another function of the undergrowth that is not well documented but may contribute substantially to herbivore control and food chain stability is the harboring of predacious arthropods, mainly insects and spiders. A given species of arthropod spends much of its lifetime inhabiting a particular species of plant. The greater the number of plant species available in an area, the greater the diversity of predacious arthropods. This feature is realized by specialists in the biological control of crop pests. They have found that pest control is enhanced by having a diverse array of native plant species growing in close association with crops. It seems likely that these same predacious insects and spiders are also controlling herbivorous insects that attack native forest trees. Another array of insects associated with floristically diverse undergrowth may serve to pollinate flowers, including those of trees.

Undergrowth vegetation adds complexity to biogeochemical cycling of nutrients because root systems vary from species to species. The greater the diversity in the kinds of root systems, the greater the efficiency of conserving and cycling nutrients released by detrital decomposition. Undergrowth vegetation contributes to detrital biomass upon which soil microflora and detritivores depend. Undergrowth vegetation may also provide benefits to a forest in terms of mycorrhizal associations (a symbiotic relationship between certain fungi and the roots of some plants). In addition, understory vegetation can incorporate a tremendous amount of organic matter into the soil.

In summary, undergrowth plays various roles in forest processes and ecological functions. The importance of these roles may be much greater than has thus far been appreciated.

Natural Regeneration of Undergrowth

A considerable area of bottomland forests has been cleared for agriculture and later left to lay fallow. These lands generally become reforested through the well known process of old-field succession. This natural regeneration includes a substantial development of herbaceous and shrubby vegetation beneath the new forest canopy. Initial undergrowth may consist largely of relatively undesirable species that persist for some time following canopy closure. The undergrowth may be dominated by one or a few species such as goldenrod or wild onions or exotics such as Johnson grass or Japanese honeysuckle.

In contrast, forests occupying undisturbed soils have more undergrowth species, with no one species being disparately abundant. These species tend to be less weedy and more characteristic of deep forest conditions. The weedier species predominate only in disturbed areas, such as in canopy gaps formed by the loss of an overstory tree. Plant species (including overstory trees) that are typical of mature, undisturbed forests are particularly welcome at a restoration project site because they may hasten forest development. For this reason, they may be termed "preferred species."

Even old-growth forests contain contingents of weedier undergrowth species in their canopy gaps that presumably contribute to ecological functioning and should not be discounted. In fact, four categories of undergrowth species can be distinguished, although some species may defy easy classification. Each category description is followed by examples of species for the category, as they occurred in mature forests along the Alafia River (Clewell and others, 1982). These species do not necessarily belong in the same categories in other regions or other forest types. See appendix B for scientific names of all species.

Category 1. Species largely or entirely restricted in their regional distribution to mature, undisturbed stands (e.g., restricted to a floodplain swamp and also to adjacent mesic forests in the same valley). These are all preferred species: aquatic milkweed, small-spike falsenettle, shiny spikegrass, millet beakrush, water pimpernil, and species of swamplily, bugleweed, lizard's tail, and ferns (*Osmunda, Thelypteris,* and *Woodwardia*).

Category 2. Species that are frequent or at least locally abundant in mature stands and are also abundant in other regional ecosystems (e.g., in a floodplain swamp as well as in open marshes). These are all preferred species: small-fruit beggartick, Mexican water-hemlock, hairlike mock bishop-weed, and species of pickerel weed, smartweed, and burreed.

Category 3. Species occurring much more frequently or abundantly in other regional ecosystems **or** species that are much more abundant in disturbed or early serial stages than in more mature stands. These are **not** preferred species: bushy bluestem, southern carpetgrass, sheathed flatsedge, small dogfennel, Peruvian seedbox, Florida pokeweed, licorice weed, and cattail.

Category 4. Species occurring adventively **or** exotic species, including naturalized exotics. These are **not** preferred species: annual ragweed, American wormseed, crabgrass, Japanese climbing fern, and coffeeweed.

A satisfactory restoration should have a diversity of undergrowth species, including most species from Category 1. In order to determine in which category each species belongs, an experienced botanist will have to use baseline information to group the undergrowth species into the four categories.

Number of Species Necessary for Restoration

A mature, fully restored forest should contain most of the "preferred species," as determined from baseline studies, particularly those from Category 1. In the Alafia River study (Clewell and others, 1982), at least 60 (20%) of the 292 terrestrial herbaceous species qualified as preferred species (i.e., Categories 1 and 2).

Preferred species need not be planted concurrently with trees. Several years will pass before the planted trees can provide the shade that many forest undergrowth plants require for their survival. At that time, an inspection can be made to determine what preferred species have already colonized the project site through natural regeneration. Category 1 species that are absent may then be planted. Preferred species of vines, however, should not be intentionally established. As a class, vines tend to proliferate and become nuisance species at new restoration sites, sometimes threatening the establishment of key tree species.

The remaining question is, how many plants of each preferred species should be established? The answer is only a few of each species. The guiding assumption is that as forested conditions develop, preferred plants will proliferate at the expense of the weedier species, which initially colonized the site and are succumbing to competition from the planted trees. Such proliferation indeed happened at two maturing restoration sites on mined and reclaimed land in central Florida: Hall Branch Restoration (Clewell, 1999) and Dogleg Branch Restoration (Clewell et al., 2000). Clusters of a few plants of each preferred species should be planted at wide intervals to ensure establishment on different parts of the project site. Clustering is needed to ensure cross-fertilization in self-incompatible species. Particularly large project sites can be partitioned into smaller units of perhaps 4 ha (10 acres), in which each preferred species will be established.

Establishing Undergrowth Plantings

Transplanting

There is currently little demand for preferred species of forest undergrowth, and native plant nurseries rarely stock them. Over time, this situation should improve, but presently it is usually necessary to collect seeds, rootstocks, or whole plants from natural populations. Ideally, collections of rootstocks and whole plants should be made as rescue or salvage operations at sites that are scheduled for development. These collections can be transferred directly to the project site, or, if a nursery is available, salvaged stock can be propagated for later distribution. Some Natural Resources Conservation Service facilities are making space available to propagate such native plant materials.

Plant material may have to be removed from donor forests that are not scheduled for development. Plants selected for removal should be spaced far enough apart to prevent localized extirpation. Holes where plants are removed should be filled. A posthole digger frequently proves useful in removing herbaceous plants. This work is labor-intensive and expensive in the absence of volunteer effort. Transplants should be planted in semishade in moist soil. Care should be taken not to leave air pockets around the root balls. For many species, transplanting from the shade of a closed canopy forest to an open field is fatal, therefore, the restoration site must have developed sufficiently enough to provide at least semishaded conditions for these species.

Topsoiling

Topsoiling (mulching with topsoil) is another method of preferred species establishment. The method has been attempted at reclaimed phosphate mines in central Florida. A layer of topsoil only 10 cm (4 inches) thick can provide a bountiful regrowth of vegetation (see topsoiling section, Chapter 9). Topsoiling has proven most successful when the soil is transferred from the donor site directly to the restoration site without stockpiling and when the restoration site is permanently moist or wet (see restoring soil characteristics section, Chapter 5).

Plant propagules (seeds, rootstocks, spores) can quickly lose their viability when stockpiled, owing to poor aeration and to the generation of lethally high internal temperatures. Topsoil that is subjected to seasonal drying after being spread at an open restoration site is unable to sustain most undergrowth plants as they arise from its propagule bank. These plants are adapted to uniformly moist soils. If the amount of topsoil is scarce, it can be transferred from a donor site with a tree spade and planted as if it were a tree. The soil is transferred intact, and undergrowth plants within the soil are less traumatized than they would be if they were spread in a layer. Topsoiling by any method introduces both organic matter and soil microbiota, both of which may hasten soil development, especially on surface-mined sites.

Topsoiling as a technique is largely limited to salvage operations at wetlands that are being cleared for development. Because such sites are rarely permitted for development, the opportunity of using topsoil is becoming rare. Whenever a wetland is permitted for clearing, its topsoil should be salvaged for restoration projects in the vicinity. Unfortunately, hauling costs are prohibitive for transport of topsoil to all but local projects.

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Chapter 11: Postplanting Control of Undesirable Vegetation

Bottomland hardwood forests have an abundance of naturally occurring woody and herbaceous plants that may be regarded as undesirable in a restoration project, especially in the early stages when they might affect the survival and growth of planted trees. Also, exotic species are very well established in all areas covered by this guide. In southern Illinois, for example, early stages of succession on old-field sites used to be dominated by native broomsedge, smooth and winged sumac, sassafras, and common persimmon. Now, similar sites might be dominated by sericea lespedeza, Chinese bushclover, Japanese honeysuckle, multiflora rose, and autumn olive, all of which are exotics.

Control of undesirable plant species is typically only needed in the first few years of a restoration project, after which the planted vegetation should be large enough to compete on its own. Control can be achieved manually, with machines, or with herbicides.

Although an intensive program of postplanting weed control may substantially increase survival and growth of planted stock, control should be employed sparingly. Weed control will reduce the initial value of a restoration site for small mammals and bird species that use the weeds as food and cover. Also, these weeds may be promoting forest development by contributing humus to the soil and partial shade to forest tree seedlings.

Another reason to use postplanting weed control sparingly is that the long-term benefits may not justify the costs. In some experiments where a significant growth enhancement with weed control was found over the first 5 to 10 years, the effect virtually disappeared after a few more years.

Figure 11.1. Manual vine control can be accomplished using brushhooks or machetes.

Manual Vegetation Control

Vegetation control using hand tools such as hoes, axes, brushhooks, and machetes has the potential advantage of being highly selective in what is removed (fig. 11.1). A disadvantage of manual methods is that they usually result in a very temporary form of control; unless the undesirable plants are being uprooted, they are likely to resprout quickly. Because the labor forces employed for weeding are likely to be relatively inexperienced, there is also a high probability of injury to workers and inadvertent damage to desired species.

Manual weed control may be best employed on small projects or as a supplement to other forms of weed control on larger projects. It also may be the safest method to use to remove vines from young hardwood trees because the vines grow too close to the tree to be removed by cultivation, and herbicide applications may also damage the tree.

Mechanical Vegetation Control

Mechanical weed control is widely used in commercial forestry operations and has proven to be highly effective on bottomland sites. A disadvantage of mechanical weed control is that it is difficult to employ if the trees are not planted in rows. Other disadvantages are the high equipment costs and energy consumption.

Cultivation should begin early in the first growing season (March or April) and may need to be repeated as many as three to four times during the first year. Supplementary hand weeding may also be needed to control vines that are too close to planted trees to be removed mechanically. There are many types of equipment available for cultivating bottomland hardwoods, but most foresters prefer tractors of about 110 horsepower. Tractors of this size are small enough for cultivating between rows but also large enough for other jobs such as clearing, disking, and planting.

Front-mounted cultivators allow the driver to have better visibility and control than rear-mounted cultivators, resulting in less damage to planted trees. Cultivators equipped with chisel- or shovel-type plows allow tillage close to the young trees but do not damage them appreciably. Two types of cultivators are most frequently used. One is a large, front-mounted cultivator with 19 to 21 shanks that will straddle one row while covering the space within the rows. The second type is an offset front-mounted cultivator equipped with five or six shanks that straddle the row while covering a small area on each side; with this system, a disk or spring-tooth harrow drawn behind the tractor covers the area between rows.

The unit in a cultivation operation therefore consists of a tractor plus either a large cultivator or a small cultivator with a disk or harrow (fig. 11.2). When the trees become too tall to straddle, the cultivators are removed and tillage between rows is accomplished with just a disk or harrow.

To ensure the best results from cultivation and to minimize tree damage and equipment breakage, the restoration site should be as free as possible from stumps, large roots, and other debris. The cultivator shanks that straddle the trees should be set to plow 8-10 cm (3-4 inches) deep to within 8-10 cm (3-4 inches) on each side of the tree. The area between rows should be plowed to a depth of 10-15 cm (4-6 inches). Cultivation to these depths will probably cut some of the roots that lie in the top 20 cm (8 inches) of soil, but some researchers believe that cutting causes root proliferation and is therefore beneficial because it increases the absorptive surface.

Disking patterns should be alternated during cultivation; that is, a row cultivated in, say, a north-south direction during the first trip down a row should be cultivated south-north during the next trip. If tandem disks are used, the front blades should be set to throw soil toward the trees and the rear ones to throw soil away from the trees. The disk blades should be about 50-60 cm (20 to 24 inches) in diameter. The width of the disk or harrow would be determined by tree spacing but would be 0.6-0.9 m (2-3 ft) narrower than the spacing to allow plowing to within 30-45 cm (12-18 inches) of the trees.

Cultivation should be postponed during wet weather to avoid soil compaction, damage to tree roots, and equipment damage.

Figure 11.2. Mechanical cultivation of a restoration site.

Vegetation Control with Herbicides

The many different herbicides and herbicide application methods available for use on restoration projects are continuously evolving. It is important to refer to the most up-to-date sources of information on such issues as personal and environmental safety and relevant State and Federal regulations. Recent sources of information on herbicides for forestry and agricultural use are cited at the end of this chapter, but keep in mind that little research on the appropriate herbicides for use in bottomland hardwood sites has been conducted (but see Miller, 1993 and Ezell and Catchot, 1998). When herbicide use is planned, a combination of proper herbicide prescriptions, technically sound applications, and a commitment to minimizing negative impacts to the environment are the keys to successful use.

Table 11.1 lists some of the most commonly used herbicides for control of herbaceous and broad-leaved (woody) vegetation. This table is meant to serve as an initial source of information on herbicides, not as the final basis for herbicide selection and does not constitute an endorsement of any of the herbicides listed. Also, not all these herbicides are labeled for herbaceous or woody vegetation control in all states.

The weed species controlled by specific herbicides should be investigated thoroughly before making the final selection(s) for use on a particular project. Information such as that presented in table 11.2 is available for most herbicides and should be referred to once the restorationist knows which weeds are most in need of control.

The optimum timing for herbicide applications varies with the type of weeds being controlled and the particular herbicide and application method being used. Guidance on timing for some of the most common herbicides used in commercial forestry operations is presented in fig. 11.3.

Since weed control should be used very sparingly on most restoration projects, only the most selective application methods are recommended. To control herbaceous vegetation around individual planted trees, backpack or hand-held sprayers (fig. 11.4) are very effective. To control undesirable woody species, tree injectors, hypohatchets, hatchet and spray bottle combinations, or spot guns are recommended.

Table 11.1. Commonly used herbicides (adapted from Mitchell and Lowery, 1994).

Common Name	Trade Name	Use
Atrazine	Atrazine 4L	Herbaceous
	AAtrex 4L	Herbaceous
	AAtrex 80W	Herbaceous
	AAtrex Nine-O	Herbaceous
Dicamba	Banvel CST	Broad-leaved
Dicamba + 2,4,D	Banvel 720	Broad-leaved
Fluazifop-butyl	Fusilade 2000	Herbaceous
Glyphosate	Accord CR	Herbaceous
	Roundup	Herbaceous
Hexazinone	Pronone 5G	Herbaceous
	Velpar L	Herbaceous
Imazapyr	Arsenal Applicator Concentrate	Herbaceous
Oxyfluorfen	Goal	Herbaceous
Picloram + 2,4-D	Tordon	Broad-leaved
Sethoxydim	Poast	Herbaceous
Sulfometuron methyl	Oust	Herbaceous
Triclopyr	Garlon 3A	Broad-leaved
Triclpoyr + Butoxyethyl ester	Garlon 4	Broad-leaved
2,4-D	Weedone 2,4,DP	Broad-leaved

Table 11.2. Weed species susceptible to Oust (Mitchell and Lowery, 1994).

Susceptible Controlled by 3 oz/acre	Moderate Controlled by 5 oz/acre	Tolerant Not controlled
Panic grasses	Goldenrod	Bermuda grass
Fescue	Dogfennel	Morning glory
Horseweed	Bahia grass	Broomsedge
Burnweed	Johnson grass	Wooly croton
Boneset		Trumpet creeper
Ragweed		Sicklepod
Sunflower		Cocklebur
Poorjoe		Nutsedge
Dewberry		
Vetch		
Geranium		
Goldenweed		
Sweet clover		
Crabgrass		

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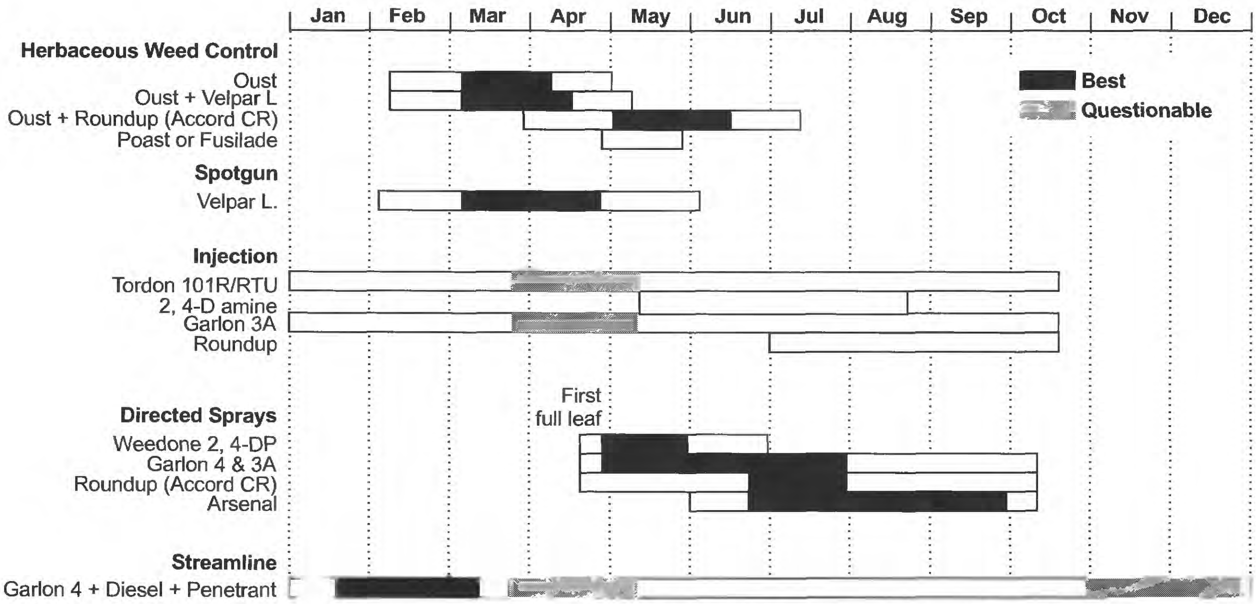

Dates are approximate for the upper coastal plains. Spring dates will shift to the right going from the coastal plains to the mountains. Likewise, fall dates will shift to the left going from the coastal plains to the mountains because of earlier frost.

Figure 11.3. Guidance on the timing of herbicide applications in commercial forestry (modified from Miller and Bishop, 1989).

Figure 11.4. Herbicide application with a backpack sprayer.

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Chapter 12: Protection of the Restoration Site

Restoration projects can be damaged or destroyed by a variety of agents, ranging from depredation by herbivores to vandalism. To the degree possible, the needs for protection from these agents should be anticipated in the site evaluation stage, and plans should be drawn up for implementing protective measures.

Protection from Animals

Herbivores (and the occasional omnivore) can seriously damage or destroy planted seed or seedlings. The most frequent offenders are deer, raccoons, squirrels, beaver, nutria, and small rodents. In some cases, cattle, hogs, or birds may cause damage.

One of the best forms of protection against the smaller rodents is to plant seed or seedlings on a relatively weed-free site, since this minimizes the amount of cover available to protect rodents from predation. Usually by the time the weeds provide enough cover for small rodents, the seedlings are relatively safe; however, if there is evidence of damage to seedlings (e.g., girdling, clipped twigs), it is advisable to carry out some postplanting weed control.

Protection of some planted sites can be achieved by controlling water levels, but specific guidelines for use of this technique are not available. For example, water tolerant species can be temporarily flooded to protect them from small rodents, or in the case of beaver and nutria, the site can be kept drained until the seedlings are well established. In large open fields, provision of perches for raptors may be an effective strategy for reducing rodent populations.

More direct forms of control may be necessary in cases where animal populations are particularly high and/or cover cannot be reduced adequately by other means. These forms of control, however, should only be employed as a last resort, especially near populated areas and on public lands. Traps or poison can be used to temporarily reduce populations of small rodents. Larger animals can also be shot. For instance, shooting nutria or beaver can be a very effective means of short-term control; one technique is to go out at night with a light and use a .22 rifle (which is fairly quiet). The only practical direct control measure for deer is an either-sex harvest in conjunction with state hunting seasons, which is obviously out of the control of most restorationists.

Fencing the site will protect it from cattle and hog damage. Fencing may also provide protection from beaver and nutria, although these animals, especially nutria, may be able to burrow under or even climb over a fence. Fencing will only work well if it is done right (using good quality fencing material and sturdy, metal or treated wooden posts) and if it is periodically inspected and maintained.

Individual seedlings can be protected by using either wire predator guards or plastic tree shelters (fig. 12.1a,b), but costs can be prohibitive on large projects.

a. b.

Figure 12.1. Herbivory protection by (a) wire predator guard and (b) plastic tree shelter.

Tree shelters have the additional advantages of enhancing growth and making it easier to safely apply herbicides around the base of individual seedlings. While generally effective, neither wire guards nor tree shelters can ensure complete protection in cases where animal populations are high and alternative food sources are low. For example, both methods have occasionally failed to protect newly planted baldcypress seedlings from nutria, which have burrowed under, climbed over, knocked over, and chewed through these protectors. In extreme cases, these wire guards or tree shelters should be used in conjunction with direct population control measures.

Protection from Fire

Although most bottomland hardwood sites are wet throughout much of the year, they do occasionally dry out, and there are several instances in which restoration sites have been damaged by fire. The best protection is to make a firebreak around the site, usually by disking (see fig. 5.1). Firebreaks should be periodically inspected and maintained, particularly before and during periods of peak fire danger. Firebreaks are particularly important in areas where prescribed fire is frequently used or where the restoration site is close to a heavily traveled road.

In peninsular Florida and in the northern Gulf of Mexico Coast the rapid spread of cogongrass, an exotic species, has created a fire hazard. This species burns readily and can spread and intensify a fire rapidly. Heavy applications of herbicides are being made to eliminate this grass as it appears in bottomland hardwood creation sites on mined lands. As cogongrass continues to spread, its threat of carrying fires could increase substantially in the next few years.

Protection from Human Impacts

In most areas, restoration sites are subject to some damage from humans, be it intentional or unintentional. Fencing and "No Trespassing" signs may prove necessary in areas that could be used by off-road recreational vehicles, play areas for children, or places to dump trash and yard wastes. Informing nearby residents of the project and/or putting an informative sign about the project on the site (fig. 12.2) may also help reduce damage.

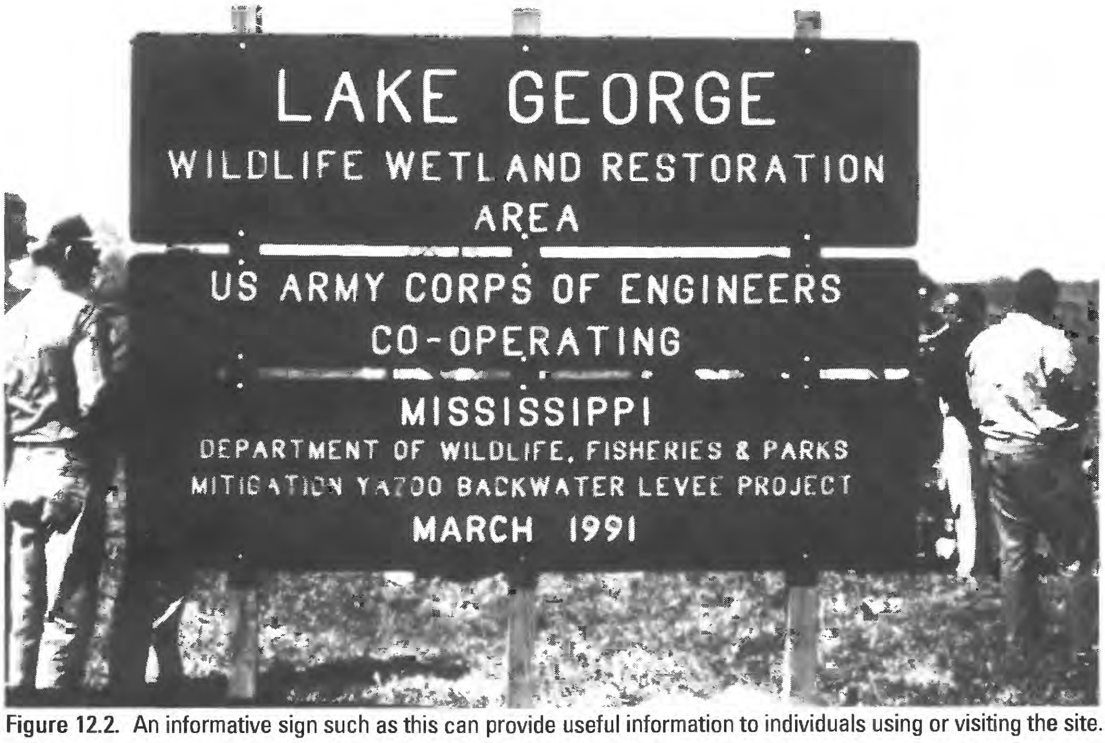

Figure 12.2. An informative sign such as this can provide useful information to individuals using or visiting the site.

