Forest Stewards Guild

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