In agricultural areas, some restoration sites have been damaged or destroyed by farm machinery or aerial drift from nearby herbicide applications. Farmers on adjacent land should be informed about restoration sites on which they might potentially have an impact.

In urban areas, plants have actually been stolen from some restoration sites. This is most likely to happen when larger, high-value planting stock has been used, such as tree seedlings that were in 1-gallon or larger size containers. Sites where theft is a possibility should be protected by fencing. In some cases armed guards have been employed to protect restoration sites. Where theft or vandalism is likely to be a problem, it may be desirable to use smaller, less conspicuous (and less valuable) planting stock.

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Chapter 13: Monitoring

Monitoring is an important element in any properly conducted restoration project. Too often, however, restoration projects are put in place and monitored poorly if at all. Failure to follow up on a project obviously results in a lack of information on how well the project is succeeding in meeting its objectives. Success criteria (as discussed in Chapter 2) can only be evaluated through a program of monitoring. The lack of monitoring also eliminates the chance for promptly carrying out postplanting corrective measures (midcourse corrections) that may save a project. Furthermore, the failure to monitor projects may result in repeating mistakes in future projects.

Monitoring does not always have to be sophisticated and expensive to be effective. Simply walking through a restoration site may be enough to spot some problem that needs to be remedied, such as excessive weed competition, damage to a fence, herbivory problems, or a malfunctioning water control structure. To be most effective, this type of monitoring should be done frequently at first (at least monthly), especially if extensive earthmoving or hydrologic modifications were done, or the site is an area subject to human disturbance.

When designing a monitoring program involving the collection of quantitative information, five things should be considered carefully: (1) what is the purpose of the monitoring program? (goals which are tied directly to success criteria should be specified), (2) what are the most appropriate methods for achieving the goals? (3) how should the data be handled and analyzed? (4) how will the data be interpreted (and who will do the interpretation)? and (5) when will the monitoring program achieve its goals and be terminated? Two guiding principles should be to keep the program as simple as possible and to collect data only if it meets a specific need and addresses a specific success criterion. It should also be kept in mind that because of the relatively long-term nature of many monitoring projects, personnel will change over time. Good records should therefore be kept on all aspects of the program, including sampling protocols, plot locations, and information on how and where data are stored.

Vegetation Monitoring

A wide range of techniques developed by plant ecologists and foresters is available for use in vegetation monitoring. Most of these techniques are based on the sampling of vegetation along transects and/or in plots. Some of the most commonly used measures of vegetation abundance or plant performance are summarized in table 13.1. In general, an effective monitoring program will use a combination of absolute measures of abundance and selected measures of performance.

If transects or plots are used, they should be permanently marked because remeasuring the same area each time will provide information on trends in survival and plant performance. Sections of PVC pipe placed at either end of transects or in plot centers works well in most cases, especially where vandalism is not a major problem. Plots and transects should also be located in a truly random or systematic fashion, not selected subjectively.

One example of a simple, inexpensive, and yet appropriate monitoring system is that used by the Louisiana Department of Wildlife and Fisheries to evaluate the survival of their direct-seeded reforestation sites. They establish 50-ft (15.2 m) transects along every third row at the time of planting. The transects are marked with five flags; some of the flags are tagged in such a way that the exact position of the transect can be relocated if one or more flags are lost. The transects are established so they stretch out either diagonally across the field (fig. 13.1) or in another arrangement that captures the variability of topography within the field. In late summer and again 2 or 3 months later, at the end of the first growing season, the seedlings along these transects are counted. If the average number of seedlings per transect is below the target of three, then the field may be replanted. Since the only stated goal of these restoration projects is reestablishment of the hard mast producing species that were actually planted, there is no need for more extensive monitoring. The decision to replant a site should only be made after consideration of the fact that many seedlings may be difficult to see (hidden by herbaceous vegetation, delayed germination of direct-seeded acorns, clipped by rodents but retaining living roots, etc.). It is usually advisable to wait until at least 3 to 5 years post planting before evaluating seedling survival and stocking rates.

An example of a somewhat more complicated and expensive vegetation monitoring system is that used by Agrico Chemical Company on their Morrow Swamp restoration site in central Florida. They established a system of 12 permanent belt transects (elongated quadrats) that are 29.5 ft (9 m) in width and from 300 to 900 ft (90-275 m) in length (fig. 13.2). All trees were measured for height and crown diameter and classified into one of seven categories based on the tree's condition (live, stressed, tip dieback, basal sprouts, apparently dead, dead, and missing). The transects are measured annually, and the data are summarized in a series of tables and graphs (fig. 13.3).

Where reference wetlands have been used as a guide for designing the restoration project, various indices can be employed to compare the reference and restoration

Table 13.1. Measures of vegetation abundance and plant performance that can be used for monitoring.

Abundance measures	Description
Presence or absence of vegetation	This is a simple list of what species are present without more specific information on abundance.
Presence or absence of vegetation combined with frequency estimates	In addition to listing species present, an estimate of frequency (e.g., common, occasional, rare) is made. Simple, but relatively imprecise.
Absolute measures	
Density	Number of individuals per unit area. Easy to use with trees but difficult with herbaceous plants.
Cover	Proportion of ground covered by a species (should be envisioned as a vertical projection of the species to the ground). Often estimated by eye, although this can be inaccurate, and results will vary from worker to worker.
Biomass/yield	Usually involves destructive sampling of plots to obtain dry weight estimates for each species. Cannot be recommended for restoration projects unless samples are small or biomass/yield can be accurately estimated from variables such as plant height and diameter.
Basal area	Cross-sectional area of each species per unit area (e.g., ft^2/acre). Widely used for tree and shrub species.
Nonabsolute measure	
Frequency	The proportion of plots containing a particular species. Simple, but results may vary with plot size and sampling intensity.
Measures of plant performance	
Growth	Most commonly defined as height or diameter growth.
Mast/seed production	Could include proportion of individuals producing seed and/or a quantitative measure of seed production (i.e., yield).
Indicators of plant health or damage	Possible indicators include evidence of branch dieback, defoliation, nutrient stress, and fire or browsing damage.

sites. These include simple tallies of the number of species on each site (species richness) and more complex diversity and similarity indices. Index values should be evaluated with caution, however. High species richness or diversity, for example, may be due to the presence of weeds and undesirable exotic species. It is therefore advisable to limit some index comparisons to those preferred species that are typical of mature, undisturbed forest. Also, such indices are of limited use for most restoration projects because of the large differences that naturally occur between forests in early successional stages (the project site) and mature forests (the reference sites).

Hydrologic Monitoring

On restoration sites with minimal disturbance, qualitative monitoring of hydrology may be adequate. Hydrologic monitoring could involve visiting the site during seasons when flooding or saturated soils are expected to occur, or inspecting the site at other times for evidence that the hydrology is adequate (e.g., drift lines, sediment deposited on leaves, water lines on trees).

The use of quantitative monitoring techniques is worthwhile for projects on heavily disturbed sites. Staff gages, piezometers, and shallow monitoring wells (fig. 13.4) can be used for measuring water table levels and/or groundwater flow directions. Staff gages provide a measure of standing water above the soil surface. They are inexpensive, easy to install, and easy to read. Piezometers, which are screened for water entry (and sediment exclusion) only near their bottom end, are used to measure the potentiometric surface, which is not necessarily the same as water table level. These data are used to determine groundwater flow directions and water levels (pressures) below a confining layer in the soil. Piezometers are especially useful for monitoring contaminant movement (Freeze and Cherry, 1979). Shallow monitoring wells are screened along most of their length and are useful for measuring the water table depth in soils without a confining layer. Great care must

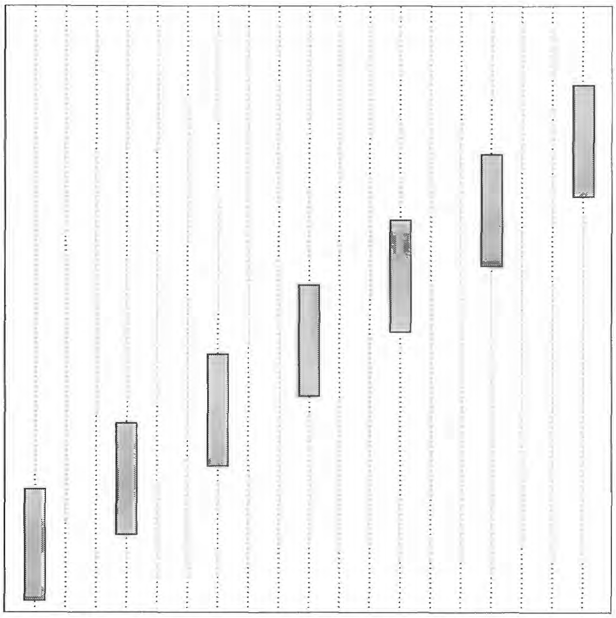

Figure 13.1. Diagonal layout of sample transects across a direct-seeded field.

be exercised in the installation of monitoring wells (Sprecher, 1993). If a well is installed through a confining layer, such as a clay layer, water may be able to flow through the well casing from a perched aquifer above the confining layer into a lower layer below the clay, resulting in bad data and possible damage to the local wetland.

Staff gages, piezometers, and monitoring wells should be distributed to cover the range of hydrologic variability within the restoration site. As an example, figure 13.5 shows the placement of piezometers and staff gages on a phosphate mine reclamation site in Florida. Readings of these gages and wells should be taken on at least a monthly basis for the first year of most projects. The actual measurement interval will depend on the hydrologic regime, soil type, topography, and type of study.

In some cases periodic water level measurements may be inadequate, and more frequent monitoring will be necessary. Several methods are available to provide continuous measurements of above- or belowground water levels. Chart type water level recorders have been used extensively in the past. These recorders typically use a chain/cable and weight attached to a float in a stilling well. As the float moves up and down with water levels, a chart is rotated under a pen and water levels are recorded on the scaled chart. The main shortcoming of these types of recorders is that they are relatively expensive and can only measure one variable (water level) at one location. Another disadvantage is that the data on the chart must be read and recorded separately, adding another step and delay in making the data available. Updated (and more expensive) versions of these recorders that log the measurements electronically are also available.

More recently, dataloggers have been used extensively for recording water levels and numerous other variables, such as wind direction and speed, total solar radiation and/or photosynthetically active radiation, temperature of the air, soil or water, relative humidity, precipitation, etc. A good quality datalogger can be obtained for about the same price as a chart type recorder, but individual probes push the cost somewhat higher. Although some probes such as air/water/soil temperature probes are inexpensive at about $70 each, other probes such as commercially available water level sensors can be quite expensive at about $600 each. Inexpensive water level sensors can, however, be constructed using readily available materials for about $60 or less each (Keeland and others, 1997).

Many researchers have started using single purpose water level recorders, such as the WL-40 or WL-80 manufactured by Remote Data Systems (fig. 13.6). An

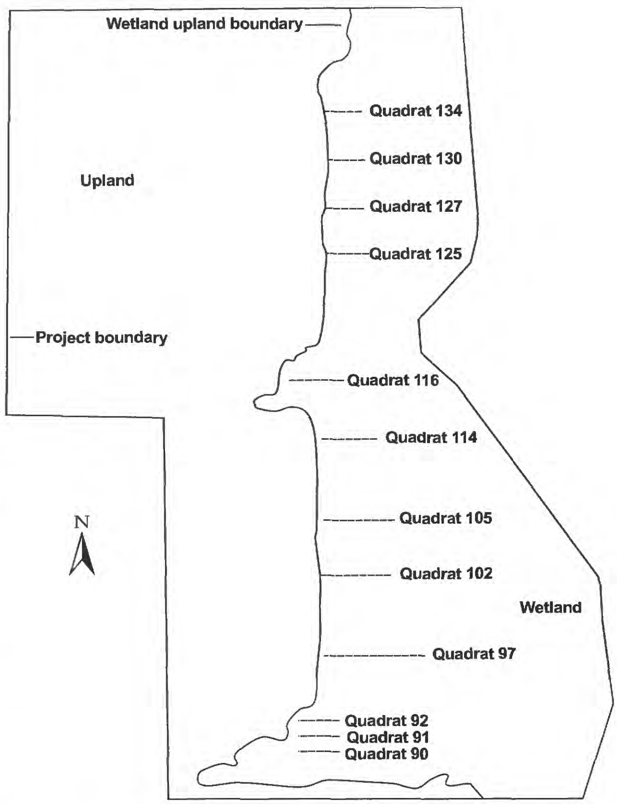

Figure 13.2. Location of forest reclamation strip quadrats at the Morrow Swamp (Agrico Swamp West) restoration site (from Kevin L. Erwin, Consulting Ecologist, Inc., 1990).

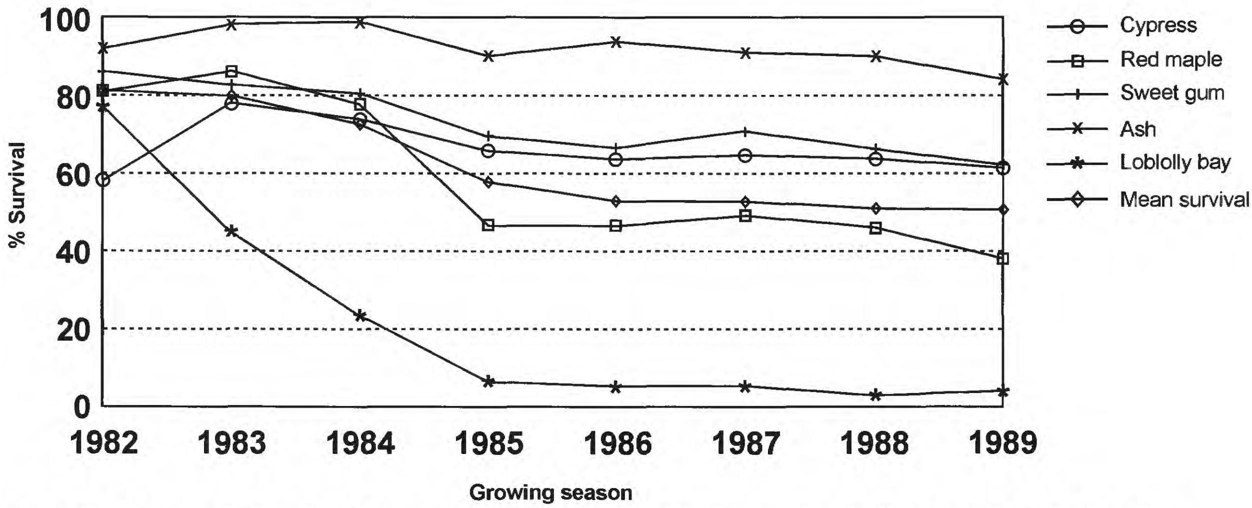

Figure 13.3. Tree survival trends at Morrow Swamp (Agrico Swamp West) restoration site (from Kevin L. Erwin, Consulting Ecologist, Inc., 1990).

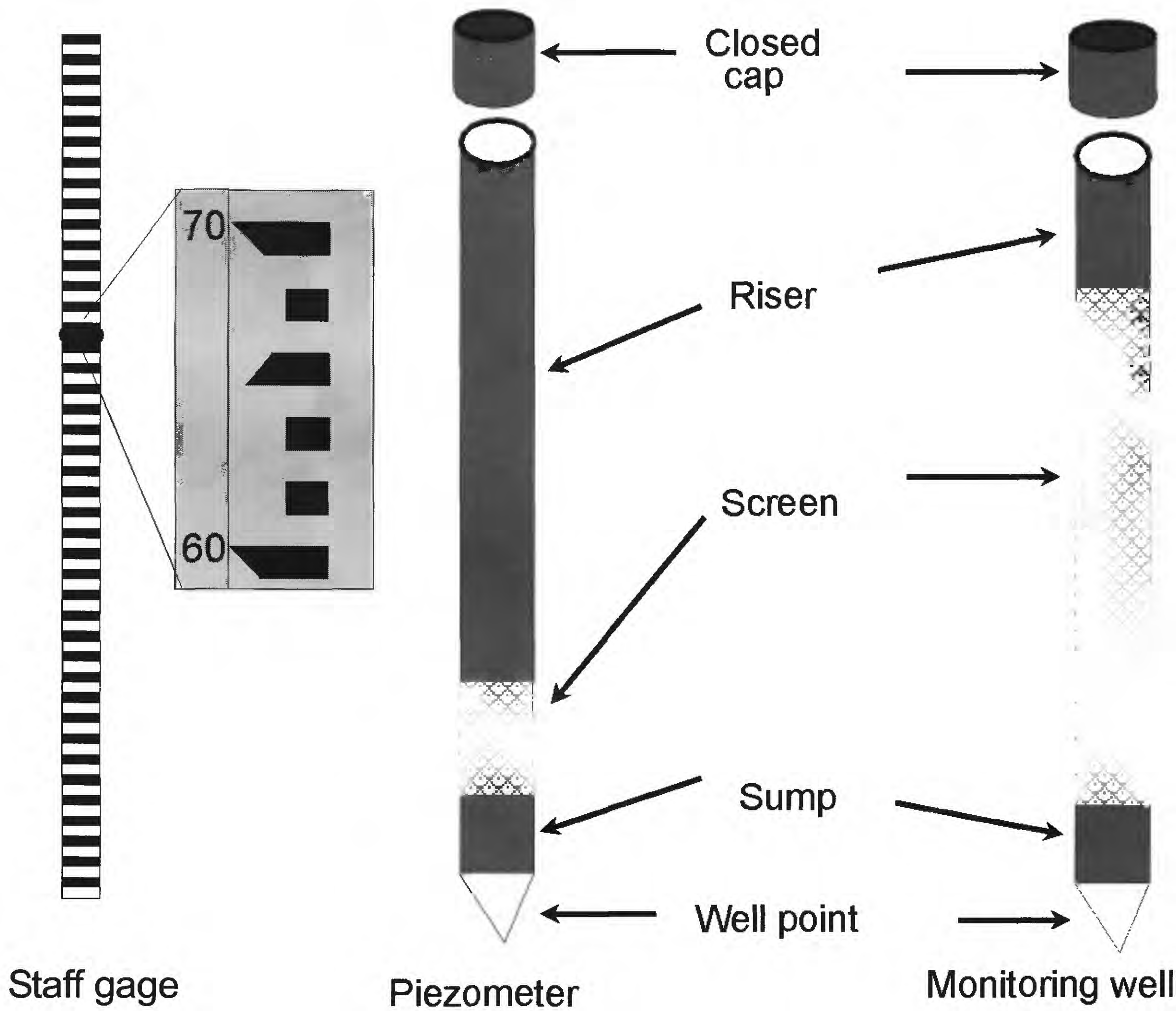

Figure 13.4. Staff gages, piezometers, and monitoring wells can be used to determine the pattern of flooding (hydrologic regime) of a restoration site. Such piezometers and wells can be purchased commercially or made from PVC pipe.

advantage of these instruments is the ease of data downloading, which is accomplished with a hand held calculator using an infrared-light communications pathway. The instruments can be easily camouflaged (do not use paint for camouflage as it may block the water entry pathways) in field situations where tampering may be likely. A disadvantage is that they only work over a limited range (1 or 2 m - 40 or 80 inches) and are almost as expensive as the chart type recorders or more capable dataloggers which work over a much wider range of water levels. In areas with a limited range of water level fluctuations, single purpose water level recorders are probably the instrument of choice, but in riverine sites where water levels fluctuate more than 2 m, they may not be adequate.

Water Quality Monitoring

Water quality monitoring of bottomland hardwood restoration projects may be required to demonstrate compliance with state water quality regulations; otherwise, monitoring will be useful primarily in those cases where specific problems are anticipated. Examples of water quality parameters that may be measured include pH, alkalinity, dissolved oxygen, nitrogen, phosphorus, turbidity, suspended solids, total organic carbon, presence of heavy metals, water temperature, redox potential, specific conductance and/or salinity, etc.

Considerations for a water quality monitoring program include measurement protocols (these should generally conform to Environmental Protection Agency standards), sample size and frequency, distribution of

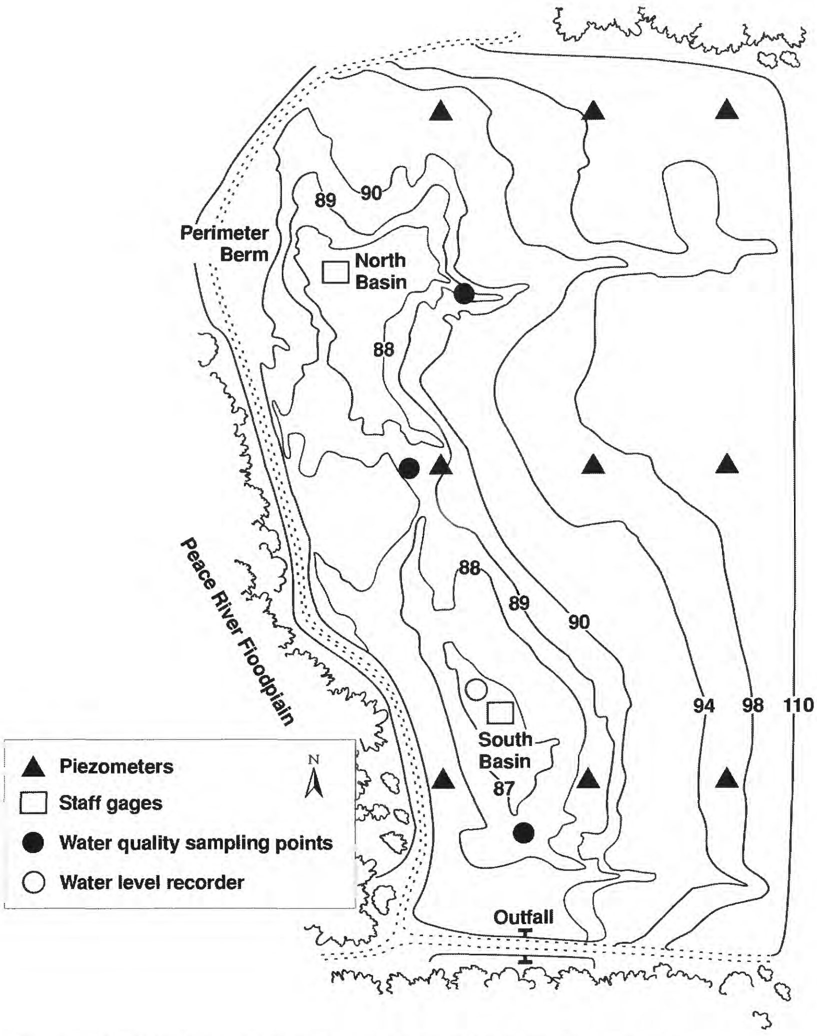

Figure 13.5. Placement of piezometers and staff gages on a reclaimed phosphate site in Florida (from Kevin L. Erwin, Consulting Ecologist Inc., 1990).

Figure 13.6. Example of an automated, single purpose water level recorder, the WL-80 being downloaded. The WL-80 (arrow) is mounted next to the stilling well of a Stevens type recorder. Inset shows the head of the WL-80 and the calculator used for downloading.

sampling stations, and the availability of a suitable site for comparison (i.e., a reference site or a suitable upstream location). The MiST document (White and others, 1990) suggests that at a minimum, 24 sets of samples from surface water and groundwater be taken on a monthly basis from both the restoration site and a reference site for the first 2 years of the project (see table 2.1). Other monitoring programs, such as the Agrico phosphate mine site in Florida, have sampled water quality on a quarterly basis.

In addition to regular sampling, it may be desirable to sample water quality during unusual conditions, such as peak floods and low water events. Water quality conditions during these times may be a controlling influence on the overall success of the wetland restoration project.

Soils Monitoring

On sites with minimal soil disturbance, such as old-field sites, very little soil monitoring is necessary, especially if the project is not being conducted as mitigation for a specific development project. It might be worthwhile, however, to inspect the site and determine if one or more of the field indicators of hydric soils described in the U.S. Army Corps of Engineers Wetlands Delineation Manual (Environmental Laboratory, 1987) are present. These field indicators include presence of organic soils; histic epipedons; sulfidic material; an aquic or peraquic moisture regime; direct evidence of reducing conditions; gleyed, low chroma and low chroma/mottled soils; and iron and manganese concretions. The delineation manual provides additional indicators of wetland hydrology for special soils, such as highly sandy soils or soils with spodic horizons.

On heavily disturbed sites, bulk density, soil pH, nutrient status, organic matter, and in some cases, redox potential or specific phytotoxin levels need to be assessed. Measurement of soil macroinvertebrates and microorganisms may also be worthwhile, especially when compared to an appropriate reference wetland, since the biomass and species composition of these communities are two of the best indicators of whether a soil is functioning as desired.

Wildlife Monitoring

Monitoring the wildlife use of restored bottomland forests is in some ways more difficult than monitoring vegetation, hydrology, and soils. For one thing, many animal species are secretive, and it may therefore be very difficult to determine whether they are using the restoration site. A more fundamental problem is that many years must pass before an adequate evaluation can be made if the goal is to provide habitat for wildlife that use mature forest habitat.

One way to address the difficulties of monitoring wildlife is to characterize use of the site by common, relatively conspicuous (or easily trapped) species that use forested wetlands in early stages of succession. Table 13.2 lists some wildlife species that use forested wetland sites in the early stages of forest development, from open fields or forest gaps to a stage just before crown closure. More extensive lists of expected species could be developed for particular project sites and compared with the species actually found on the site.

Where direct monitoring is employed, techniques will vary depending on the species being sought and whether the goal is simply to determine presence or absence (qualitative monitoring) or approximate numbers of individuals present (quantitative monitoring). Another

Table 13.2. Wildlife species that use early successional stages of bottomland hardwood forested wetlands (order of species, common names, and scientific names follows Banks and others, 1987).

Common Name	Scientific Name	Common Name	Scientific Name
Amphibians		***Birds, continued***	
Eastern newt	*Notophthalmus viridescens*	Wild turkey	*Meleagris gallopavo*
Flatwoods salamander	*Ambystoma cingulatum*	Northern bobwhite	*Colinus virginianus*
Eastern tiger salamander	*Ambystoma tigrinum*	American woodcock	*Scolopax minor*
Southern dusky salmander	*Desmognathus auriculatus*	Mourning dove	*Zenaida macroura*
Two-lined salamander	*Eurycea bislineata*	American crow	*Corvus brachyrhynchos*
Dwarf salamander	*Eurycea quadridigitata*	House wren	*Troglodytes aedon*
Mud salamander	*Pseudotriton montanus*	American robin	*Turdus migratorius*
Many-lined salamander	*Stereochilus marginatus*	Gray catbird	*Dumetella carolinensis*
Greenhouse frog	*Eleutherodactylus planirostris*	Brown thrasher	*Toxostoma rufum*
Bird-voiced tree frog	*Hyla avivoca*	Loggerhead shrike	*Lanius ludovicianus*
Pine woods treefrog	*Hyla femoralis*	White-eyed vireo	*Vireo griseus*
Squirrel treefrog	*Hyla squirella*	Yellow-rumped warbler	*Dendroica coronata*
Gray treefrog	*Hyla versicolor*	Common yellowthroat	*Geothlypis trichas*
Ornate chorus frog	*Pseudacris ornata*	Yellow-breasted chat	*Icteria virens*
Striped chorus frog	*Pseudacris triseriata*	Northern Parula	*Parula americana*
Wood frog	*Rana sylvatica*	Prothonotary warbler	*Protonotaria citrea*
		Northern cardinal	*Cardinalis cardinalis*
Reptiles		Bachman's sparrow	*Aimophila aestivalis*
Common mud turtle	*Kinosternon subrubrum*	Dark-eyed junco	*Junco hyemalis*
Snapping turtle	*Chelydra serpentina*	Song sparrow	*Melospiza melodia*
Painted turtle	*Chrysemys picta*	Rufous-sided towhee	*Pipilo erythrophthalmus*
Diamondback terrapin	*Malaclemys terrapin*	White-throated sparrow	*Zonotrichia albicollis*
Eastern fence lizard	*Sceloporus undulatus*	Red-winged blackbird	*Agelaius phoeniceus*
Eastern glass lizard	*Ophisaurus ventralis*	Common grackle	*Quiscalus quiscula*
Ground skink	*Scincella lateralis*		
Eastern indigo snake	*Drymarchon corais couperi*	***Mammals***	
Black rat snake	*Elaphe obsoleta*	White-tailed deer	*Odocoileus virginianus*
Yellow rat snake	*Elaphe obsoleta quadrivittata*	Virginia opossum	*Didelphis virginiana*
Green rat snake	*Elaphe triaspis*	Nine-banded armadillo	*Dasypus novemcinctus*
Eastern mud snake	*Farancia abacura*	Carolina shrew	*Blarina carolinensis*
Rainbow snake	*Farancia erythrogramma erythrogramma*	Least shrew	*Cryptotis parva*
		Prairie mole	*Scalopus aquaticus machrinus*
Common kingsnake	*Lampropeltis getulus*	Gray fox	*Urocyon cinereoargenteus*
Plain-bellied water snake	*Nerodia erythrogaster*	Red fox	*Vulpes vulpes*
Gopher snake	*Pituophis melanoleucus*	Black bear	*Ursus americanus*
Pine woods snake	*Rhadinaea flavilata*	Raccoon	*Procyon lotor*
Midland brown snake	*Storeria delayi wrightorum*	Mink	*Mustela vison*
Eastern ribbon snake	*Thamnophis sauritus*	Striped skunk	*Mephitis mephitis*
Common garter snake	*Thamnophis sirtalis*	River otter	*Lontra canadensis*
Southern copperhead	*Agkistrodon contortrix contortrix*	Bobcat	*Lynx rufus*
Eastern cottonmouth	*Agkistrodon piscivorus piscivorus*	Muskrat	*Ondatra zibethicus*
		Beaver	*Castor canadensis*
Birds		Eastern woodrat	*Neotoma floridana*
Great blue heron	*Ardea herodias*	Marsh rice rat	*Oryzomys palustris*
Green-backed heron	*Butorides striatus*	Southern golden mouse	*Peromyscus aureolus*
Great egret	*Casmerodius albus*	Cotton mouse	*Peromyscus gossypinus*
Yellow-crowned night heron	*Nycticorax violaceus*	White-footed mouse	*Peromyscus leucopus*
Wood stork	*Mycteria americana*	Fulvous harvest mouse	*Reithrodontomys fulvescens*
Wood duck	*Aix sponsa*	Eastern harvest mouse	*Reithrodontomys humulis*
Blue-winged teal	*Anas discors*	Hispid cotton rat	*Sigmodon hispidus*
Mallard	*Anas platyrhynchos*	Nutria	*Myocaster coypus*
Red-tailed hawk	*Buteo jamaicensis*	Swamp rabbit	*Sylvilagus aquaticus*
American swallow-tailed kite	*Elanoides forficatus*	Cottontail rabbit	*Sylvilagus floridanus*
American kestrel	*Falco sparverius*	Marsh rabbit	*Sylvilagus palustris*

alternative for monitoring wildlife is to take an indirect approach. Indices such as those provided by habitat suitability index models (Schamberger and Farmer, 1978; U.S. Fish and Wildlife Service, 1981), the Wetland Evaluation Technique (WET; Adamus, 1983), the Hydrogeomorphic Method (Brinson and others, 1994; Smith and others, 1995), or the Rapid Impact Assessment Method (Stein and Ambrose, 1998) can be used to evaluate the suitability of wildlife habitat for key species or species groups.

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Chapter 14: Rehabilitation and Management of Existing Forests

Although this guide emphasizes restoration of bottomland forests on sites without tree cover, there are extensive areas of degraded natural forests in need of rehabilitation. Often the degradation is due to past mismanagement such as high grading or holding water late into the growing season in green-tree reservoirs. In other cases, hydroperiod alterations, hurricanes, severe floods, or insect outbreaks may have degraded the stands. Many southern bottomland hardwood stands have deteriorated to such a point that they have little value for timber, wildlife production, recreation, or aesthetics (fig. 14.1).

This chapter presents basic information on bottomland hardwood silviculture. The suite of techniques employed by silviculturists can be used to achieve a wide range of objectives, including forest rehabilitation. The principles described in this chapter can be applied not only to rehabilitating existing degraded stands but also to the long-term management of restoration forests as described in the preceding chapters of this guide.

There are three key steps in planning the management of bottomland hardwood forests: (1) understanding current forest and environmental conditions; (2) clarifying objectives (the desired future condition); and (3) defining feasible actions that will transform the stand to the desired condition. In most cases, the silviculturist has several options for intervening in stand development, as there are multiple silvicultural pathways toward the desired future condition. The choice of silvicultural treatment will affect the financial cost, the nature of intermediate stand conditions, and the time it takes to achieve the desired condition. In general, silvicultural treatments consist of partial to complete removal of the trees on a site. Partial removals may consist of thinnings of desirable species to allow greater growing space of the leave trees or removal of undesirable species. If the silvicultural treatment can be combined with a timber sale, the landowner may be able to accomplish the treatment at no cost or even at a profit. It is imperative that silvicultural decisions are made with clear objectives in mind and with an eye toward rehabilitation success.

Determining Present Site and Stand Conditions

Diagnosing present site and stand conditions requires information to be gathered in an organized and rigorous fashion. The first step in forest management, including rehabilitating degraded bottomland forests, is to determine what currently occupies the site. A simple reconnaissance can give much of the preliminary information

Figure 14.1. Bottomland hardwood stand degraded by years of mismanagement.

needed for planning subsequent forest management. The initial reconnaissance should be followed by a more detailed site inventory before a silvicultural system is selected and interventions are prescribed. These activities should be performed by a knowledgeable forester.

Site Reconnaissance and Inventory

In the reconnaissance, boundaries of the site should be located and possible boundary-related problems identified. Potential problems could stem from trespassing or land-use practices on adjacent tracts, such as burning or herbicide spraying that may endanger the forest to be rehabilitated. Examples of other urgent problems discovered at this stage include destructive grazing, the presence of dump sites containing hazardous materials, or beaver dams in areas where they will cause excessive damage to the stand or limit access to the site. These problems should be addressed immediately.

The operability of the site, including soil and flooding conditions affecting accessibility to logging and other heavy equipment, existence of roads, and other practical considerations that will affect management options, should also be assessed during the reconnaissance. Included in this assessment should be a rough estimate of the timber volume and quality on the site. Getting a contractor to carry out desired management on the site may depend on the existence of enough timber to cover the costs of the operation.

A final goal of the reconnaissance should be to identify logical subunits of the site, called compartments, for subsequent inventory and management. Identifying subunits is important if the project site is large enough to contain different forest types, stands of different ages, or areas with special problems such as lack of access. Readily identifiable compartment boundaries, such as roads, streams, or power lines, should be used when possible.

A more detailed inventory of the site should generally follow the reconnaissance. If an area is large and rehabilitation will proceed over several years, it may be advantageous to delay the inventory until just before the first managed cut (i.e., the first thinning or the regeneration cut). The main advantage of delaying the inventory is that more accurate information on timber volume and quality will be available for setting up a contract with a timber buyer. Several references listed at the end of this chapter describe forest inventory techniques. Most often, the inventory will make use of randomly or systematically located sample plots for the overstory trees and nested subplots for seedlings and saplings. Methods for evaluating regeneration potential are discussed later in this chapter.

Assessment of Site Potential

Site "potential" refers to the combination of relatively unchanging physical factors which affect species composition and stand vigor: soil and landform (characteristics of which determine moisture availability, aeration, and fertility) and hydroperiod (flood frequency, duration, depth, and seasonal timing). These physical factors are not immutable, however, and changes in hydroperiod especially can degrade a site. On the other hand, selectively logging the biggest and best trees of a few species may degrade the stand without lowering the potential of the site.

Often a stand is so degraded that true site potential, in terms of species composition and productivity, is masked. Conversely, one must be careful to avoid attributing a higher potential than is warranted and mistakenly blaming degradation for inherently poor site conditions. A site's potential, and whether it has been degraded, sets limits on what can be achieved by silvicultural intervention. Site potential also determines the general direction of stand development and the likely outcome of any major disturbance that affects the existing stand. Because site potential has to do with physical factors, it is necessary to first place a site within a landscape context; for example, a silviculturist should assess whether a site occurs in the floodplain of a major or minor river system (Hodges, 1998; Kellison and others, 1998). On major river systems, sediment deposition causes a pattern of higher sites (ridges, fronts, natural levees) nearer to present or historic river channels, with lower lying sites farther away (flats). Inactive older channels (sloughs) and depressions are the wettest sites. Each of these "topographic sites" has the potential of being managed as a different compartment. Minor river bottomlands occur within a narrow floodplain, and therefore landform patterning is at a much finer scale. Stands in minor river bottoms may not differentiate into large enough areas to manage as separate compartments.

Each of these differences in topography and hydrology affect the species composition of the individual stands. Eight important species groups of bottomland hardwood forests are described briefly in table 14.1; more detail can be found in Meadows and Stanturf (1997); Hodges (1997); Johnson (1981); and Kellison and others (1988). The adaptation of species important for timber production to specific site conditions can be found in Baker and Broadfoot (1979), and the important silvical characteristics of most bottomland hardwood trees are treated by individual authors in Burns and Honkala (1990). Once a site's potential is understood, it is important to compare that to actual stand conditions and then to diagnose why there may be a difference.

Table 14.1. Species groups and expected regeneration under different silvicultural systems for important southern bottomland hardwood associations (Clatterbuck and Meadows, 1993; Meadows and Stanturf, 1997).

Species Association	Site Preference: Major Bottom	Site Preference: Minor Bottom	Silvicultural System	Species Favored
Cottonwood	Front (new land)		Seed tree with site preparation	Eastern cottonwood
			Clearcut	Sycamore, sweet pecan, green ash, boxelder
Black willow	Bar (new land)		Seed tree with site preparation	Black willow
			Clearcut	Sugarberry, green ash, baldcypress, American elm, overcup oak, bitter pecan, Nuttall oak
Cypress-water tupelo	Swamp	Slough	Group selection	Baldcypress, water tupelo, sometimes green ash, overcup oak, bitter pecan
			Clearcut	Baldcypress, water tupelo, sometimes green ash, overcup oak, bitter pecan, or elm and maple
Elm-sycamore-pecan-sugarberry	Front, high ridge		Group selection or clearcut	Sweetgum, red oaks[1], sycamore, sweet pecan, sugarberry, green ash
Elm-ash-sugarberry	Wide flats		Clearcut or group selection	Elm, green ash, sugarberry, Nuttall oak, willow oak
Sweetgum-red oaks	Ridges	High flats	Group selection	Sweetgum, red oaks, green ash
			Clearcut	Sweetgum, red oaks, and green ash favored, with sweetgum favored the most
			Shelterwood	Red oaks, sweetgum, green ash
Red oaks-white oaks[2]-mixed	Second bottoms, high ridges	Terrace	Shelterwood or group selection	Red oaks, white oaks, hickory, green ash, sweetgum, American hornbeam
Overcup oak-bitter pecan	Low flats, sloughs	Flats	Group selection	Overcup oak, bitter pecan
			Shelterwood	Overcup oak, bitter pecan, Nuttall oak, green ash

[1] Cherrybark oak, laurel oak, Nuttall oak, pin oak, Shumard oak, water oak, and willow oak.

[2] Bur oak, Delta post oak, live oak, overcup oak, swamp chestnut oak, white oak, and swamp white oak.

Site Inventory

Ideally, the inventory should quantify the species composition, timber volume, and quality of the overstory trees. Just as important is the inventory of the seedling and sapling component of the stand. This understory component, called advance regeneration, has the potential to dominate the stand in time. Quantifying advance regeneration helps the silviculturist predict the future species composition of the stand and decide whether planting of desired species will be necessary. Quantifying existing regeneration is particularly important if the management goal is to obtain a large component of oak species (or other heavy-seeded species with limited or unreliable seed dispersal) in the stand.

Advance regeneration can also alert the silviculturist to possible changes in site hydrology; if the flood tolerance of the species making up the overstory and understory differ substantially, hydrologic changes probably have occurred. At this point, the silviculturist will have to decide whether to work with the new hydrologic regime or attempt to restore the former regime.

Oaks are an important component of bottomland hardwood forests, valued for their timber quality, their hard mast production for wildlife, and generally for their aesthetically pleasing growth habit. As a group, oaks, and red oaks in particular, are difficult to perpetuate in successive stands on a site. In addition, oaks are the most likely species to have been selectively removed in high grading. Therefore a key challenge for silviculturists is successfully maintaining a viable oak component, which can be done by ensuring that adequate oak advance regeneration exists before timber removal or by artificial regeneration (i.e., planting seedlings or direct seeding of acorns). Information on oak regeneration potential is critical in most stand rehabilitation efforts. Johnson (1980) developed a system for assessing regeneration potential for a variety of bottomland hardwoods. Belli and others (1999) evaluated Johnson's system for high quality sites in terms of red oaks and green ash, which is another valuable timber species. Their method is based upon 1/100-acre (0.004 ha) circular plots systematically located throughout a stand. Each plot is evaluated for the number of red oak or green ash seedlings in three height classes: less than 1 ft (30 cm), 1 to 3 ft (30-90 cm), and greater than 3 ft (90 cm) tall. In addition, points are given for trees with high potential for producing acceptable stump sprouts (red oak or green ash trees 1 to 5 inch [2.5-12.7 cm] dbh). Each plot can be evaluated for the probability that it will have at least one seedling in a free-to-grow position after three growing seasons. From this information, one can determine the number and distribution of "stocked" plots, an indication of the future stocking of the stand.

Identifying Cause of Site Degradation

The cause of site or stand degradation should be identified. Stand degradation from high grading can often be remedied through vegetation manipulation alone. Alteration of the site by changed hydroperiod, on the other hand, poses broader questions. Can the hydroperiod be restored or the effects of alteration somehow mitigated? Should the rehabilitation effort target a different vegetation assemblage more adapted to the present hydroperiod and site conditions? Hydroperiod alterations caused by flood control projects, dams, or highway construction tend to be irrevocable, at least in the short-term. Flooding caused by beaver dams, however, can be reduced by removing the dam, but ongoing management of beaver population levels will be required to avoid recurring problems. Management of green-tree reservoirs is often politicized, and management of water levels to protect the vigor and survival of the hardwood stand in many instances conflicts with public perception of how to optimize waterfowl habitat. The guiding principle should be to rehabilitate or restore in accordance with existing hydroperiod, unless alteration is feasible, affordable, and within the control of the silviculturist.

Clarifying Objectives

Appropriate silvicultural practices can be designed for any objective. Most common objectives include timber, wildlife habitat for game species, or aesthetics. Increasingly other objectives are considered, including carbon sequestration, biological diversity, nongame mammals and birds, endangered animals and plants, protection of water quality and aquatic resources, and recreation. Different outputs may be sought for each objective. The timber management objective, for example, may be for sawlogs and veneer logs, or for pulpwood. Appropriate timber management, in particular rotation length, will vary according to the desired product size. Appropriate management techniques for wildlife will also vary for different species. Even Neotropical migratory birds have different habitat requirements, from mature closed forests to early successional seres. Choosing the appropriate silvicultural techniques presents a challenge for those individuals managing for apparently incompatible objectives. Slight modifications in technique may have negligible impacts on outcomes or outputs for one objective but major effects on another objective. Clarity of objectives, combined with an adequate understanding of feasible goals developed from information on current conditions, allows the silviculturist to choose a silvicultural system that will maximize satisfaction of multiple objectives; however, no single objective is usually optimized when multiple objectives are undertaken. Nevertheless, the chosen system may be adjusted to minimize impacts on other ecosystem functions.

The most developed basis for specifying a silvicultural system to meet an objective is for timber production. To the extent that we know the habitat requirements for a wildlife species, we can prescribe an appropriate silvicultural system that will provide suitable habitat. All species of bottomland hardwoods provide some benefit to wildlife (table 14.2), but we lack the knowledge to specify optimal habitat conditions for many species. Nevertheless, most objectives can be tied to some combination of vegetation species composition and stand structure, which can be manipulated by silvicultural techniques.

Choosing the Silvicultural System

Silvicultural systems in southern bottomland hardwoods integrate regeneration and intermediate treatments in an orderly process for managing stand development (Meadows and Stanturf, 1997). Techniques can be designed for manipulating species composition and stand structure to meet any management objective. Species favored under any silvicultural system can support several objectives. Although the greatest emphasis is usually placed on maintaining an oak component, forests can be managed without oaks and still yield multiple benefits. Silvicultural systems are commonly divided into even-aged and uneven-aged management, with the regeneration method used defining the system. Even-aged regeneration methods include clearcut, seed-tree, and shelterwood. Uneven-aged methods include single-tree and group selection (Meadows and Stanturf, 1997). In practice, there are many variations of these practices with some overlap and hybridization. A general guide to the types of regeneration expected under different silvicultural systems applied to important bottomland hardwood associations is given in table 14.1.

Management Versus Regeneration

The silviculturist must initially decide whether the degraded stand has the potential to attain the future desired condition through judicious manipulation, or whether the stand is so lacking in vigor, stocking, or acceptable species that the only alternative is to regenerate. Manuel and others (1993) developed a model to help make this decision. Their model is based on expert judgement and is constrained to consider only clearcutting for regeneration. It has been calibrated for a limited set of timber management objectives, but the approach is valid for any management objective. Each tree in a sample from the stand is evaluated for its contribution to future stocking, based on species, size (dbh), crown class, merchantable height, butt log grade, and vigor. This approach can be extended to include other management objectives and additional regeneration techniques.

Is Oak An Objective?

If maintaining oak in the stand is necessary to meet objectives, extra attention to regeneration potential is needed and extraordinary steps may be necessary. Clatterbuck and Meadows (1993) summarized the complexity of attempting to regenerate oaks in bottomland hardwood forests. Although no blanket prescription can account for all the factors which impact oak regeneration potential, their generalized prescription offers the best approach present knowledge can provide (table 14.3).

A regeneration evaluation is necessary at the outset. A modified system such as that of Belli and others (1999), where points are assigned based on species and size of advance regeneration can be used. For example, if a regeneration plot has at least 20 points from oak advance reproduction or stump sprouting potential, the probability of obtaining at least one free-to-grow oak stem at age three is 83% or more. If most of the regeneration plots in a stand meet this criterion, the regenerated stand has a high probability of oak dominance at maturity. We recommend that 80% of the plots in the entire stand meet this level of oak stocking. This is a judgement, however, and should be adjusted depending upon site conditions and landowner objectives. For example, if most of the points come from large seedlings (greater than 1 m or 3 ft tall), a lower probability level may be justified. On the other hand, sites prone to growing season flooding may require a more stringent criterion.

When the prospects for oak regeneration are good, the stand should be harvested while trees are dormant to maximize stump sprouting. All residual stems 2 inches dbh and larger should be felled to create the proper light environment for the oak regeneration and to minimize competition from other species. Retaining some stems in a clearcut (depending on the purpose of these residual trees, this may be called a deferment cut, clearcut with residuals, or an irregular shelterwood) may be necessary to meet wildlife or aesthetic objectives.

A follow-up examination to determine regeneration stocking at age three is needed to guide future management. Experience has shown that as few as 150 free-to-grow oaks per acre (370 per ha) at age three will result in an oak dominated stand.

Table 14.2. Selected species of bottomland hardwood trees and their associated values as wildlife food. FO = foliage; FR = fruit; S = seed; LA = leaf gall aphids; BU = buds; IB = inner bark; BA = bark.

Species	Deer	Turkey	Squirrel	Waterfowl	Quail	Songbirds	Raccoon	Beaver	Other
Ash, green	FO				S	S			S[1]
Ash, pumpkin						S			S[1]
Ash, white	FO				S	S			S[1]
Birch, river	FO					S			S[1]
Buckthorn bumelia						FR			
Buttonbush	FO			S				FO	
Cottonwood, eastern	FO	LA							
Cypress, bald (baldcypress)									S[1]
Dogwood, swamp	FO	FR	FR			FR	FR		FR[2], FO[3]
Elm, American						FR			
Elm, cedar						FR			
Elm, water				FR					
Elm, winged						FR			
Blackgum	FO,FR	FR				FR	FR		FR[1,2]
Sweetgum			S, BU	S	S			IB	S[1]
Hawthorn		FR	FR	FR	FR	FR			FR[1]
Pecan, sweet	FR		FR				FR		
Hickory, water			FR	FR					FR[1]
Holly, American	FO	FR			FR	FR			
Holly, deciduous	FO	FR			FR	FR			FR[1]
Hornbeam, American	FR	FR							
Locust, black[6]	FR		FR		FR				FO[3], FR[1,3]
Locust, honey[6]	FO		S		S				
Locust, water	FR		FR						FR[3]
Boxelder	FO					S			S[1]
Maple, red	FO		S, BU			S			S[1]
Mulberry, red	FO	FR	FR			FR	FR		FR[1], BA[3]
Oak, cherrybark	FO,FR	FR	FR	FR		FR			FR[1]
Oak, Delta post	FR	FR	FR			FR			FR[1]
Oak, Nuttall	FO,FR	FR	FR	FR					FR[1]
Oak, overcup	FR		FR						FR[1]
Oak, Shumard	FO,FR	FR	FR			FR			FR[1]
Oak, swamp chestnut	FR,FO		FR						FR[1]
Oak, swamp white	FR	FR	FR	FR			FR		FR[1]
Oak, water	FO,FR	FR	FR	FR	FR				FR[1]
Oak, white	FR,FO		FR			FR	FR		FR[1]
Oak, willow	FO,FR	FR	FR	FR		FR			FR[1]
Pawpaw							FR		FR[2]
Persimmon, common	FO,FR	FR			FR	FR	FR		FR[1,2,4]
Privet, swamp				FR		FR			FR[1]
Sassafras	FO	FR	FR		FR	FR	FR		FR[5]
Sugarberry	FO				FR	FR			FR[1]
Sycamore, American						S			
Tupelo, water[6]	FO,FR		FR	FR		FR	FR		
Willow, black							IB		

[1] Small mammals
[2] Opossum
[3] Rabbit
[4] Skunk and fox
[5] Black bear
[6] Flowers furnish nectar for honey bees

Table 14.3. Decision key for choosing a regeneration procedure for bottomland oaks (Clatterbuck and Meadows, 1993; Belli and others, 1999)

	Go to
1. Regeneration Evaluation	
a. 20 points or more, average of all plots; oak prospects good	2
b. Less than 20 points, oak prospects poor	6
2. Treat and harvest during dormant season; control residual stems prior to next growing season	3
3. Evaluate at age 3	
a. More than 150 free-to-grow oaks per acre	4
b. Less than 150 free-to-grow oaks per acre	5
4. Leave alone or clean, weed, or thin if needed	
5. Oak stocking is less than adequate	
a. Accept	
b. Convert to plantation	
6. Promote oak advance reproduction and evaluate again	
a. Increase light to forest floor (understory removal and/or overstory reduction, shelterwood)	1
b. Shelterwood with understory removal and supplemental planting of oak seedlings	1
c. Convert to plantation	

If oak regeneration is inadequate in the current stand (table 14.3), the challenge is to create the proper light conditions on the forest floor to promote seedling growth. Reducing the overstory and removing the understory through a shelterwood treatment can be successful if small oak seedlings are already present. It may even be possible to time the shelterwood treatment (see shelterwood section, this chapter) with a good mast year; otherwise underplanting oak seedlings before the final overstory removal can augment the shelterwood. This may require releasing the oak seedlings from competition by using herbicides. There are no guidelines on how to accomplish this successfully. Another approach is to supplement a clearcut by planting or direct seeding of oak but again, no guidelines are available.

Managing the Existing Stand

In a stand with trees of commercial value, a logical sequence of management actions would be (1) initial intermediate management, consisting of an "improvement cut" to favor a desirable species composition and to increase the quality and value of the stand; (2) advanced intermediate management, where thinning is used mostly to favor growth on residual trees but also to improve stand value; and (3) regeneration cutting. Intermediate stand management in most bottomland hardwood situations is a combination of improvement cutting and thinning. The relative emphasis changes with the degree of stand management (initial versus advanced).

In the short term, the silviculturist will be most concerned with improvement cutting because thinning and regeneration cuts may not be needed for 10 or more years. In the case of extremely degraded stands with inadequate advance regeneration, however, it may be necessary to bypass the first two management steps and go straight to a regeneration cut. A general guideline used by some foresters to decide whether to proceed straight to a regeneration cut is shown in figure 14.2. If the average basal area per acre for a stand of a given age is below the line, then the stand is promptly cut. For most stands older than 40 years, basal areas below 60 ft^2 per acre indicate the need to regenerate. More precise guidance is available in stand density diagrams that take into account average stem size and age.

Timber Stand Improvement

By definition, degraded stands have a history of high grading, liquidation cuts, fire, and other destructive influences that have resulted in a high proportion of trees that are undesirable as future growing stock. Low-grade, overcrowded, damaged, diseased, and cull trees, as well as exotic or otherwise undesirable species, may be occupying space and competing for light, water, and nutrients that ideally could be supporting more valuable trees. Therefore the first stand manipulation is usually a judicious improvement cut designed to "clean up" the forest.

In ideal cases, the stand will be accessible and there will be enough timber to interest potential buyers. In such a situation, timber stand improvement can be done at no cost (or possibly even at a profit) to the landowner. Some desirable growing stock may need to be cut to make openings for regeneration or to have enough timber to interest a buyer. The goal, however, should be to cut the over-mature, damaged, or dying trees of marketable size and quality. One should not remove a large component of desirable growing stock just to make

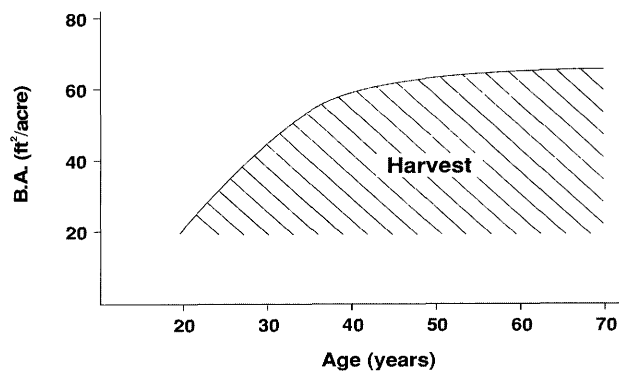

Figure 14.2. A generalized guide for regenerating southern hardwoods based on basal area (measured in ft^2 per acre) of desirable trees and stand age (redrawn from Kellison and others, 1988).

a sale, as such trees are often growing at a high rate and will be much more valuable to the landowner in the future.

Landowners unfamiliar with contracting with buyers for removal of timber are well advised to consult with a professional forester. A properly designed and supervised timber sale should lead to the improvement of the forest. Under the wrong conditions, however, a buyer may end up removing trees that should remain, damaging remaining trees in felling or skidding of harvested trees, creating inordinate amounts of soil disturbance, or degrading water quality of adjacent streams (fig. 14.3).

After marketable trees are cut and removed, cull and otherwise undesirable trees that remain should be killed to enlarge or clear openings for regeneration. Injection is the usual method of killing unwanted trees. Generally, injection just after full leaf-out in the spring gives good results, but satisfactory results have also been obtained with applications in other seasons. Girdling is another method that is occasionally used to kill unwanted trees, but this is often unsuccessful when used alone because trees can heal over incomplete wounds and girdled trees may sprout.

It should be kept in mind, of course, that a "clean" forest from a strictly timber management perspective may not be the goal of the silviculturist. Mature cane breaks (fig. 14.4) will not bring any financial return to the landowner but they provide habitat for numerous wildlife species (including swamp rabbits and several species of rare warblers). Leaving some large, poorly formed trees and snags may be beneficial to several species of wildlife or may meet other objectives (fig. 14.5). As with other silvicultural techniques, timber stand improvement should be viewed as a flexible tool that can accomplish a variety of objectives.

Thinning

Once timber stand improvement has produced a stand consisting of good quality trees at desirable spacing, growth rates of the remaining "leave" trees should increase. Eventually, the leave trees will fully occupy the space opened up by the removal of undesired trees and begin to compete intensely with each other. Thinning at this point allows for the use of trees that would otherwise die and allows for distribution of growth over fewer, larger trees. Thinning has the additional advantages of increasing mast production in the overstory and allowing more light to reach the forest floor. This stimulates understory and midstory plant growth, which increases vertical structure important to some Neotropical migratory birds.

Thinning has not been widely practiced in southern bottomland hardwood stands, especially in stands with

Figure 14.3. Example of damage caused by poor logging practices.

Figure 14.4. Mature cane brakes provide habitat for numerous wildlife species.

only pulpwood or smaller sized trees (i.e., less than about 25-30 cm [10-12 inches] dbh). As markets develop for pulpwood and firewood, thinning is becoming more common. The first commercial thinning typically occurs when trees reach small sawtimber size, about 35 cm (14 inches) dbh. A second thinning may be conducted when trees reach 50-56 cm (20-22 inches) dbh. Earlier thinning (precommercial) is practical from an economic standpoint if one of the major goals of management is production of sawtimber.

Because of inherent growth differences among species, it would be hard to give an average age for the first thinning. Cottonwood may reach merchantable size by age 5 to 10 years, whereas it may take green ash 20 to 30 years to reach pulpwood or small sawtimber size. Findings thus far in natural and planted stands offer some guidelines for thinning (Meadows, 1996). Thinning should begin early, and larger trees with well-developed crowns should be favored. For good diameter growth, most species require a minimum live crown to total height ratio of 40%. Trees with less crown are usually in a subordinate position, so thinning is from below (i.e., the trees removed in the thinning are usually partially or completely overtopped by other trees).

Frequent light thinnings are better than infrequent heavy thinnings. Light thinnings allow fuller use of the site and less chance for epicormic branches to develop on the leave trees. One disadvantage of frequent thinnings, though, is the greater chance of logging damage to the leave trees. As a stand matures, thinning should be used to develop advance reproduction of desirable species so that the need for corrective measures at the time of regeneration will be less.

Regeneration

Bottomland hardwoods reproduce naturally and prolifically through seedlings established in the understory, through sprouts that emerge from stumps or roots of cut trees, or through seedlings that start in new openings. As long as there are no fundamental changes to the site, management of the natural regeneration can generally be relied upon to yield the desired forest composition.

As a rule, silviculturists should rely on natural regeneration. Artificial regeneration, however, will be needed for rehabilitation when none of the natural means of reproduction can be counted on to provide adequate numbers of desirable species. This situation

Figure 14.5. Snags left in a clearcut on Scott Paper land near Mobile, Alabama.

arises where there is inadequate advance regeneration of desirable species and there are no mature trees of desired species in the overstory or adjacent to the site to provide a seed source. In such cases, the silviculturist has two main alternatives. First he or she must try to increase the component of desirable species by planting before (enrichment underplanting) or after a regeneration cut (supplemental planting). Second, the silviculturist can take the more drastic measure of converting the stand to another vegetation type by clearcutting the site, shearing all remaining trees and saplings, and preparing the soil to plant seedlings of one or more species (fig. 14.6). Generally, this will only be warranted if the site has been captured by invasive exotic species such as Chinese tallow, Japanese privet, or melaleuca.

Regeneration Cuts

A landowner may wish to manage a stand as an old-growth forest without any human intervention. Over time, natural mortality and gap phase regeneration will convert the forest to shade tolerant species. Otherwise, all stands will eventually reach a stage when it is appropriate to harvest some or all of the large trees. This not only allows for an economic return from the stand, but also gives the landowner the ability to control the future composition of the stand to meet any of a variety of management goals. By proper choice and application of a regeneration system, the landowner can help ensure that the desired type of forest will occur on the site for many years to come.

Bottomland hardwoods can be managed as even-aged or uneven-aged forests. Silvicultural systems used for even-aged management are clearcuts, shelterwood cuts, and seed tree cuts. The primary silvicultural system for uneven-aged management is single-tree selection. Group selection is technically an uneven-aged management system, but as practiced in bottomland hardwood forests, it should be viewed as a compromise between even- and uneven-aged management. All of these systems can be used effectively in bottomland hardwood forests. The choice of silvicultural system will depend primarily on the management goals for the forest, as constrained by the initial condition of the stand. Even-aged management, in particular clearcutting, is the most common form of management when timber is the primary goal or when rehabilitating a high-graded stand. Shelterwood and group selection are more commonly used when wildlife management is an important goal, when aesthetics

Figure 14.6. Natural forest site that has been clearcut, sheared, root-raked, and disked.

are important, and when adequate advance regeneration is not present. Group selection can be used for timber production in fully stocked stands, and variations on shelterwood can be used especially when attempting to regenerate oak.

Clearcuts

Clearcutting involves the cutting and removal of all merchantable trees in an area of about 4 ha (10 acres) or more. Typically, the residual trees, which are comprised of undesirable species or are of poor quality and may interfere with regeneration of desirable trees, are either cut down and left in place or killed by injection or girdling. The site usually will be left to regenerate naturally, although site preparation, supplemental planting, and other measures may be applied to control species composition. A clearcut site will go through a jungle-like stage for about 10 years before individual stems begin to restore a forest-like appearance to the area (fig. 14.7).

Clearcutting is designed to favor the reproduction of shade-intolerant species, which also tend to be the more economically valuable species. While often criticized as a destructive and unsightly form of forest management, clearcutting with natural regeneration repeatedly has been demonstrated to be effective for regenerating nearly every major forest type found on bottomland hardwood sites in the Southeast. The aesthetic impacts and risk of erosion associated with clearcutting are real but are less in relatively flat bottomland settings as compared to steep mountainsides.

As a general rule, clearcutting with natural regeneration will tend to favor shade-intolerant, light-seeded species that are easily transported by wind or water (see table 4.1). Species that regenerate from coppice such as the oaks must be present prior to cutting as large seedlings or small trees. Conversely, seedlings of more shade-tolerant species such as hickories, elms, ashes, ironwood, and some oaks tend to become established in small openings.

To the silviculturist, it will be appropriate to employ clearcutting as the first step in rehabilitating a stand that is so completely degraded that there is very little advance regeneration of desirable species. In such cases, there is little point in attempting to manipulate the stand by timber stand improvement and thinning. Essentially starting over by clearcutting with natural regeneration and possibly some planting, or totally by artificial regeneration, will be the most efficient means of rehabilitation.

Shelterwood Cutting

The goal of shelterwood cutting is the same as clearcutting—to favor species that require high light levels to regenerate. With a shelterwood cut, however, the overstory is harvested in at least two stages. In the first stage, a large portion of the existing overstory (perhaps about 50%) is harvested. Trees that are left are

Figure 14.7. Five to ten-year-old regenerating clearcut.

generally of good quality and expected to be good seed producers (fig. 14.8). After about 5-8 years, either all or about half of the remaining overstory trees are removed. In the latter case, the remaining trees are generally harvested in a third cut after another 5-8 years. Shelterwood may be combined with the underplanting of oaks before final overstory removal. Usually midstory removal is necessary in bottomland hardwoods to gain the full benefits of the shelterwood system.

The main purpose of the shelterwood system is to favor regeneration of species with limited seed dispersal and those that regenerate best in partial shade. Oaks, for example, are believed to respond well to shelterwood regeneration when there are sufficient individuals in the existing overstory. The shelterwood system is also a good alternative to clearcutting when aesthetics are important and complete overstory removal in one cut is not an option.

Seed Tree System

The purpose of the seed tree system is to provide a seed source after a complete overstory removal. Theoretically, heavy-seeded species such as oaks can be regenerated by this method, but in reality this method regenerates light-seeded species in bottomland hardwoods. Approximately 25 per ha (10 per acre) are usually retained after the first cut, so the area will resemble a clearcut with just a few, large scattered trees remaining. In appearance, this is the same as a deferment cut for aesthetics or leaving potential den trees for wildlife. What separates these variants on even-aged management is the purpose for leaving residual trees.

As a regeneration method, seed tree cuts are more effective for light seeded species such as sweetgum. When coupled with intensive site scarification, it is the recommended method to naturally regenerate Eastern cottonwood and black willow. Experience suggests that bottomland hardwood stands dominated by oaks respond to a seed tree cut as if they were clearcut (i.e., by advance regeneration, by sprouts, and by germination of existing seeds or seeds brought in by wind, water, or animals). Furthermore, the remaining trees often become degraded by epicormic branching, lightning strikes, and wind damage, and therefore lose much of their economic value.

Single-Tree Selection

This system involves the selective removal of individual mature trees at regular intervals. It may also be accompanied by deadening (i.e., injection, girdling) or

Figure 14.8. Shelterwood cut.

removal of unmerchantable trees. Because single-tree selection opens relatively small holes in the canopy, it tends to favor regeneration of species that are shade tolerant. Repeated application of single-tree selection in a stand will shift species composition to the less valuable, more shade-tolerant sugarberry, boxelder, elms, maples, and hickories (table 14.1).

Properly practiced, this method can be very effective for maintaining a relatively dense uneven-aged forest over a large area. It can, however, result in the degradation of the forest. In fact, many of the degraded bottomland hardwood forests that are the subject of this chapter were created by what might be considered a very poor form of single-tree selection. Too often, only the best trees were selected for harvest. If this cycle is repeated, then over time the stand will become dominated by a mix of damaged, diseased, and poorly formed trees and trees of undesirable species. This form of management is known as high-grading.

Single-tree selection is not generally viewed as economically feasible because it leaves species which are generally less valuable and also because it requires frequent small harvests, thereby sacrificing the economy of scale of larger harvests. Frequent entry into the stand with heavy logging equipment also poses the risk of damage to the remaining trees and the introduction of diseases. Such stresses may predispose a stand to insect outbreaks.

Group Selection

The goal of group selection is to develop a patchy environment made up of numerous very small even-aged groups. This is accomplished by making numerous scattered large openings (small patch clearcuts) ranging in size from 1 to several acres (fig. 14.9). The distinction in opening size between group selection and patch clearcut is a blurry one. A 10-acre cut can be viewed as a very large group selection or a small clearcut, depending on one's perspective. The real difference is whether the resultant stand will be managed as an uneven-aged stand or several even-aged stands.

The group selection system has several advantages. By creating sufficiently large openings, it favors the more economically valuable shade-intolerant species such as oaks. In addition, by creating a patchy environment of several different age classes, it favors numerous species of wildlife. As the openings are small and scattered, group selection is more aesthetically pleasing

Figure 14.9. Aerial photo of several group selection cuts.

than larger clearcuts. Although group selection may not be desirable for maximizing income from timber production, it has become widely used on wildlife refuges and other areas where wildlife management is a primary goal. Disadvantages include the necessity of more entries into a stand and higher risk of logging damage to residual trees, higher incidence of disease from the logging damage, and the need for more demanding management in terms of expertise, inventory, and record keeping.

Bringing Back the Bush

The preceding sections have covered traditional silvicultural approaches to rehabilitating degraded forests. These are the most appropriate techniques for rehabilitating relatively large tracts and those tracts where timber harvests are feasible. In some situations, especially on very small tracts and in urban settings where exotic vegetation is a primary concern, a smaller scale but more labor-intensive approach might be more acceptable.

An interesting approach to this type of rehabilitation has developed in Australia under the catchphrase "bringing back the bush" (Bradley, 1988). This approach was developed to restore small areas of Australian bush in urban settings that have been overrun by exotic plants.

The Bradley method is based on the gradual weeding out of the exotics by working through the tract in small increments. Landowners and managers are advised to follow three principles that guide this approach: (1) work from areas of native plants towards weed-infested areas, (2) make minimal disturbance, and (3) let native plant regeneration dictate the rate of weed removal. From the third principle, it should be clear that this is a slow approach to rehabilitation. It also requires a fairly high degree of knowledge about the growth habits and ecology of plant species and is very labor intensive.

The best way to apply this approach may be to work with knowledgeable volunteers to rehabilitate a small tract of forest in or near an urban area. The most valuable aspect of this approach may be as a tool for promoting environmental awareness and education.

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Glossary

Advance regeneration - Advance growth seedlings or saplings that develop and are present in the understory.

Adventive plants - Nonnative plants that have been introduced to an area but have not become permanently established.

Basal area - The cross-sectional area of a stand of trees measured at breast height (140 cm or about 4 ft 6 inches aboveground). The area is expressed in square meters per hectare (ft per acre) and is a measure of stocking density.

Broad-leaved - Characterizing plants that have leaves that are broad and flat rather than needle-shaped.

Clustering - With respect to the planting of seed or seedlings, clustering refers to planting in groups within close proximity of each other so that cross-fertilization within species can occur with some level of certainty.

DBH (diameter at breast height) - The diameter of a standing tree measured 140 cm (4.5 ft) from the ground.

Deciduous - Pertaining to perennial plants that lose their leaves part of the year, that is, hardwood trees such as oak, hickory, and maple.

Epicormic branching - The development of small branches along the bole, or trunk, of a tree. This often develops in response to thinning operations where substantially greater sunlight penetrates to the tree stems.

Even-aged management - Silvicultural system in which the individual trees originate at about the same time and are removed in one or more harvest cuts, after which a new stand is established.

Exotic species - Species that are not native to an area and have become naturalized.

Gap phase regeneration - Progressive changes in community structure, composition, and diversity resulting from the canopy gap created by the death of individual trees (as a result of events such as old age, wind, lightning strikes, insect attacks, etc.) being filled by young individuals of the same or other species.

Green manure - Refers to herbaceous plants that are plowed under while still green to add large quantities of organic matter to the soil, improving soil structure.

Green-tree reservoir - Any impoundment created with the intention of flooding a forested area for a portion of the year, yet retaining the forest cover. Green-tree reservoirs are usually flooded during a portion of the fall and winter to provide waterfowl habitat. Quite often, however, the tree species desirable for waterfowl habitat are gradually killed by the repeated flooding.

Hard mast-producing - Species such as oaks, pecans, or hickories that produce a large nut (acorn) that in turn provide food for a variety of wildlife such as deer, turkey, hogs, and some waterfowl (see heavy-seeded species).

Heavy-seeded species - Species such as oaks, pecans, or hickories that have heavier seeds. These species are generally believed to provide the greatest overall value to wildlife such as deer, turkey, squirrel, and waterfowl.

Herbaceous - Soft and green vegetation which dies back to the ground each year, generally containing little woody tissue.

High grading - Forest harvesting where only the most commercially valuable trees are cut. This method of harvest usually results in a forest dominated by undesirable or weedy tree species.

Hydric - Characterized by or requiring an abundance of moisture.

Hydrologic regime - The pattern of water level dynamics, generally referring to the timing, frequency, depth, and duration of aboveground flooding, but hydrologic regime also refers to belowground water level fluctuations.

Hydroperiod - Generally synonymous with hydrologic regime, but hydroperiod is often considered to refer to aboveground flooding only.

Improvement cutting - A cutting made in a stand past the sapling stage primarily to improve composition and quality by removing less desirable trees of any species.

Initial management - The first management action being performed as part of a long-term multiphase management plan for a given forest stand.

Invader - Any species that disseminates to and becomes established on a site without human intervention can be considered an invader. Invading seedlings can be either desirable or undesirable. The term invader does not refer only to exotic species.

Light-seeded species - Species such as ash, elm, sweetgum, and sycamore that have light weight seeds that can be easily dispersed by wind or water. Many of these seeds, however, can also be dispersed by animals.

Mesic - Characterized by intermediate moisture conditions that are neither excessively wet nor dry.

Nonpoint source pollution - Pollution that is not from a single, well-defined site such as a factory. Runoff from agricultural fields is generally considered nonpoint source.

Palustrine system - A classification by Cowardin and others, 1979, that includes all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 ppt.

Provenance - The original region in which an individual of any plant or animal species was found. Provenance tests take individuals of any selected species from several regions and grow them in a common area (plantation) to search for maximum growth or productivity for that species.

Regeneration - The natural or artificial replacement of old trees with new tree growth.

Self-incompatible species- Plant species for which one flower on an individual cannot fertilize another flower on the same individual.

Sere - Collectively, all temporary plant communities in a chronosequence of change, as different species invade and later dominate or are competitively excluded from a given local area.

Shelterwood cut - A cut in which the mature stand is generally removed in a series of two or more cuts, the last of which is when the new even-aged stand is well developed.

Silviculture - The science and art of regenerating and managing a forest to meet specific objectives.

Soil horizon - A distinct layer of soil parallel to the surface that has definitive physical, chemical, and hydrologic characteristics.

Stand - A contiguous group of trees sufficiently uniform in age class distribution, composition, and structure, and growing on a site of sufficiently uniform quality to be a distinguishable unit.

Stocking - An indication of growing-space occupancy relative to a preestablished standard.

Thinning - Intermediate cuttings aimed primarily at controlling growth of timber stands by adjusting stand density.

Tiling - The placement of drain tiles below the ground to eliminate excess flooding or soil saturation.

Understory - Any plants growing under the canopy formed by other plants, particularly herbaceous and shrub vegetation under a brushwood or tree canopy.

Uneven-aged management - Silvicultural system in which individual trees originate at different times and result in a forest with trees of various ages and sizes. Harvest cuts are often on an individual-tree selection basis.

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Appendix A
Society of American Foresters Cover Type Descriptions

The cover type descriptions listed in this manual for bottomland hardwoods are from Society of American Foresters (SAF) publication, "Forest Cover Types of the United States and Canada," reprinted verbatim with permission from Eyre, 1980. Numbers listed below the cover types refer to the classification system used by the SAF. For a more complete list of forest cover types or for scientific names of the common names used in the cover type descriptions, please see Eyre, 1980.

River Birch–Sycamore
61

Definition and composition. River birch and sycamore, commonly found along rivers and streams in eastern North America, may be recognized as a type when occurring together as dominants in floodplain or bottomland forests. River birch usually has the greater density of stems, but sycamore may be more conspicuous because of its generally greater size and many stem sprouts (Fowells 1965). The type is of minor importance in its contribution to forest cover except in relatively narrow bands of about 30 m (100 ft.) on frequently flooded, moist alluvial soils.

Associated tree species may include black willow at the edge of the river, and farther back, other flood-tolerant species such as sweetgum, cottonwood, red maple, silver maple, boxelder, hackberry, American elm, slippery elm, walnut, and butternut. Mesophytic species such as sugar maple, yellow-poplar, white oak, overcup oak, loblolly pine, and Virginia pine from adjacent terraces and uplands may appear in the community.

Geographic distribution. The type occurs sporadically where the ranges of the two species overlap. Generally, this is a region that extends from northeastern Florida west to eastern Texas, north to southern Illinois, east through southern Ohio, and then northeast into parts of southern New England (Little 1971). In combination with other bottomland types river birch-sycamore occurs primarily along rivers and streams and occasionally on wet lake margins. The type has been reported at an elevation of 457 m (1,500 ft.) in the southern Appalachian Mountains (Allen R. Bateson 1978, personal communication) and may occur as high as 762 m (2,500 ft.).

Ecological relationships. The position of the type adjacent to rivers and streams suggests that it appears early in the establishment of floodplain vegetation and follows pioneer species such as black willow. However, either or both species may occur in the absence of a willow border (Wistendahl 1958). Seedling establishment and survival are more closely associated with flooding patterns and with the absence of competition for light from other bottomland and floodplain species than with a rigid successional sequence. Although tolerant of periods of soil saturation, both species grow best in the generally moist but periodically drained sandy alluvium of natural levees, where litter accumulation is sparse and there is direct light.

River birch may form almost pure stands along streams flooded by acidic water where a consequential increase in dissolved aluminum is toxic to associated species but not to river birch (Cribben and Ungar 1974).

The occurrence of river birch and sycamore together in numbers sufficient to be recognized as a type is probably fortuitous and dependent on seed dispersal at a time when bare soil (deposited by floods or exposed by erosion) is available for seedling establishment. Flooding kills many seedlings. River birch seed germinate in large numbers soon after dispersal in late spring or early summer, whereas sycamore seed are dispersed in the fall but germinate the following spring (Forest Service, USDA, 1948). Flooding subsequent to these times reduces seedling density of one or the other or both species.

Variants and associated vegetation. The relative proportion of each species in a given stand varies greatly. In areas affected by acid mine water drainage, the type may be composed of but six or fewer species of trees, with river birch comprising 90 percent or more of the stem density. Elsewhere, a greater mix of species (12 or more) may be found, with river birch having approximately half of the total stem density. In such stands the density of sycamore stems is generally less than 10 percent (Cribben and Ungar 1974).

Locally within any stand river-bank grape or winter grape may be abundant. Poison-ivy occurs on disturbed, open sites. Few shrubs are present, but small trees such as common (hazel) alder, American bladdernut, and

American hornbeam may form a dense understory. Herbaceous plants are highly diverse and are abundant seasonally, especially spotted touch-me-not and woodnettle.

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Silver Maple–American Elm
62

Definition and composition. Silver maple and American elm are the majority species in this type, although the proportion of either depends on the history of the stand. Major associates may include sweetgum, pin oak, swamp white oak, eastern cottonwood, sycamore, green ash, and other moist-site hardwoods, according to the region.

Geographic distribution. The type is common throughout the central forest region of the United States and in the deciduous southern portion of the Great Lakes-St. Lawrence forest region of Canada. It occurs primarily on well-drained moist sites along river bottoms and floodplains and beside lakes and larger streams. This type is only sparingly represented along the East Coast and is absent at the high elevations in the Appalachians. It is most common in the Ohio, Wabash, upper Mississippi, and Missouri river valleys of the United States and in the floodplains of southern Ontario.

Ecological relationships. Silver maple–American elm is generally regarded as a subclimax type in the portion of its range in the United States, following cottonwood and willow, and as a climax type in the portion of its range in southern Ontario, where it regenerates in willow and red-osier dogwood thickets. Small pockets may sometimes develop as pioneer succession on abandoned agricultural lands on floodplains. The type is more common on organic soils than on medium- to fine-textured mineral soils; rarely does it occur on clays and gravels.

Variants and associated vegetation. A variant, silver maple–American elm–pin oak–sweet gum, is found in sloughs and well-drained benches along major streams in southern Illinois and southern Indiana (Telford 1926). In southern Ontario the type generally consists of a mixture of silver maple, American elm, green ash, and eastern cottonwood in varying proportions. However, in the washboard swamps where high and low ground is intermingled the type often includes such species as red maple, basswood, black walnut, black cherry, black gum, hackberry, and boxelder. The understory may include willow, redberry elder, red-osier dogwood and greenbriar. The ground cover mainly consists of woodnettle, jewelweed, poison-ivy, ferns, sedges, cardinalflower, Joe-pye-weed, swamp milkweed, and boneset.

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Cottonwood
63

Definition and composition. Cottonwood is pure or comprises a majority of the stocking, but it is associated with other bottomland hardwoods. Eastern, plains, and swamp cottonwood are included under the type name. The chief associates in the younger stages are black and sandbar willow. Sweetgum is rare. White or green ash, silver maple, and American elm may occur in the northern extremities of the type and pecan, sycamore, and sugarberry in the southern.

Geographic distribution. The type is characteristic of the fronts or banks of all major streams in the central and southern forests. It is found along major streams of the Great Plains, but particularly within the Mississippi, Ohio, and Missouri river systems. Along the East Coast, cottonwood as a type occurs only in small groups along river and stream bottoms.

Ecological relationships. Cottonwood is a temporary, pioneer type capable of phenomenal growth. Along with the willows, it establishes itself wherever moist, bare soil is available: on newly made sandbars, front land ridges, and well-drained flats, and occasionally on abandoned fields on well drained ridges in the first bottoms. Where cottonwood and willow occur together, cottonwood outgrows willow and eventually becomes dominant unless frequent and extended flooding during the growing season covers the trees and only willow survives. Sites commonly silt in during the life of the stand, with possible elevation changes as great as 6 m (20 ft.), though the increment from any one flood may range from only 2.5 cm (1 in.) to .9 to 1.5 m (3 to 5 ft.). Cottonwoods and willow are relatively short lived and cannot regenerate under shade. Invaders in the next successional stage are sycamore, pecan, sugarberry, hackberry, river birch, green ash, American elm, silver maple, red maple, and boxelder. As soils build up and willows and cottonwoods drop out, succession in the central forest usually passes to the silver maple–American elm type or to boxelder, and in the southern forest to sycamore–sweetgum–American elm, sugarberry–American elm–green ash, or boxelder. The cottonwood type merges with the cottonwood–willow type in the Great Plains area.

Variants and associated vegetation. Common understory tree species are boxelder, sugarberry, red maple, silver maple, American elm, red mulberry, roughleaf dogwood, and swamp-privet. Undergrowth may consist of stinging nettle, pokeweed, poison-ivy, greenbrier, trumpet creeper, peppervine, dewberry, and grape. Herbs may or may not be present, depending on how dense the overstory is and how long flood waters cover the ground during the growing season.

Levee systems and stream channelization have restricted the area available for formation of the cottonwood type.

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Pin Oak–Sweetgum 65

Definition and composition. Pin oak and sweetgum form the majority of trees in the overstory, although the proportion of each varies according to geographic location and edaphic factors. Associates may include red maple, American elm, blackgum, swamp white oak, willow oak, overcup oak, bur oak, green ash, Nuttall oak, swamp chestnut oak, white oak, and shellbark and shagbark hickories.

Geographic distribution. This forest cover type occurs in the Ohio River Valley and tributaries from West Virginia through southwestern Ohio, southern Indiana, southern Illinois, Kentucky (except the eastern mountains), and in the western two-thirds of Tennessee. It extends southward in the central Mississippi River Valley from southeastern Missouri to central Arkansas and western Tennessee and through central Arkansas in the Arkansas River Valley (Telford 1926, Chapman 1942).

Ecological relationships. In broader stream valleys the type occurs on clay flats and in depressions where shallow water accumulates during the winter, and on clay ridges of first bottoms (Putnam and Bull 1932; Braun 1936,1950; Kilkus 1977). The type is rare, however, on the most poorly drained sites and does not occur where inundation is permanent. It also occurs in old fields on poorly drained, impervious wet uplands of the Illinoian till plain, but pure pin oak stands much more commonly occupy these sites, which comprise the "pin oak flats."

The pin oak–sweetgum type is an early successional stage in the regrowth of bottomland forests, although it was common in the original forests and may persist for prolonged periods on poorly drained sites (Braun 1936). Where drainage is better sweetgum will remain as a component of later successional phases whereas pin oak is the first to disappear with further successional development. In southwestern Ohio where sweetgum and red maple are abundant in the initial regrowth phase, beech follows in the intermediate phase; where pin oak is more abundant in the initial phase, white oak follows (Braun 1936). Similar patterns probably do not develop in the western and southern portions of the range of this type.

Variants and associated vegetation. The proportion of sweetgum to pin oak increases from north to south and from wetter sites to drier, and nearly pure stands of each species may occur accordingly. In central Arkansas this type may grade into sweetgum–willow oak as the southern range limit of pin oak is reached. In the north, variants include white oak–pin oak–sweetgum (an intermediate successional stage), pin oak–American elm, pin oak–red maple, red maple–American elm–sweetgum, and pure pin oak. In the lower Ohio and central Mississippi valleys, pure pin oak stands are more abundant than mixed pin oaks and sweetgum (L.S. Minckler 1978, personal communication). Shrubs and small trees, if present, may include blue beech (American hornbeam), deciduous holly (possumhaw), poison-ivy, and trumpet creeper. The herbaceous stratum is well developed only in more open stands and includes numerous sedges and grasses (Braun 1936, Voigt and Mohlenbrock 1964).

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Willow Oak–Water Oak–Diamondleaf (Laurel) Oak 88

Definition and composition. The three species together comprise a majority of the stocking, but the proportion of each may vary widely depending on site and location. The associated tree species may include Nuttall oak, red maple, green ash, sweetgum, swamp hickory, honeylocust, and, on the wetter sites, water hickory, waterlocust, and overcup oak. On better-drained areas, spruce pine loblolly pine, swamp chestnut oak, and cherrybark oak may be found in the association.

In his checklist, Little (1979) does not recognize a difference between diamondleaf oak and laurel oak, but in the past diamondleaf has been given the status of both a variety and a separate species (*Q. obtusata* Ashe.) (Sargent 1965). Those who favor separate species status point out that there are not only recognizable anatomical differences but also vast differences in site preference. Specimens first recognized as *Q. laurifolia* occur on deep, well drained soils such as the sandy banks of streams, whereas diamondleaf oak occurs on poorly drained flat sites.

Geographic distribution. The type is found in the Coastal Plain from southeastern Virginia to western Florida and through the Gulf States into the pine region of eastern Texas. It also extends into southeastern Oklahoma and southern Arkansas. The type is most abundant in Louisiana, southern Mississippi, and south central Alabama.

Ecological relationships. The type is most common on alluvial floodplains. It occupies relatively poorly drained, flat sites. Where drainage is unusually poor, diamondleaf oak makes up most of the stand, sometimes forming almost pure stands. As elevation increases and drainage improves, the willow and water oak component increases. Of the two, water oak usually occupies the somewhat better drained areas. Topographically, the type is usually located between the swamp chestnut oak–cherrybark oak type on the better-drained sites and the overcup oak–water hickory type on the poorer-drained sites. The type may also occur on terrace flats and poorly drained flatwoods sites and is often referred to as "oak glades" or "pin oak flats." It probably represents a topographic/edaphic climax, but when it is heavily cut, species such as sugarberry, green ash, American elm, and red maple may capture the site, at least temporarily.

Variants and associated vegetation. In the Mississippi River drainage, especially north of Vicksburg, the type is replaced by sweetgum–Nuttall oak–willow oak, which occupies sites similar to those of Type 88 in other drainages. In areas elsewhere than the Delta of the Mississippi, diamondleaf may gradually be replaced by Nuttall oak as the northern range of the type is approached. Some common understory components are poison-ivy, grape, Alabama supplejack (rattan), and greenbriers.

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Live Oak
89

Definition and composition. Live oak typically comprises a majority of the stocking and on coastal ridges it may be pure. Common associates are water oak and southern magnolia. On sites less well drained, sugarberry, American elm, and green ash accompany live oak.

Geographic distribution. The live oak type occurs in southern Louisiana and southwestern Mississippi on natural levees or "frontlands" and on islands within marshes and swamps.

Ecological relationships. Elevation of the frontlands where live oak is present has been determined by the flood height of the river that deposited the silt. Width of a live oak forest belt varies; at a minimum it may be only 100 m (a few hundred feet) wide or even less, and at a maximum usually under 1.6 km (less than a mile). In many places the belt becomes narrower with time as the land subsides and man-made levees prevent further flooding and silting.

The silt soils that support live oak forests represent some of the best agricultural land in the region, and much has been cleared for that purpose. Nonetheless, there are abandoned fields in the New Orleans area that have regrown to forests now about 73 years old (Bonck and Penfound 1945, Penfound and Howard 1940). The sequence is as follows: annual and perennial weeds occupy the fields for about five years, after which shrubs, especially southern bayberry (waxmyrtle) and roughleaf dogwood, begin to take over. By 25 years the shrub community approximates a young forest, but live oak seedlings begin to appear and seem destined to grow into a typical live oak forest in another 50 years.

Live oak grows on uplands but not as a majority species. Several salt domes that rise 30 to 180 m (100 to 600 ft.) above marshes in southwestern Louisiana have good soil and a climate comparable to that where live oak forests grow. However, the domes support a mixed angiosperm forest, with live oak in mixture with southern magnolia, white basswood, and American beech. Live oak here is in the majority only where planted.

Variants and associated vegetation. Variation in tree composition is due to differences in drainage that result from an elevation change of only about 1 m (a very few feet). Shrubs in the live oak forest usually include dwarf palmetto, yaupon, American elder; vines are Alabama supplejack, grape, poison-ivy, and Virginia creeper; and herbs are oak forest grass and *Tradescantia* (spiderwort).

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Swamp Chestnut Oak–Cherrybark Oak
91

Definition and composition. Swamp chestnut oak and cherrybark oak together usually constitute a majority of the stocking, but when many species are in mixture, they may comprise only a plurality. Prominent hardwood associates are the ashes (green and white) and the hickories (shagbark, shellbark, mockernut, and bitternut), as well as white oak, Delta post oak, Shumard oak, and blackgum. Sweetgum may occasionally be of high importance on first bottom ridges. Minor associates include willow oak, water oak, southern red oak, post oak, American elm, winged elm, water hickory, southern magnolia, yellow-poplar, beech, and occasionally loblolly and spruce pines.

Geographic Distribution. Small areas of the type are scattered over a large part of the South within the floodplains of the major rivers, except that of the Mississippi, where the type is rare.

Ecological relationships. The type occurs on the highest first-bottom ridges in the terraces on the best, most mature, fine sandy loam soils, and also on first-bottom ridges on a few well drained soils other than sandy loam. The site is seldom covered with standing water and rarely, if ever, overflows, though it may be hummocky and wet between hummocks. Swamp chestnut oak–cherrybark oak succeeds sycamore–sweetgum–American elm on the ridges in the terraces. Typically it is climax on older alluvium (Putnam et al. 1960). Site indexes at 50 years range from 80 to 100 for swamp chestnut oak and from 95 to 115 for cherrybark oak (Broadfoot 1976).

Variants and associated vegetation. The type most commonly occurs adjacent to the sycamore–sweetgum–American elm type and to beech–southern magnolia stands (formerly recognized as type No. 90). Among the subordinate tees and undergrowth are painted buckeye, pawpaw, American hornbeam, flowering dogwood, dwarf palmetto, Coastal Plain willow, American snowbell, southern arrowwood, possumhaw, devils walkingstick, eastern redbud, and American holly.

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Sweetgum–Willow Oak
92

Definition and composition. Sweetgum and willow oak comprise a plurality of the stocking, with sweetgum essentially the key species. Willow oak may be superseded by water oak in the southernmost range of the type. Sugarberry, green ash, American elm, and Nuttall oak are major associates, especially on slightly lower elevations. Minor associates are overcup oak, water hickory, cedar elm, eastern cottonwood, laurel oak, red maple, honeylocust, persimmon and, rarely, baldcypress. The type was formerly named sweetgum–Nuttall oak–willow oak (SAF 1954).

Geographic distribution. The type is widespread in the alluvial floodplains of major rivers in Arkansas, Louisiana, Mississippi, Alabama, eastern Missouri, and eastern Texas. Most extensive stands are in the Mississippi River delta.

Ecological relationships. The type perpetuates itself on first-bottom ridges and terrace flats, except in deep sloughs, swamps, and the lowest flats. Usually it is interspersed with the sugarberry–American elm–green ash type and the overcup oak–water hickory type. Elsewhere, heavy cutting usually increases the sweetgum component because of that species' sprouting characteristics. The sprouts grow rapidly early and continue growing well on sites where this type occurs. On transitional sites, the sweetgum–willow oak type is usually superseded by the sugarberry–American elm–green ash type. Major reasons are the oak's insufficient acorn crops, poor seedling establishment, and very slow early growth.

Variants and associated vegetation. The type becomes predominantly sweetgum on well-drained first-bottom ridges and pervious silty clays on terrace flats. It is predominantly willow oak combined with water oak on clay soils on first-bottom ridges and better drained flats and on poorly drained terrace flats. Nuttall oak dominates on well-drained, first-bottom flats. Willow oak prevails on first bottom ridges and poorly drained terrace flats. Near the Gulf Coast, laurel oak dominates. A cedar elm–water oak–willow oak variant occurs on poorly drained impervious soils on low, indistinct or flattened first-bottom ridges; this variant is also of minor importance on certain impervious terrace sites, amounting to high, shallow flats.

Understory species are sugarberry, green ash, oaks, red maple, and red mulberry. Undergrowth includes greenbrier, dwarf palmetto, and several vines—redvine, peppervine, trumpet-creeper, and poison-ivy.

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Sugarberry–American Elm–Green Ash
93

Definition and composition. The type species sugarberry, American elm, and green ash together constitute a plurality of the stocking. Hackberry replaces sugarberry in the northern part of the range. Major associates include water hickory; Nuttall, willow, water, and overcup oaks; sweetgum; and boxelder. Other associated species are cedar and winged elm, blackgum, persimmon, honeylocust, waterlocust, red and silver maple, American sycamore, and eastern cottonwood.

Geographic distribution. The type is found throughout the southern forests from east Texas to the Atlantic, from the Gulf Coast to southern Illinois. It is found within the floodplains of the major rivers.

Ecological relationships. The type is usually located in transitional areas between the sweetgum–willow oak type, which occupies higher elevations, and the overcup oak–water hickory type, which occurs at the lower elevations. It occupies low ridges, flat, and sloughs in first bottoms; terrace flats and sloughs; and occasionally new lands or fronts. Rarely does it occur on maltreated terrace ridges. It may be found on clay or silt loam soils, and it tends to be long term in the successional scale. The type species are all shade tolerant when small and reproduce readily. All three, but especially green ash, sprout prolifically.

Variants and associated vegetation. Occasional small stands of pure green ash may occur almost anywhere within the type, but most notably on moist flats or in shallow sloughs. Stands composed predominantly of sugarberry occur on new land or front sites.

The understory commonly includes sugarberry, ash, elm, water hickory, Nuttall oak, overcup oak, red maple, roughleaf dogwood, hawthorn possumhaw, and red mulberry. Undergrowth includes several vines—trumpet-creeper, peppervine, redvine, rattan (Alabama supplejack), Carolina moonseed, Virginia creeper, grape, and poison-ivy. Herbaceous plants include bedstraw, violet, wild carrot, wild lettuce, amsonia, mint, legumes, sedge, smartweed, and false indigo. When openings are created in the stands, a heavy growth of annual grasses and cocklebur may occur.

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Sycamore–Sweetgum–American Elm
94

Definition and composition. American sycamore, sweetgum, and American elm together comprise a plurality of the stocking, but composition varies widely from mixed stands to nearly pure stands of one of the type species. The type includes the river front species-site type described by Putnam et al. (1960), which occurs on the banks or front land of major rivers in the southern forest. The most common associated species are green ash, sugarberry (and hackberry in the northern Mississippi River Valley), boxelder, silver maple, cottonwood, black willow, water oak, and pecan. This type was formerly designated sycamore–pecan–American elm (SAF 1954).

Geographic distribution. Sycamore–sweetgum–American elm occurs as scattered stands throughout the southern forest region (exclusive of Florida). This area includes the southeastern Coastal Plain (Delaware to Georgia), the Gulf Coastal Plain (Alabama to Texas and north to southern Arkansas and southeastern Oklahoma), and the Mississippi River floodplain (Louisiana to southern Missouri). The type is also present in the lower Ohio River Valley and its lower tributaries, and in the Piedmont and Cumberland plateaus, and adjacent areas.

Ecological relationships. The type occupies river fronts in the first bottoms of major rivers, the banks of smaller rivers and large creeks that flood, and occasionally branch heads and coves of small creeks. Slightly elevated sites with somewhat poorly drained to well-drained silty soils of alluvial origin characterize the river fronts (Broadfoot 1976). In small creek bottoms the type occurs on nonalluvial soils that are usually coarser textured. The soils of both kinds of sites typically are rich, with moderately good drainage, and have adequate moisture throughout the growing season. Site indexes at 50 years range from 100 to 130 for sycamore and 90 to 120 for sweetgum (Broadfoot 1976).

The type succeeds the cottonwood type on river front sites, but may pioneer on heavily cut over sites or old fields in either river bottoms or small creek bottoms. Where repeated disturbances such as floods occur, the type may represent a persistent subclimax, but the climax on these sites will be swamp chestnut oak–cherrybark oak or sweetgum–willow oak.

Variants and associated vegetation. Sycamore–pecan–American elm variant is found on river fronts in the Mississippi River Valley. On wetter sites with heavier soils in alluvial bottoms of rivers, the type becomes transitional with sweetgum–willow oak. On branch heads and coves of small creeks in the uplands the type intergrades with sweetgum–yellow-poplar. The companion types in the central forest region are river birch–sycamore and silver maple–American elm.

Some common understory components of the type include pawpaw, giant cane, and pokeweed (McKnight 1968). Vines often present are poison-ivy, grape, Alabama supplejack (rattan), greenbriers, and Japanese honeysuckle. Wood-nettle is sometimes present in moist coves and bottoms.

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Black Willow
95

Definition and composition. Black willow and other species of *Salix* together comprise a majority of the stocking. Cottonwood is the chief associate, particularly in the early stages, but green ash, sycamore, pecan, persimmon, waterlocust, American elm, baldcypress, red maple, sugarberry, boxelder, and in some areas, silver maple are invaders preceding the next successional stage.

Geographic distribution. The type is characteristic of the fronts and banks of most major streams through the central and southern forests but extends also into the northern forest. Along the East Coast, the black willow type has only minor distribution and then generally in swamps rather than in river bottoms.

Ecological relationships. Black willow is a temporary, pioneer type of very rapid growth. Along with cottonwood, it is the first to appear on newly formed sandbars and river margins, almost to the exclusion of other species. It is also frequently found in front land, sloughs, and low flats and occasionally in shallow swamps and deep sloughs throughout the first bottom. Where willow and cottonwood occur together, cottonwood outgrows willow and becomes dominant except where frequent and extended growing-season flooding covers the trees and kills the cottonwood. Sites may silt in 6 m (20 ft.) during the life of the stand, and any one flood may increase the elevation from 2.5 cm (1 in.) to 1.5 m (5 ft.).

Black willow is relatively short lived and cannot regenerate under shade. As the soils build up and the willow and cottonwoods drop out, the type is usually replaced in the central forest by the silver maple–American elm type and by boxelder; and in the southern forest by the sycamore–sweetgum–American elm type and by boxelder and, on the lower sites, by swamp-privet. The type merges with the cottonwood–willow type in the prairie-plains area.

Variants and associated vegetation. Common understory tree species are boxelder, red maple, red mulberry, swamp-privet, and planer tree (waterelm). Undergrowth may consist of buttonbush, possumhaw, poison-ivy, trumpet-creeper, redvine, and peppervine. Herbs may or may not be present, depending on length of growing season overflow and density of overstory.

Levee systems and stream channelizations have restricted the area available for formation of this type.

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Overcup Oak–Water Hickory
96

Definition and composition. Overcup oak and water hickory together make up a majority of the stocking. Major associates are green ash, sugarberry, American elm, waterlocust, red maple, and Nuttall oak. Willow oak, persimmon, and cedar elm are minor associates.

Geographic distribution. The type occurs in the floodplain forests of the Gulf and south Atlantic states and also in Tennessee and southern Illinois. The most extensive areas occupied are backwater basins of the principal rivers.

Ecological relationships. The type usually occurs in areas where water stands into the growing season–low-lying, poorly drained flats with clay or silty clay soils. It also occurs in sloughs in the lowest backwater basins and on low ridges with clay soils that are subject to late spring inundation. Site quality is usually quite poor and most species cannot survive where this type exists. Where drainage is improved, the type may revert to sugarberry–American elm–green ash. Overcup oak reproduces more consistently than other oaks; its good seed crops are frequent and its acorns, which seem to be less desirable to wildlife than most, receive some protection from the water. Water hickory is a prolific sprouter and reproduces in this fashion when the stand is cut. Both overcup oak and water hickory are among the last tree species to leaf out in the growing season and thus are less subject to the mortality that occurs when seedlings or sprouts in leaf are covered by standing water.

Variants and associated vegetation. Nearly pure water hickory stands or pure overcup oak stands can be found representing the type. Sometimes there is clear demarcation between the overcup oak–water hickory and the sugarberry–American elm–green ash type, but usually the two types mix in a transitional zone.

Understory includes the water hickory, overcup oak, and occasionally Nuttall oak, green ash, sugarberry, roughleaf dogwood, swamp-privet, and planertree (water-elm). Undergrowth includes buttonbush and numerous vines—redvine, peppervine, trumpet creeper, and poison-ivy. Because of the depth and duration of standing water in this type, associated herbaceous plants are few. Following cutting or partial opening of the stands, heavy growth of annual grasses and cocklebur may occur.

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Baldcypress
101

Definition and composition. Baldcypress is pure or comprises a majority of the stocking. Its main associates are water tupelo in the alluvial floodplains or swamp tupelo in the swamps and estuaries of the Coastal Plain. Other associates are pondcypress, black willow and, occasionally, swamp cottonwood, red maple, Atlantic white-cedar, American elm, green ash, pumpkin ash, Carolina ash, waterlocust, redbay, common persimmon, overcup oak, and water hickory.

Geographic distribution. The type occurs intermittently through the Coastal Plain from southern Delaware to south Florida, and west to southeastern Texas almost to the Mexican border. Inland, it occurs along the many streams of the coastal plains and northward through the Mississippi Valley to southeastern Oklahoma, southeastern Missouri, southern Illinois, and southwestern Indiana (Fowells 1965).

Ecological relationships. The baldcypress species is unusual in form, shape, and habitat requirements. Sites are usually characterized by frequent prolonged flooding. Floodwaters may be 3 m (10 ft.) deep or more and may be stagnant or may flow at rates up to 7 km (4 mi.) per hour. Cypress knees are common on trees on most sites, but are usually absent where the floodwater remains at a constant level or where there is no flooding. It is not clear what role cypress knees play in aeration of the root system, but it is known that they exchange oxygen and carbon dioxide with their surroundings under normal atmospheric conditions. Thus it appears that they may be beneficial as an aeration organ but not critical to tree survival.

Baldcypress shows adaptations to flooding similar to those of water and swamp tupelos, the main associates in the type. Under prolonged flooding newly adapted roots develop near the base of the tree. The new roots are more succulent, larger in diameter, and less branched than roots of cypress grown in moist well-aerated soils. Newly adapted roots of tupelos have been observed to oxidize their rhizosphere in floodwaters (Hook et al. 1971). Cypress roots also show evidence of oxidation at depths up to 1.2 m (4 ft.), thus providing oxygen to active root tips and facilitating nutrient uptake from otherwise highly reduced soil environment. Baldcypress grows along the estuaries near the coast, but apparently cannot tolerate salinities above 0.89 percent salt (Montz and Cherubini 1973).

Cypress, highly prized for its lumber, was so heavily exploited during the first half of the 20th century that there was much concern for its future. All recent evidence, however, suggests a general replacement by second growth (Sternitzke 1972).

Variants and associated vegetation. The type has one major variant, baldcypress–pondcypress (Langdon 1958). Where the two species occur together it is difficult and sometimes impossible to tell them apart. These two intermingle in varying proportions in the lower coastal plains from southeastern Virginia to eastern Louisiana. The baldcypress type has only a few shrub associates and these vary widely. The most prominent in south Florida are common buttonbush, swamp (stiffcornel) dogwood, and Walter viburnum. In contrast, the most common associates in North Carolina are the coast leucothoe, Carolina rose, poison-sumac, swamp dogwood, and possumhaw viburnum. In addition, ferns, vines, epiphytes, alligator-weed, and duckweeds are present.

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Baldcypress–Tupelo
102

Definition and composition. Baldcypress together with water tupelo or swamp tupelo comprises the majority of the stocking. On deep alluvial swamps, the common associates are red maple, black willow, Carolina ash, pumpkin ash, swamp cottonwood, planertree (water-elm), and waterlocust. In the shallower margins, overcup oak, water hickory, American elm, green ash, Nuttall oak, laurel oak, sweetgum, persimmon, and sweetbay are also present. In Coastal Plain swamps, red maple, black willow, redbay, sweetbay, pondcypress, slash pine, and loblolly pine are found. Ogeechee tupelo is an associate in southwestern Georgia and northern Florida. Atlantic white-cedar and pond pine are also present in some acid, peaty swamps of the Atlantic Coastal Plain.

Geographic distribution. The type occurs in the southern Coastal Plain, particularly on the seaward margins, from southeastern Texas to Maryland, excluding the lower third of the Florida peninsula. It is also present in the Mississippi River bottom and along the lower reaches of its tributaries north to southern Illinois.

Ecological relationships. The type is always found on very wet sites where, in years of normal rainfall, surface water stands well into or throughout the growing season. These include swamps, deep sloughs, very low, poorly drained flats of the major river floodplains, swamps of tidal estuaries, margins of coastal marshes and the deeper, more extensive landlocked depressions of the Coastal Plain (Penfound 1952).

Soils of the alluvial bottoms are mineral soils and usually range in texture from silt loam to almost pure clay; surface soil pH varies from moderately acid to slightly alkaline. Coastal swamps and depressions of the Coastal Plain usually have a surface of muck or shallow peat. The mineral fraction of the soil may range from fine sand to clay, and soil pH ranges from moderately to strongly acid.

Stand makeup is strongly influenced by site as well as by cutting. Water tupelo cannot survive where soil acidity is high or surface water brackish. Consequently, it is almost completely restricted to alluvial floodplains and is replaced by swamp tupelo on colluvial soils of the Coastal Plain and in coastal swamps. Swamp tupelo also occurs in mixture with baldcypress and water tupelo around the edges of alluvial swamps where maximum water depth is less than 0.6 m (about 2 ft.). Baldcypress and water tupelo are most tolerant of complete inundation and advance into the deepest sites when water depth is reduced during periodic droughts, particularly around quiet ponds and lakes. In shallow swamps, water and swamp tupelo regenerate more successfully than baldcypress because of greater seed production and somewhat faster early growth. Here, following heavy cutting, the type usually reverts to water or swamp tupelo (Putnam et al. 1960). Regeneration of swamp tupelo and water tupelo by stump sprouts is also of major importance in cut over stands; sprouting of baldcypress is minor.

No clear succession has been observed in this type and, barring aggradation, it is considered permanent and is held in this stage by prolonged periods of deep flooding (Wells 1928). The relative shade tolerance of baldcypress and water tupelo has not been clearly established; both are rated intolerant and both endure heavy stocking in even-aged stands. When in association with baldcypress, water tupelo is usually the younger component, suggesting the greater tolerance of the latter and a possible trend towards pure stands of that species without periodic disturbance.

Variants and associated vegetation. Small, pure stands of baldcypress are scattered throughout the type. Regeneration of baldcypress is very uncertain, however, and stands usually revert to tupelo following heavy cutting.

In the deep swamps and under dense stands, undergrowth, sparse because of low light intensity and long hydroperiods, is limited to a few shrubs and some aquatic herbs. Mosses and lichens are common on the lower exposed portions of the tree trunks. Spanish moss often drapes the crowns. In shallow swamps and along the fringes of the deep swamps, a wide variety of wet-site shrubs may commonly occur: buttonbush, swamp-privet, Virginia sweetspire (Virginia-willow), swamp cyrilla, buckwheat-tree, stiffcornel (swamp) dogwood, fetterbush lyonia, leucothoe, dahoon, yaupon, southern bayberry, possumhaw, swamp rose, and poison-sumac. Woody vines that may be common include greenbriers, Alabama supplejack, southeast decumaria, crossvine, peppervine, and poison-ivy.

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Water Tupelo–Swamp Tupelo
103

Definition and composition. Where the type is most extensive, water tupelo is pure or provides a majority of the basal area stocking. On certain more limited sites, however, swamp tupelo tends to take the place of water tupelo. On some sites the two type species mix. Common associates of water tupelo where flooding is deep are baldcypress, red maple, black willow, Carolina ash, pumpkin ash, swamp cottonwood, planer tree (water-elm), and waterlocust. In shallow water, swamp tupelo, overcup oak, water hickory, American elm, green ash, Nuttall oak, laurel oak, sweetgum, persimmon, and sweetbay are also present. Common associates of swamp tupelo in addition may include pondcypress, redbay, sweetbay, slash pine, and loblolly pine. Ogeechee tupelo is an associate in southeastern Georgia and northern Florida. Atlantic white-cedar and pond pine are also associates in some acid, peaty swamps of the Atlantic Coastal Plain. The type formerly was named water tupelo.

Geographic distribution. The type occurs in the southern Coastal Plain from southeastern Texas to southern Florida and northward to southeastern Virginia. It also occurs in the Mississippi River bottom and the lower reaches of its tributaries and in bottomlands of the Tennessee River in Alabama. The water tupelo component is nearly absent from most of the Florida peninsula and the southeastern corner of Georgia.

Ecological relationships. The type is always found on very wet sites where, in years of normal rainfall, surface water stands well into or throughout the growing season. Stands of water tupelo are restricted to deep swamps, sloughs, and low flats of the alluvial floodplains, whereas those of swamp tupelo occur in upland swamps and ponds of the Coastal Plain and in slightly brackish swamps of coastal estuaries and marsh borders (Penfound and Hathaway 1938). Mixtures occur along the shallow borders of alluvial swamps and flats and where such sites grade into upland swamps. Water tupelo sites are characterized by deeper and longer periods of flooding than swamp tupelo sites, and by higher pH and silt-plus-clay content but lower organic matter content of the surface soil (Klawitter 1962).

The type is permanent on most sites because of annual flooding. Relatively rapid soil aggradation over limited areas in alluvial bottoms undoubtedly does occur. The resulting improvement in soil aeration should favor changes in composition following the sequence observed in southern bottoms on sites with increasing drainage (Putnam et al. 1960).

Variants and associated vegetation. There are no common variations of this type. Uncut stands of water or swamp tupelo are typically very densely stocked. In water tupelo stands with normally deep flooding, undergrowth is often limited to scattered shrubs with some aquatic herbs. Epiphytic mosses and lichens are common on the exposed tree trunks, particularly the lower and north-facing portions, and the crowns may be draped with Spanish moss. Wet-site shrubs become more abundant along shallow margins of the swamps or in stand openings; species occurring widely and frequently include buttonbush, swamp-privet, Virginia sweetspire (Virginia-willow), swamp dogwood, swamp cyrilla, leucothoe, possumhaw, swamp rose, and poison-sumac. Woody vines frequently occurring along the shallow swamp margins are greenbriers, Alabama supplejack, southeast decumaria, crossvine, peppervine, and poison-ivy.

In the usually shallower upland swamps where swamp tupelo is dominant there are additional woody plants not common to the alluvial swamps. These include such species as buckwheat-tree, dahoon, yaupon, southern bayberry, fetterbush lyonia, summersweet clethra (sweet pepperbush), and several hawthorns.

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Sweetbay–Swamp Tupelo–Redbay
104

Definition and composition. Combinations of sweetbay with swamp tupelo, redbay, or both provide a majority of the stocking, and locally any one of the three may possess a plurality. A great many species that grow on moist to wet sites may be associated with this type, depending upon geographic location, site and stand history. Common hardwoods include red maple, black tupelo, loblolly-bay, sweetgum, water oak, laurel oak, yellow-poplar, American holly, Carolina ash, southern magnolia, and flowering dogwood. Associated conifers include baldcypress, pondcypress, slash pine, longleaf pine, loblolly pine, pond pine, and Atlantic white-cedar.

Geographic distribution. The type is found throughout the southern Coastal Plain from Maryland and southeastern Virginia to southeastern Texas. It is most extensive in the lower Coastal Plain. Individual stands of this type are commonly limited in area, although locally they may predominate.

Ecological relationships. The type occurs on sites where the soil is normally saturated, or at least moist, throughout the growing season. Surface flooding also occurs on some sites, but it does not persist through the growing season. Sites include branch heads; the narrow bottoms of small perennial or intermittent streams or branches; pocosins; and poorly drained upland depressions in the Coastal Plain such as small ponds, peat bogs, and the borders of swamps.

Soils are sandy in texture and predominantly colluvial in origin, although narrow alluvial floodplains occur in stream bottoms. The wetter sites are consistently very acid, pH 4.0-4.5, and relatively sterile, whereas sites with better drainage are frequently very productive. Stands on more acid, sterile sites generally contain a high proportion of hardwood evergreens, such as redbay, sweetbay, and loblolly-bay, as well as the conifers pond pine and Atlantic white-cedar (Monk 1966).

Deep flooding in ponds and around swamp borders favors swamp tupelo, pondcypress, baldcypress, and red maple. Improved drainage increases representation of such species as black tupelo, yellow-poplar, sweetgum, American holly, and southern magnolia. Changes in soil drainage and related properties are often abrupt, and over short distances stands may contain species representative of both the more deeply flooded swamps and the surrounding uplands. The type is permanent because of persistent soil saturation.

Despite the usual wetness of the sites, fires frequently spread into stands from the surrounding uplands. Fire during drought can be very destructive because of the flammable nature of the peat accumulations and the evergreen foliage of many species. In peaty bogs and shallow swamps, Atlantic white-cedar may dominate if the peat is too wet to burn. Shallow burns favor pond pine, but stands may revert to pondcypress–swamp tupelo after deep burns (Wells 1942). Fires on better-drained sites with mineral soils increase the representation of shade-intolerant species such as slash and longleaf pine, yellow-poplar, and sweetgum, but selective cutting of these species has kept their numbers low (Gemborys and Hodgkins 1971). Recurrent fires on any site tend to develop evergreen shrub or grass-sedge-rush communities.

Variants and associated vegetation. The type itself exhibits such wide variation that there is no single common variant. Undergrowth is both abundant and diverse. Evergreen shrubs and small trees are prevalent, particularly on the poorly drained acid sites. Common species include buckwheat tree, swamp cyrilla, southern bayberry, odorless bayberry, dahoon, yaupon, large gallberry, inkberry, coast leucothoe, fetterbush and staggerbush lyonia, summersweet clethra (sweet pepperbush), and switchcane. Common deciduous shrubs are Virginia sweetspire (Virginia-willow), hazel alder, swamp dogwood, red chokeberry, poison-sumac, American snowbell, possumhaw viburnum, and numerous ericaceous species.

Greenbriers, muscadine grape, poison-ivy, Japanese honeysuckle, Virginia creeper, southeast decumaria and climbing hempweed are common perennial vines. Herbaceous species occurring within this type are incompletely catalogued and are too numerous and variable to list. Some relatively common and characteristic representatives, however, are ferns, mosses, pitcher plants, pipeworts, yellow-eyed grasses, and sedges.

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Appendix B
Common and Scientific Names of Plant and Tree Species

Common name	Scientific name
Plants	
America pokeweed (see pokeberry)	*Phytolacca americana*
American wormseed (see Mexican tea)	*Chenopodium ambrosioides*
Annual ragweed (see ragweed)	*Ambrosia artemisifolia*
Aquatic milkweed (see milkweed)	*Asclepias perennis*
Autumn olive	*Elaeagnus umbellata*
Bahia grass	*Paspalum notatum*
Beakrush (see millet beakrush)	*Rhynchospora miliacea*
Beggartick (see small-fruit beggartick)	*Bidens mitis*
Bermuda grass	*Cynodon dactylon*
Blackberry	*Rubus argutus*
Boneset	*Eupatorium perfoliatum*
Brazilian pepper tree	*Schinus terebinthifolius*
Broomsedge	*Andropogon virginicus*
Bugleweed	*Lycopus* spp.
Burnweed	*Erechtites hieracifolia*
Bur-reed (burreed)	*Sparganium* spp.
Bushy beardgrass (bushy bluestem)	*Andropogon glomeratus*
Cane	*Arundinaria gigantea*
Cattail	*Typha latifolia*
Chain-fern	*Woodwardia* spp.
Chinese bushclover	*Lespedeza cuneata*
Chinese tallow	*Triadica sebiferum*
Cocklebur	*Xanthium* spp.
Coffeeweed	*Sesbania macrocarpa*
Cogongrass	*Imperata cylindrica*
Common carpetgrass (see Southern carpetgrass)	*Axonopus fissifolius*
Coral honeysuckle	*Lonicera sempervirens*
Crabgrass	*Digitaria* spp.
Dewberry	*Rubus hispidus*
Dog fennel (see small dogfennel)	*Eupatorium capillifolium*
Falsenettle (see small-spike falsenettle)	*Boehmeria cylindrica*
Fern, various species	*Osmunda* spp., *Thelypteris* spp.
Fescue	*Festuca* spp.
Florida pokeweed	*Phytolacca americana* var. *rigida*
Geranium (see purple crane's-bill geranium)	*Geranium carolinianum*
Golden club	*Orontium aquaticum*
Goldenrod	*Solidago* spp.
Goldenweed (see groundsel)	*Packera aureus*
Groundsel (see goldenweed)	*Packera aureus*
Hairlike mock bishop-weed (see mock bishop-weed, herbwilliam)	*Ptilimnium capillacium*
Herbwilliam (see hairlike mock bishop-weed, mock bishop-weed)	*Ptilimnium capillacium*
Honeysuckle, (Japanese)	*Lonicera japonica*
Horseweed	*Conzya canadensis*
Japanese climbing fern	*Lygodium japonicum*
Japanese privet	*Ligustrum japonicum*
Johnson grass	*Sorghum halepense*

Common name	Scientific name
Kudzu	*Pueraria lobata*
Licorice Weed	*Scoparia dulcis*
Lizard's tail	*Saururus cernuus*
Melaleuca	*Melaleuca leucadendron*
Mexican tea (see American wormseed)	*Chenopodium ambrosioides*
Mexican water-hemlock (see water-hemlock)	*Cicuta maculata*
Milkweed (see aquatic milkweed)	*Asclepias perennis*
Millet beakrush (see beakrush)	*Rhynchospora miliacea*
Mock bishop-weed (see hairlike mock bishop-weed, herbwilliam)	*Ptilimnium capillacium*
Morning glory	*Ipomoea* spp.
Multiflora rose	*Rosa multiflora*
Nutsedge	*Cyperus* spp.
Panic grass	*Panicum* spp.
Peruvian seedbox (see primrose willow)	*Ludwigia peruviana*
Pickerel weed (see pickerelweed)	*Pontederia cordata*
Pickerelweed (see pickerel weed)	*Pontederia cordata*
Pineland pimpernel (see water pimpernil)	*Samolus valerandi* var. *parviflorus*
Pokeberry (see American pokeweed)	*Phytolacca americana*
Poorjoe	*Diodia teres*
Primrose willow (see Peruvian seedbox)	*Ludwigia peruviana*
Purple crane's-bill geranium (see geranium)	*Geranium carolinianium*
Ragweed	*Ambrosia* spp.
Rough button-weed	*Diodia radula*
Sericea lespedeza	*Lespedeza cuneata*
Sheathed flatsedge	*Cyperus haspan*
Shiny spikegrass (see spikegrass, shiny wood-oats)	*Chasmanthium nitidum*
Shiny wood-oats (see shiny spikegrass, spikegrass)	*Chasmanthium nitidum*
Sicklepod	*Cassia obtusifolia*
Small dogfennel (see dog fennel)	*Eupatorium capillifolium*
Small-fruit beggartick (see beggartick)	*Bidens mitis*
Small-spike falsenettle (see falsenettle)	*Boehmeria cylindrica*
Smartweed	*Polygonum* spp.
Southern carpetgrass (see common carpetgrass)	*Axonopus affinis*
Southern crabgrass	*Digitaria ciliaris*
Spikegrass (see shiny spikegrass, shiny wood-oats)	*Chasmanthium nitidum*
Sumac, poison	*Toxicodendron vernix*
Sumac, smooth	*Rhus glabra*
Sumac, winged	*Rhus copallina*
Sunflower	*Helianthus* spp.
Swamplily	*Crinium americanum*
Sweet broom	*Scoparia dulcis*
Sweet clover	*Melilotus* spp.
Trumpet creeper	*Campsis radicans*
Vasey grass	*Paspalum urvillei*
Vetch	*Vicia* spp.
Water-hemlock (see Mexican water-hemlock)	*Cicuta maculata*
Water pimpernil (see pineland pimpernel)	*Samolus valerandi* var. *parviflorus*
Wild grape	*Vitis* spp.
Wild onion	*Allium* spp.
Winter vetch	*Vicia villosa*
Wooly croton	*Croton capitatus*

Common name	Scientific name
Trees	
American beech	*Fagus grandifolia*
American elm	*Ulmus americana*
American holly	*Ilex opaca*
American hornbeam	*Carpinus caroliniana*
Baldcypress	*Taxodium distichum*
Bitter pecan (see water hickory)	*Carya aquatica*
Black cherry	*Prunus serotina*
Blackgum	*Nyssa sylvatica*
Black walnut	*Juglans nigra*
Black willow	*Salix nigra*
Boxelder	*Acer negundo*
Buckthorn bumelia (buckthorn bully)	*Sideroxylon lycioides*
Bur oak	*Quercus macrocarpa*
Buttonbush	*Cephalanthus occidentalis*
Carolina ash	*Fraxinus caroliniana*
Cedar elm	*Ulmus crassifolia*
Cherrybark oak	*Quercus pagoda*
Common persimmon	*Diospyros virginiana*
Dahoon	*Ilex cassine*
Deciduous holly	*Ilex decidua*
Delta post oak	*Quercus stellata* var. *mississippiensis*
Eastern cottonwood	*Populus deltoides*
Eastern hophornbeam	*Ostrya virginiana*
Fir	*Abies* sp.
Florida maple	*Acer barbatum*
Flowering dogwood	*Cornus florida*
Green ash	*Fraxinus pennsylvanica*
Hackberry	*Celtis occidentalis*
Hawthorn	*Crataegus* spp.
Honeylocust	*Gleditsia triacanthos*
Laurel (diamondleaf) oak	*Quercus laurifolia*
Live oak	*Quercus virginiana*
Loblolly bay	*Gordonia lasianthus*
Nuttall oak	*Quercus nuttallii* (current accepted nomenclature is *Q. texana*)
Ogeechee tupelo	*Nyssa ogeche*
Overcup oak	*Quercus lyrata*
Pawpaw	*Asimina triloba*
Pin oak	*Quercus palustris*
Pondcypress	*Taxodium distichum* var. *nutans*
Possumhaw	*Ilex decidua*
Pumpkin ash	*Fraxinus profunda*
Red bay	*Persea borbonia*
Red mulberry	*Morus rubra*
River birch	*Betula nigra*
Rough-leafed dogwood	*Cornus drummondii*
Sandbar willow	*Salix exigua*
Sassafras	*Sassafras albidum*
Shagbark hickory	*Carya ovata*
Shellbark hickory	*Carya laciniosa*
Shumard oak	*Quercus shumardii*
Silver maple	*Acer saccharinum*

Common name	Scientific name
Slippery elm	*Ulmus rubra*
Southern magnolia	*Magnolia grandiflora*
Spruce	*Picea* sp.
Sugarberry	*Celtis laevigata*
Swamp bay	*Persea palustris*
Swamp black gum (see swamp tupelo)	*Nyssa sylvatica* var. *biflora*
Swamp chestnut oak	*Quercus michauxii*
Swamp cottonwood	*Populus heterophylla*
Swamp dogwood	*Cornus foemina*
Swampprivet	*Forestiera accuminata*
Swamp red maple	*Acer rubrum*
Swamp tupelo (see swamp black gum)	*Nyssa sylvatica* var. *biflora*
Swamp white oak	*Quercus bicolor*
Sweet bay	*Magnolia virginiana*
Sweetgum	*Liquidambar styraciflua*
Sweet pecan	*Carya illinoensis*
Sycamore	*Platanus occidentalis*
Water elm	*Planera aquatica*
Water hickory (see bitter pecan)	*Carya aquatica*
Waterlocust	*Gleditsia aquatica*
Water oak	*Quercus nigra*
Water tupelo	*Nyssa aquatica*
White ash	*Fraxinus americana*
White oak	*Quercus alba*
Willow oak	*Quercus phellos*
Winged elm	*Ulmus alata*
Yellow poplar	*Liriodendron tulipifera*

Appendix C
Partial List of Seed and Seedling Suppliers

SEED

Alabama	International Forest Seed Company P.O. Box 490 Odenville, AL 35120 (800) 231-8079 in Alabama (800) 633-4506 out of state Fax: (205) 629-6671 Web page: http://issco.linnaeus.com
Arkansas	Barron's Inc. 1864 Ouachita 67 Camden, AR 71701
Florida	Matt Buchanan Route 1, Box 52 Mayo, FL 32066
Georgia	C.P. Daniels, Inc. P.O. Box 119 Waynesboro, GA 30830 (800) 822-5681 Fax: (706) 554-4424 Web page : www.burke.net/cpdaniel E-mail: ctdan@burke.net
	Southern Seed Company P.O. Box 340 Baldwin, GA 30511 (706) 778-4542 Fax: (706) 776-2736
Kentucky	Lassiter Enterprises 496 Shady Lane Midway, KY 40347-9740
Louisiana	Louisiana Forest Seed Company 303 Forestry Road LeCompte, LA 71346 (318) 443-5026 Fax: (318) 487-0316 E-mail: lfsco@popalex1.linknet.net
Mississippi	William H. Brown, Jr. Forestry Consultant 46 Whispering Pines Road Natchez, MS 39120
Missouri	Lovelace Seeds, Inc. 1187 Brownsmill Rd. Elsberry, MO 63343 (573) 898-2103 Fax: (573) 898-2855 Web page: www.inweb.net/~lovelace E-mail: lovelace@inweb.net
North Carolina	Mountain Farms, Inc. 307 #9 Road Fairview, NC 28730 (828) 628-4709 Fax: (800) 393-3646
South Carolina	Thomas Caverly P.O. Box 1223 Orangeburg, SC 29116
Tennessee	Don Marcum Route 1, Box 410 Spencer, TN 38585
	West Tennessee Forest Seed Co. 440 Joyner's Hill Road Bells, TN 38006 (901) 772-4213 Mobile phone: (901) 548-4043 Fax: (901) 772-7795

SEEDLINGS

STATE FORESTRY NURSERIES

Alabama	E.A. Hauss Nursery Route 3, Box 322 Atmore, AL 36502
Arkansas	Arkansas Forestry Commission Baucum Nursery 1402 Highway 391 North North Little Rock, AR 72117 (501) 945-3345 Fax: (501) 945-1755
Georgia	Flint River Nursery 9850 Riveroad Byromville, GA 31007 (912) 268-7308 Fax: (912) 268-1819

Walker Nursery
HC01, Box 217
Reidsville, GA 30453-9408
(912) 557-6821

Illinois

Mason Nursery
17855 North County Road 240 East
Topeka, IL 61567
(309) 535-2185
Fax: (309) 535-3286

Union Nursery
3520 State Rd.
Jonesboro, IL 62652
(618) 833-6125
Fax: (618) 833-8123

Kentucky

Morgan County Nursery
438 Tree Nursery Rd.
West Liberty, KY 41472
(606) 743-3511
Fax: (606) 743-1999

John R. Rhody Nursery
P.O Box 97
Gilbertsville, KY 42044
(502) 362-8331
Fax: (502) 362-7512

Louisiana

Columbia Nursery
P.O. Box 1388
Columbia, LA 71418
(318) 649-7463
Fax: (318) 649-5628

Jeane Farms
11627 Highway 4
Castor, LA 71016
(318) 544-8501

Mississippi

Mississippi Forestry Commission
90 Highway 51
Winona, MS 38967
(601) 283-1456
Fax: (601) 283-4097
E-mail: hardwood@network-one.com

Missouri

George O. White Nursery
14027 Shafer Road
Licking, MO 65542
(573) 674-3229
Fax: (573) 674-4047

North Carolina

Claridge Nursery
762 Claridge Nursery Road
Goldsboro, NC 27530
(919) 731-7988
Fax: (919) 731-7993

Edwards Nursery
701 Sanford Drive
Morganton, NC 28655
(828) 438-6270
Fax: (828) 437-2517

Coastal Plain Conservation Nursery
3067 Conners Drive
Edenton, NC 27932
(252) 482-5707
Fax: (252) 482-4987

Oklahoma

Forestry Division Nursery
830 Northeast 12th Avenue
Goldsby, OK 73093
(405) 288-2385
Fax: (405) 288-6326

South Carolina

South Carolina Forestry Commission
P.O. Box 21707
Columbia, SC 29221
(803) 737-8800

Tennessee

Pinson Nursery
P.O. Box 120, Ozier Road
Pinson, TN 38366
(901) 988-5221
Fax: (901) 426-0817

Texas

Indian Mound Nursery
P.O. Box 617
Alto, TX 75925-0617
(409) 858-4202
Fax: (409) 858-4303
E-mail: imn@inu.net

Virginia

Augusta Forestry Center
P.O. Box 160
Crimora, VA 24431
(540) 363-7000

New Kent Forestry Center
11301 Pocahontas Trail
Providence Forge, VA 23140
(804) 966-2201
Fax: (804) 966-9801

State of Virgina Forestry
Web page: http://state.vipnet.org/dof/

PRIVATE NURSERIES

Alabama

Beck's Nursery
P.O. Box 752
Auburn, AL 36830

International Paper
Alabama Supertree Nursery
264 County Road 888
Selma, AL 36701
(800) 222-1280 or (205) 872-5452
Fax: (334) 872-2358

Arkansas

International Paper
Fred C. Gragg Supertree Nursery
Route 2, Box 23
Bluff City, AR 71722
(800) 222-1270
Fax: (870) 685-2825

Weyerhauser
Magnolia Regeneration Center
2960 Columbia 11 East
Magnolia, AR 71753
(800) 736-9330 or (800) 221-5452
Fax: (870) 234-7918

Florida

Apalachee Native Nursery
Route 3 Box 156
Lloyd, FL 32344
(850) 997-8976
Fax: (850) 342-1216

American Native Products
P.O. Box 549
Scottsmoore, FL 32775
(407) 383-1967 or (407) 267-4176
Fax: (407) 383-4150

Central Florida Lands and Timber
Nursery Division
Route 1, Box 899
Mayo, FL 32066
(904) 294-1211
Fax: (904) 294-3416
E-mail: cflat@alltel.net

Central Florida Native Flora, Inc.
P.O. Box 1045
San Antonio, FL 33576-1045
(904) 588-3687

Coastal Revegetation
1050 South Federal Highway
Delray Beach, FL 33483
(407) 495-0198

Creative Native
P.O. Box 713
Perry, FL 32347
(850) 584-3571

Dan's Native Nursery
2325 Lake Easy Road
Babson Park, FL 33827

Ecoshores, Inc.
3869 South Nova Road
Port Orange, FL 32127
(904) 767-6232
Fax: (904) 756-9895

Florida Natives Nursery, Inc.
5121 Ehrlich Road, Suite 103A
Tampa, FL 33624
(813) 264-5765

Gone Native Nursery
P.O. Box 1122
Jensen Beach, FL 34958-1122
(407) 334-1643 or (407) 283-8420

Green Images
1333 Taylor Creek Road
Christmas, FL 32709
(407) 568-1333
Fax: (407) 568-2061
E-mail: greenimage@aol.com

The Liner Farm
P.O. Box 701369
Saint Cloud, FL 33770-1369
(407) 892-1484
Fax: (407) 892-3593

Plants for Tomorrow
16361 Norris Road
Loxahatchee, FL 33470-9430

Salter Tree Farm
Route 2, Box 1332
Madison, FL 32340
(850) 973-6312

Save-on-Plants Liner Nursery, Inc.
Route 1, Box 500
Arcadia, FL 33821

Superior Trees, Inc.
P.O. Box 9325
U.S. 90 East
Lee, FL 32059
(850) 971-5159
Fax: (850) 971-5416

The Natives
2929 JB Carter Road
Davenport, FL 33837
(813) 422-6664

The Palmetto Patch
1715 Pasco Road
Wesley Chapel, FL 33544
(813) 973-1425

The Wetlands Company, Inc.
P.O. Box 2434
Sarasota, FL 34230

Urban Forestry Services
Route 2, Box 940
Micanopy, FL 32667

Georgia

Oak Pond Farm
Route 1, Box 44
Twin City, GA 30471
(912) 562-3946

Spandle Nursery
Route 2, Box 125
Claxton, GA 30417
(800) 553-5771
Fax: (912) 739-2701
E-mail: spandlag@net.net

Iowa

Cascade Foresty Service
22033 Sillmore Rd
Cascade, IA 52033
(319) 852-3042
Fax: (319) 852-5004
Web page: www.cascadeforestry.com
E-mail: Cascade@netins.net

Louisiana

Bosch Nursery, Inc.
18874 Hwy 4
Jonesboro, LA 71251
(318) 259-9484
Fax: (318) 259-9443

Cypress Creek Nursery
10506 Clay-Ansley Highway
Ruston, LA 71270

Natives Nursery
320 North Theard St.
Covington, LA 70433
(504) 892-5424
Fax: (504) 892-8698
E-mail: natives@wild.net

Northeast Delta RC&D
4274 Front Street
Winnsboro, LA 71295
(318) 435-7328
Fax: (318) 435-7436
E-mail: nedrcd@linknet.net

Richard's Nursery
Route 1, Box 41
Forest Hill, LA 71430

Maryland

Environmental Concern, Inc.
210 West Chew Avenue
P.O. Box P
St. Michaels, MD 21663
(410) 745-9620
Fax: (410) 745-9620

Mississippi

Bear Creek Nursery
1267 Patrick Road
Canton, MS 39046
(601) 898-8071
Fax: (601) 605-1001
E-mail: gh2571@aol.com

Delta View Nursery
Route 1, Box 28
Old Highway 61 South
Leland, MS 38756
(800) 748-9018
Fax: (601) 686-2353
Web page:www.tecinfo.com/~hardwoods
E-mail: hardwoods@tecinfo.com

East of Eden Nursery
Route 2, Box 206A
Yazoo City, MS 39194
(601) 746-5577

Thomas Nursery
Route 2, Box 180A
Highway 11
Enterprise, MS 39330

Yazoo Hardwood Nursery
Rt. 1, Box 76
Philipp, MS 38950
(601) 658-2255
Fax: same as phone number
E-mail: yhnursery@microsped.com

Missouri

Forrest Keeling Nursery
Hwy 79 South
Elsberry, MO 63343
(573) 898-5571

Tom Lett Nursery
Route 2, Box 383C
Cape Girardeau, MO 63701
(573) 335-0909

North Carolina

Weyerhauser
George Hunt Walker Nursery
1123 Dinah's Langing Rd.
Washington, NC 27889
(800) 344-0399
Fax: (252) 946-2218

Oklahoma

Greenleaf Nursery
Route 1, Box 163
Park Hill, OK 74451
(918) 457-5172

Tennessee

Boyd Nursery
P.O. Box 71
McMinnville, TN 37110
(931) 668-4747 or (931) 668-9898
Fax: (931) 668-7646

Greenwood Nursery
636 Myers Cove Rd.
McMinnville, TN 37110
(931) 668-3041 in state or
(800) 426-0958
Fax: (931) 668-2223

Hillis Nursery
92 Gardner Rd.
Highway 56 S
McMinnville, TN 37110
(931) 668-4364
Fax: (931) 668-7432
Web page : www.hillisnursurer.com
E-mail: hillisnsy@blomand.net

Joyner's Hills Nursery
440 Joyner's Hill Road
Bells, TN 38006
(901) 772-4213
Fax: (901) 772-7795

Trees by Touliatos
2020 Brooks Road
Memphis, TN 38116
(901) 346-8065
Fax: (901) 398-5217

Warren County Nursery
6492 Beersheba Hwy
McMinnville, TN 37110
(931) 668-8941
Fax: (931) 668-2245
Web page: wcnursery@blomand.net

Texas

Greenleaf Nursery
HC 62 Box 73
Highway 71 S
El Campa, TX 77437
(409) 543-6891
Fax: (409) 543-1886

Virginia

Union Camp Nursery
18229 Eppes Drive
Capron, VA 23829-0129
(804) 658-4184

Additional Sources of Information

Association of Florida Native Nurseries, 1992, 1992-1993 Plant and Service Locator, P.O. Box 1045, San Antonio, FL 33576, (813) 978-8006.

Plant Industry Division, 1991, Certified Nurseries and Plant Collectors of North Carolina: Raleigh, N.C., North Carolina Department of Agriculture. [Note: Other states may have similar directories.]

Soil Conservation Service Staff, 1992, Directory of Wetland Plant Vendors, Wetlands Research Program Technical Report WRP-SM-1: Vicksburg, Miss., U.S. Army Corps of Engineers, Waterways Experiment Station.

Appendix D
Species-Site Relationships in the Midsouth

Walter Broadfoot (1964) identified a number of soil types in the midsouth that support good growth of bottomland hardwood species. These soil types are located in five soil areas: Mississippi River floodplain (commonly called the Delta), Loess, Coastal Plain, floodplains of the Red and Arkansas Rivers, and the Blackland areas (figs. D.1-D.5).

The following information and tables on soil types is taken almost verbatim from Broadfoot's publication, "Soil Suitability for Hardwoods in the Midsouth." According to Broadfoot, "Information was compiled from data and observation of natural stands and may not apply where physical, chemical, and morphological conditions of the soil have been worsened, or where there are unusual soil variations such as sand ridges and exceptionally dry phases. Species-site relationships in plantations may also differ from those indicated" (Broadfoot, 1964, p. 1-3).

The reader should keep in mind that the footnotes on each table refer to "weed species" and suggest which species to favor or not in management from a timber production point of view. If the forest to be restored will be used for purposes other than timber production, the table symbols and footnotes must be interpreted carefully. Many species that are considered "weeds" from a timber production perspective are often considered desirable for wildlife (see table 4.1).

Delta

The Delta area soils lie in the floodplains of the Mississippi River. The soils are formed from alluvial material washed down from northern parts of the watershed. They are fertile, and under proper management, they are some of the best producers of hardwood timber. Four major types of soils occur in the Delta—recent natural levee, old natural levee, slackwater, and depressional soils—each of which is more suitable for some species than others (table D.1).

Variations in soils of natural levees can be traced to differences in drainage and texture. The alluvial sediments are in the first stages of development because they have been in place such a short time. The soils are usually neutral to alkaline because of lack of leaching. They are light in color because organic matter has not had time to build up.

The old natural levee soils are acid because they have been leached. These soils, in addition to species common on the younger natural levees, support oaks and hickories, as well as sassafras.

The slack-water areas are nearly level or gently sloping, occupy broad areas, and are usually some distance from the present and former channels of the Mississippi River. Their clay content is high and has developed under conditions of poor drainage. These sites support a high species diversity.

Depressional soils occur in old, partly filled river channels throughout the Mississippi River floodplain. These channels provide means for the slow return of flood waters to the bayous and main river. They are the lowest lying soils of the region and are subject to periodic flooding by local runoff. Hardwood species on these soils are limited to those most tolerant of poor drainage and aeration.

Loess

This is the narrow band of wind-deposited soils lying immediately east and west of the Delta. These are mostly upland soils, but support many of the same species found on higher bottomland sites. Soil texture is uniform, usually silt loam to silty clay loam. These soils are highly erodible; if enough erosion has occurred so that a site has less than six inches of topsoil, the site is considered more suitable for pines than hardwoods. Some soils have pans or are underlaid with stiff clays. Pine should also be favored on these sites along with species such as cherrybark, Shumard and white oak and sweetgum. The general soil classes in the Loess area are upland, terraces, acid bottoms, and neutral to alkaline bottoms (table D.2).

Terrace soils in the Loess area show considerable profile development. A number of the terrace soils are poorly drained and have strong pans that seriously limit root development and height growth of hardwoods. Presence of pans should be investigated by use of the soil survey or field inspection.

A number of river floodplains in the Loess area border the Delta on the east. Generally, the same variety of species found on the terraces of this soil are on the bottoms. The middle and lower slopes of the upland and the acid bottoms are particularly productive.

Table D.1. Soil suitability for southern hardwoods in the Delta area. Tree nomenclature follows Little (1953).

Important commercial species	Natural-levee soils					Slackwater soils		Depressional soils	
	Recent		Old						
	Crevasse, Robinsonville	Commerce, Mhoon	Beulah, Bosket	Dubbs, Dundee	Forest-dale	Bowdre, Tunica	Sharkey, Alligator	Ark	Dowling, Souva
Ash, green	●	■	---	○	□	○	■	■	■
Baldcypress	---	●	---	---	○	---	■	●	■
Cottonwood, eastern	■	■	●	●	●	■	■	●	○
Elms, slippery and American	□	□	○	□	□	□	□	○	---
Hackberry and sugarberry	■	■	○	○	□	□	□	□	○
Hickory, water	---	---	---	○	□	○	□	○	□
Honeylocust	○	○	---	○	□	○	□	○	●
Maple, red	---	---	---	○	□	■	■	●	---
Maple, silver	●	■	---	---	---	---	---	---	---
Oak, cherrybark	○	○	■	■	■	●	●	●	---
Oak, Nuttall	---	○	---	●	■	●	■	●	●
Oak, overcup	---	○	---	○	■	○	■	○	■
Oak, Shumard	---	---	●	■	○	●	○	---	---
Oak, swamp chestnut	---	---	○	■	■	●	○	○	---
Oak, water	○	●	■	■	■	■	■	●	---
Oak, willow	---	---	■	■	■	■	■	●	○
Pecan	■	■	○	●	○	●	○	---	---
Persimmon, common	○	○	○	○	□	●	■	●	●
Sassafras	○	---	■	■	○	○	○	---	---
Sweetgum	●	■	■	■	■	■	■	●	○
Sycamore, American	■	■	■	■	●	●	●	○	---
Tupelo, black (black gum)	---	---	□	■	○	○	○	---	---
Tupelo, water	---	---	---	---	---	---	---	●	●
Willow, black	○	■	---	---	○	---	○	■	■

Post and specialty species: black locust, catalpa, and flowering dogwood on moderately to well-drained acid soils; Osage-orange on neutral to alkaline soils; mulberry on all soils.

Limited commercially or in occurrence: boxelder on neutral to alkaline soils; bur oak, American holly, winged elm on acid soils; post oak, river birch, hickories (exc. water), and white oak on well-drained acid soils; swamp cottonwood and laurel oak on poorly drained acid soils; black walnut on well-drained soils; chinaberry, cedar elm, buckeye, and Kentucky coffeetree on all soils.

Weed species: American hornbeam and eastern hophornbeam on acid soils; planer tree on wet soils; hawthorn, swamp-privet, redbud, and roughleaf dogwood on all soils.

■ Occurs frequently; favor in management.
● Occurs occasionally; favor.
□ Occurs frequently; manage, but do not favor.
○ Occurs occasionally; manage, but do not favor.

Table D.2. Soil suitability for southern hardwoods in the Loess area. Tree nomenclature follows Little (1953).

Important commercial species	Uplands						Terraces		Acid bottoms		Neutral to alkaline bottoms	
	Memphis-Loring, Natchez		Lexington, Atwood, Brandon		Grenada, Providence, Franklinton, Dulac, Lax, Tippah	Calloway, Henry, Falkner, Bude, Tickfaw, Hurricane	Lintonia, Richland, Dexter, Freeland	Olivier, Calhoun, Carroll, Hatchie, Almo	Vicksburg, Collins	Falaya, Waverly	Morganfield, Adler	Wakeland, Birds, Dekoven
	Ridge and upper slope	Middle and lower slope[1]	Ridge, upper, and middle slope	Lower slope								
Ash, green and white	○	■	---	○	○	□	○	□	□	■	○	■
Baldcypress	---	---	---	---	---	---	---	---	○	■	○	■
Basswood, American	○	■	---	○	●	○	●	○	●	---	---	---
Beech, American	○	□	---	□	○	○	□	○	□	□	---	---
Cherry, black	○	■	○	●	○	○	●	○	●	○	---	---
Cottonwood, eastern	---	●	---	○	---	---	○	○	■	■	■	■
Elms, slippery and American	○	□	○	□	□	○	□	□	□	□	□	□
Hackberry and sugarberry	---	○	---	○	○	○	○	○	●	●	■	■
Hickories (exc. water)	□	□	□	□	□	○	□	○	□	○	---	---
Honeylocust	---	○	---	○	---	○	---	○	○	□	○	□
Magnolia, southern	○	■	○	○	○	○	●	○	●	●	---	---
Maple, red	○	□	○	□	□	□	□	□	□	■	○	○
Oak, cherrybark	□	■	●	■	■	■	■	●	■	■	○	○
Oak, Nuttall	---	---	---	---	---	---	●	●	●	■	○	○
Oak, overcup	---	---	---	---	---	---	---	○	○	■	---	○
Oak, Shumard	■	■	■	■	■	●	■	●	■	●	○	○
Oak, southern red	□	■	□	■	□	○	●	○	●	○	---	---
Oak, swamp chestnut	○	●	---	○	●	○	●	●	●	■	○	○
Oak, water	□	■	□	■	●	■	●	■	■	■	○	○
Oak, white	■	■	■	■	■	■	●	●	●	●	---	---
Oak, willow	○	●	○	●	○	○	○	○	●	■	---	---
Persimmon, common	□	●	□	○	□	○	□	○	●	■	■	■
Pines	●	○	■	○	○	●	○	●	○	○	---	---
Sassafras	□	●	○	○	○	○	●	○	●	○	○	○
Sweetgum	□	■	□	■	■	■	■	■	■	■	■	■
Sycamore, American	○	●	---	●	●	○	●	○	■	■	●	●
Tupelo, black (black gum)	□	■	□	■	□	□	●	○	●	○	---	---
Yellow-poplar	□	■	□	■	□	○	■	○	■	●	---	---

[1]Includes all slopes greater than 17%.

Post and specialty species: black locust, flowering dogwood, and catalpa on well-drained acid soils; eastern redcedar and mulberry on all soils.

Limited commercially or in occurrence: cucumber tree and black walnut on well-drained soils; chinkapin oak, scarlet oak, chestnut oak, black oak, sugar maple, northern red oak, and royal paulownia on well-drained upland soils; laurel oak and pin oak on wet, acid terraces and bottoms; water tupelo, swamp cottonwood, and swamp tupelo on wet, acid bottoms; boxelder on all bottoms, river birch on well-drained acid bottoms; American holly on all acid soils; post oak on uplands and terraces; water hickory and black willow on all poorly drained soils; pecan, chinaberry, cedar elm, winged elm, and buckeye on all soils; spruce pine on acid lower slopes, terraces and bottoms.

Weed species: Eastern hophornbeam, and American hornbeam on acid terraces and bottoms; blackjack oak and smooth sumac on well-drained uplands and terraces; swamp-privet and common buttonbush on wet, poorly drained bottoms; hawthorn on all soils.

■ Occurs frequently; favor in management
● Occurs occasionally; favor
□ Occurs frequently; manage, but do not favor
○ Occurs occasionally; manage, but do not favor

Coastal Plain

Many soils supporting hardwoods in the midsouth are on terraces and bottoms within the Coastal Plain. In general, they are sandy, acid, and lacking in natural fertility, but some have adequate moisture and drainage for good bottomland hardwood development. Table D.3 lists the major Coastal Plain soils and some of the major hardwood species that naturally occur on them.

Blackland

The Blackland soils occur in Alabama, Mississippi, and eastern Texas, with smaller areas in Louisiana and Arkansas. They are found within the Coastal Plain area, but differ in their prairie-like nature and color. The principal soil classes are shown in table D.4.

Most soils are neutral to alkaline, but some have weathered enough to become slightly acid. Texture is

Table D.3. Soil suitability for southern hardwoods in the Coastal Plain area. Tree nomenclature follows Little (1953).

	Terraces			Bottoms from Coastal Plain materials					
Important commercial species	Cahaba, Kalmia, Amite	Flint, Prentiss, Tilden, Izagora	Stough, Wahee, Myatt, Leaf	Ochlockonee, Iuka, Bruno	Mantachie, Urbo	Bibb	Chastain Coarse surface	Chastain Fine surface	Johnston
Ash, green and white	---	○	○	○	□	■	○	●	●
Baldcypress	---	---	---	---	○	■	○	●	●
Beech, American	---	---	---	○	□	○	○	○	---
Birch, river	---	---	---	□	○	---	---	---	---
Cherry, black	●	○	○	■	○	---	---	---	---
Cottonwood, eastern	---	---	○	●	●	●	●	●	---
Elms, slippery and American	○	○	○	□	□	□	○	---	---
Hackberry and sugarberry	---	○	○	●	●	○	○	○	---
Hickories (exc. water)	□	□	○	□	□	○	○	○	---
Magnolia, southern	○	○	---	■	■	○	○	---	---
Maple, red	○	○	□	■	■	■	■	●	□
Oak, cherrybark	●	■	■	■	■	■	■	■	---
Oak, laurel	---	---	○	○	●	■	■	■	---
Oak, Nuttall	---	---	---	---	●	■	●	■	---
Oak, overcup	---	---	---	---	○	□	○	□	---
Oak, Shumard	●	●	●	●	●	●	●	○	---
Oak, southern red	■	■	○	●	●	○	---	---	---
Oak, swamp chestnut	---	●	○	●	■	■	●	○	---
Oak, water	□	■	□	■	■	■	□	□	---
Oak, white	■	■	□	■	■	●	●	○	---
Oak, willow	○	○	□	●	■	●	●	□	---
Persimmon, common	○	○	○	○	●	●	●	●	---
Pines (exc. spruce)	□	□	■	○	○	○	○	○	---
Pine, spruce	---	---	---	●	●	●	●	○	---
Sweetgum	■	■	■	■	■	■	■	■	○
Sycamore, American	---	---	---	■	■	●	●	●	---
Tupelo, black	■	■	□	■	■	□	□	□	---
Tupelo, water	---	---	---	---	---	●	●	●	■
Walnut, black	●	○	○	●	●	○	○	---	---
Yellow-poplar	■	■	□	■	■	■	●	---	●

Post and specialty species: black locust and flowering dogwood on moist, well-drained soils; mulberry on all soils.

Limited commercially or in occurrence: basswood, pecan, post oak, and silver maple on well-drained soils; shingle oak, sweetbay, and swamp tupelo on poorly drained soils; boxelder, winged elm, honeylocust, black willow, sassafras, American holly, buckeye, chinaberry, and common sweetleaf on all soils.

Weed species: blackjack oak and smooth sumac on well-drained soils; planer tree, roughleaf dogwood, poison-sumac, and buttonbush on poorly drained soils; eastern hophornbeam, American hornbeam, devils-walking-stick, hawthorn, and flatwoods plum on all soils.

■ Occurs frequently; favor in management
● Occurs occasionally; favor
□ Occurs frequently; manage, but do not favor
○ Occurs occasionally; manage, but do not favor

Table D.4. Soil suitability for hardwoods in the Blackland area. Tree nomenclature follows Little (1953).

Important commercial species	Terrace soils:[1] Kipling, Geiger	Bottom soils					
		Recent coarse and medium-textured: Marietta, Verona	Fine-textured acid			Fine-textured calcareous	
			Kaufman	Houlka	Una	Catalpa, West Point	Leeper, Tuscumbia
Ash, green and white	□	■	○	■	■	■	■
Cottonwood, eastern	●	■	●	●	○	■	■
Elms, slippery and American	○	□	○	□	○	□	□
Hackberry and sugarberry	○	■	●	■	□	■	■
Hickories (exc. water)	○	○	□	□	○	---	---
Maple, red	○	□	○	■	□	---	○
Maple, silver	○	○	---	---	---	○	○
Oak, cherrybark	●	●	■	■	■	---	---
Oak, Durand	●	●	■	■	---	●	●
Oak, Nuttall	---	---	●	■	■	○	○
Oak, overcup	---	---	○	○	□	---	○
Oak, post	□	---	---	---	---	---	---
Oak, Shumard	●	●	■	■	○	---	---
Oak, swamp chestnut	○	●	●	■	○	○	---
Oak, water	□	■	●	■	□	○	○
Oak, white	●	---	●	●	●	---	---
Oak, willow	○	■	●	■	□	○	---
Persimmon, common	○	○	○	□	○	---	---
Sweetgum	●	●	■	■	■	●	●
Sycamore, American	○	●	●	●	●	●	●
Tupelo, black	○	○	●	●	○	○	○
Yellow-poplar	---	●	●	●	○	---	---

[1]Noneroded phases only.

Post and specialty species: black locust and catalpa on all well-drained, moist soils; eastern redcedar on all dry soils; Osage-orange on all neutral to alkaline soils; mulberry on all soils.

Species limited commercially or in occurrence: boxelder, winged elm, honeylocust, and pecan on all soils; American beech, southern magnolia, spruce pine, American holly, shingle oak, sassafras, and chinaberry on all acid soils; black walnut and black cherry on all well-drained, moist soils; laurel oak and sweetbay on acid, poorly drained soils; black willow and baldcypress on all moist, poorly drained soils.

Weed species: hawthorn and privet on all soils; American hornbeam, eastern hophornbeam, roughleaf dogwood, and flatwoods plum on all acid soils; smooth sumac on all moist, well-drained soils; redbud and Hercules-club on terraces and acid soils.

■ Occurs frequently; favor in management
● Occurs occasionally; favor
□ Occurs frequently; manage, but do not favor
○ Occurs occasionally; manage, but do not favor

mostly fine or clay-sized. The alluvial soils are fertile enough to support excellent growth of some hardwoods provided moisture and drainage are adequate.

Red and Arkansas River Floodplains

Reddish-brown soils occupy the floodplains of the Arkansas and Red Rivers, and include acid to alkaline sands, silts, and clays. The more alkaline soils occur in the Red River floodplain and the more acid soils occur in the Arkansas River floodplain. The two main soil classes described for this area are terrace and bottom soils (table D.5).

Terrace soils range from moderately to well drained acid soils to somewhat poorly drained to poorly drained acid soils. Bottomland soils range from acid to neutral to alkaline to calcareous in pH. They are generally moderately to well drained.

Table D.5. Soil suitability for hardwoods in the Red area. Tree nomenclature follows Little (1953).

Important commercial species	Terraces			Bottoms			
	McKamie, Hortman, Muskogee	Morse, Asa	Gore, Acadia, Wrightsville	Pulaski, Gallion, Lonoke, Mer Rouge	Yahola, Norwood	Hebert, Portland, Perry	Miller, Buxin, Roebuck, Pledger
Ash, green and white	□	○	□	□	■	■	■
Cottonwood, eastern	---	---	---	●	■	●	●
Elms, slippery and American	□	□	○	□	□	□	□
Hackberry and sugarberry	□	□	○	□	■	□	□
Hickories (exc. water)	□	---	□	□	---	○	○
Honeylocust	---	□	---	○	○	○	□
Oak, cherrybark	■	○	●	■	---	■	---
Oak, Nuttall	●	○	●	●	○	■	○
Oak, overcup	---	---	○	○	○	□	○
Oak, swamp chestnut	□	---	○	■	---	■	○
Oak, water	■	○	●	■	○	■	○
Oak, white	■	---	●	●	---	○	---
Oak, willow	□	○	●	●	---	■	○
Pecan	○	■	---	■	■	○	■
Pines	□	---	□	---	---	---	---
Sweetgum	■	■	■	■	■	■	●
Sycamore, American	●	●	---	■	■	●	●
Tupelo, black	○	---	□	○	---	---	---

Post and specialty species: baldcypress on all poorly drained soils; eastern redcedar on all moderately to well-drained soils; Osage-orange on neutral to alkaline soils; mulberry and persimmon on all soils.

Species limited commercially or in occurrence: post oak on well-drained acid soils; swamp tupelo on poorly drained acid soils; blackjack oak, American holly, winged elm, sassafras, and Shumard oak on acid soils; boxelder on neutral to alkaline soils; American smoketree on poorly drained neutral to alkaline soils; black willow, pumpkin ash, water hickory, and pin oak on all poorly drained soils; cedar elm, chinaberry, and red maple on all soils.

Weed species: American hornbeam and eastern hophornbeam on acid soils; hawthorn, swamp-privet, redbud, and roughleaf dogwood on all soils; devils-walking-stick on terraces.

■ Occurs frequently; favor in management
● Occurs occasionally; favor
□ Occurs frequently; manage, but do not favor
○ Occurs occasionally; manage, but do not favor

References Cited

Broadfoot, W.M., 1964, Soil suitability for hardwoods in the Midsouth: U.S. Forest Service Research Note SO-10, 10 p.

Little, E.L., Jr., 1953, Check list of native and naturalist trees of the United States (including Alaska): U.S. Department of Agriculture Handbook 41, 472 pp.

Appendix E
Species-Site Relationships in the Southern Atlantic Coastal Plain

Recognizing the increasing demand for hardwoods for both pulpwood and sawtimber, the American Pulpwood Association developed a booklet on stands of bottomland hardwoods (Kellison and others, 1988). In this booklet the authors discuss site types, stand assessments, and silvicultural systems and regeneration methods. Kellison and others (1988) discussion on site types is reproduced here with permission.

Recognition of site type is essential for proper management of bottomland hardwoods. Site types are land formations with unique soil and water characteristics and species compositions. Bottomland site types best suited for hardwoods include muck swamps, red river bottoms, black river bottoms, branch bottoms, cypress strands, cypress domes, and Piedmont bottomlands. Hydrologic characteristics and species composition of the bottomland types are shown in table E.1.

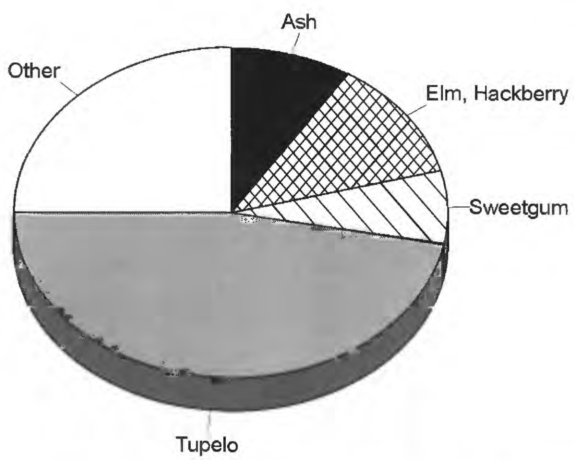
Reference Cited

Kellison, R.C., Martin, J.P., Hansen, G.D., and Lea, R., 1988, Regenerating and managing natural stands of bottomland hardwoods: Washington, D.C., American Pulpwood Association, APA 88-A-6, 26 p.

Table E.1. Bottomland hardwood site types by surface water classification and indicator species.

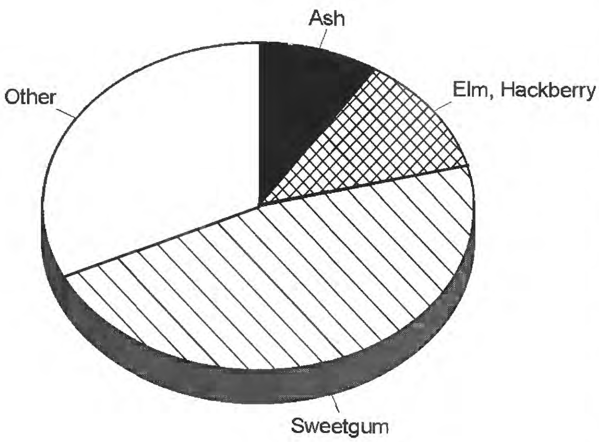
Hardwood Site Type	Surface Water Classification	Indicator Species
Muck swamp	Flooded 10 to 12 months	Baldcypress, tupelo
Red river bottom	Flooded winter, spring	Sycamore, sweetgum, cherrybark oak
Black river bottom	Flooded winter, spring	Tupelo, swamp black gum
Branch bottom	Boggy throughout year	Swamp black gum
Cypress strand	Flooded winter, spring, summer	Baldcypress
Cypress dome	Flooded throughout year	Pondcypress, baldcypress
Piedmont bottomland	Flooded winter	Yellow-poplar, sweetgum

MUCK SWAMP

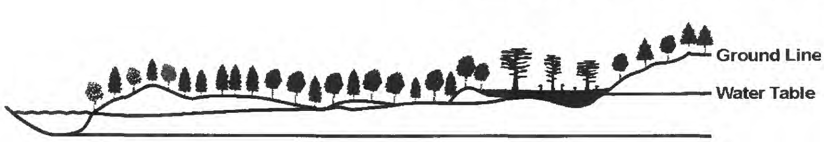


Very poorly drained area, usually with standing water, broad expanses between tidewater and upstream runs and along black rivers and branch bottom stands; also found in miniature in sloughs and old oxbows of red rivers and branch bottoms characterized by accumulation of organic matter (amorphous, lacking structure). Soils range from silt loam through clay. Water tupelo and baldcypress are common in deeply flooded areas and swamp blackgum predominates toward the fringes.

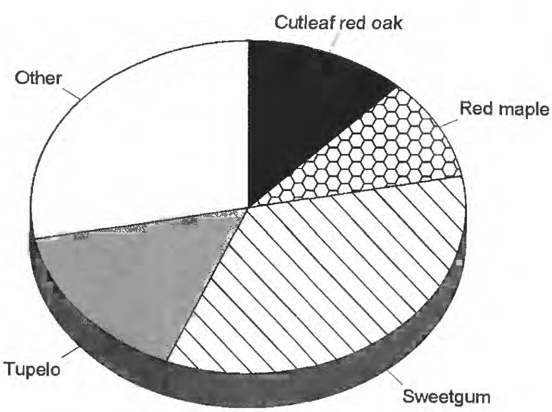
RED RIVER BOTTOM



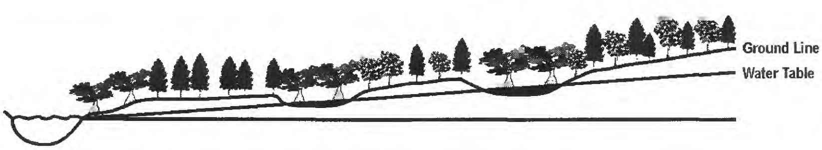
Floodplain of major drainage system originating in the Piedmont or Mountains. Immediately adjacent to the drainage systems, sloughs and oxbows are commonly found; if of sufficient size, they are classified as muck swamps. Some organic matter may accumulate on the clay soils. Water tupelo predominates over cypress, red maple, swamp blackgum, swamp cottonwood, laurel oak and others. Beyond the sloughs and oxbows are first bottoms (low ridges) which flood periodically to considerable depths. However, drainage is fairly rapid because of higher elevation. Soils range from sandy loams or clay loams. Species include sweetgum, ash, water hickory, sycamore, red maple, river birch, elm, hackberry, and willow, water, laurel and overcup oaks. At still higher elevations second bottoms and terraces are found. Flooding is infrequent or rare, and more mesophytic species of cherrybark, swamp chestnut and white oaks, hickories, beech and occasionally yellow-poplar occur. Examples of red river bottom are: Roanoke-Virginia, North Carolina; Santee-South Carolina; Oconee-Georgia; and Alabama-Alabama.



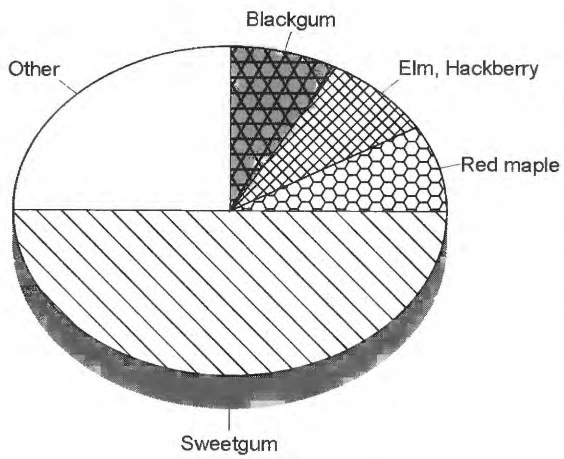
BLACK RIVER BOTTOM



Floodplain of major water system originating in the Coastal Plain. Classification of minor site types and species similar to red river bottom, with exception of muck swamps being more prevalent and first and second bottoms and terraces being on a more modest scale. Predominant species are sweetgum, tupelo, red maple and cut-leaf red oak. Examples of black river bottoms are Blackwater-Virginia; Waccamaw-North Carolina, South Carolina; Black-South Carolina; and St. Mary's-Georgia and Florida.

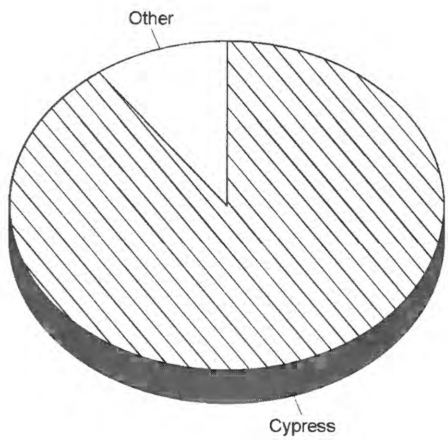


BRANCH BOTTOM



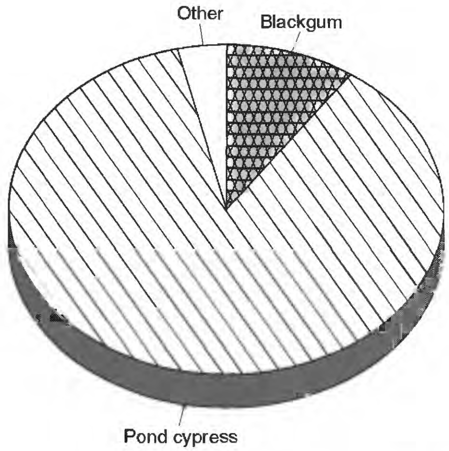
Relatively flat, alluvial land along minor drainage system which is subject to minor overflow. On wetter portions with heavier soils, the predominant species are willow, water and laurel oaks, swamp black gum, sweetgum, red maple and ash. The lighter soils of second bottoms and terraces support cherrybark, Shumard, swamp chestnut, and white oaks, sweetgum, hickory, yellow-poplar and loblolly pine. Sloughs and oxbows of limited extent along the main channel support tupelo and swamp blackgum. Examples: Big Swamp-North Carolina; Wambaw-South Carolina.

CYPRESS STRAND

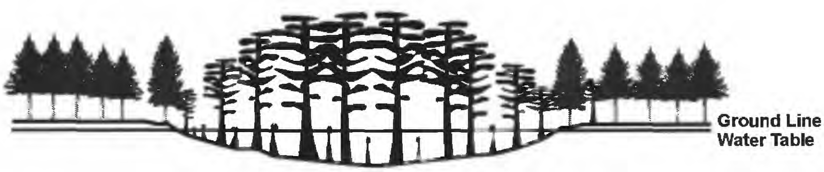


Low areas in south Georgia and northern Florida where shallow water flows during the wet season above the hardpan which is usually present. Such strands or stringers are common in the lower Apalachicola River region, including Tates Hell Swamp. Cypress forests in these strands are usually open with sedges beneath. Some cypress trees extend into adjacent savannahs and boggy flatwoods of slash pine and even longleaf pine. Blackgum is a common associate just beneath the cypress canopy. The soils very in depth of the surface organic horizon and in the presence or absence of a spodic or an argillic horizon. The values for pH and available nutrients are generally low.

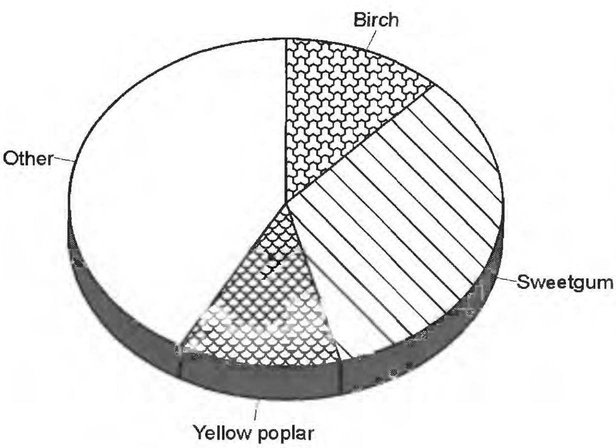
CYPRESS DOME



Isolated peaty acid depression (dome) usually found in Florida, which is moist or inundated for weeks or months at a time. Pondcypress predominates but other species such as blackgum, slash pine, sweetbay, and loblolly bay are found on small hummocks where the hydroperiod is less prolonged. Ground cover is usually absent except on hummocks. The tallest trees occur in the center of the domes where peat can accumulate to 2-4 feet in depth; other trees are progressively shorter to the periphery. Domes typically have clay pans or lenses beneath the sandy surface soils which serve to limit subsurface groundwater recharge.



PIEDMONT BOTTOMLAND



In lower Piedmont, conditions identical to red river bottom are encountered. However, upstream, sloughs, oxbows and first bottoms decrease in frequency and area until only well-drained bottomland (second bottom and terrace) is encountered. Species include sycamore, birch, yellow-poplar, sweetgum, green ash, cottonwood, water and willow oak, loblolly pine and others. Examples of bottomland site-types are: Meherrin-Virginia; Neuse-North Carolina; Saluda-South Carolina; Oconee-Georgia; and Sipsey-Alabama.

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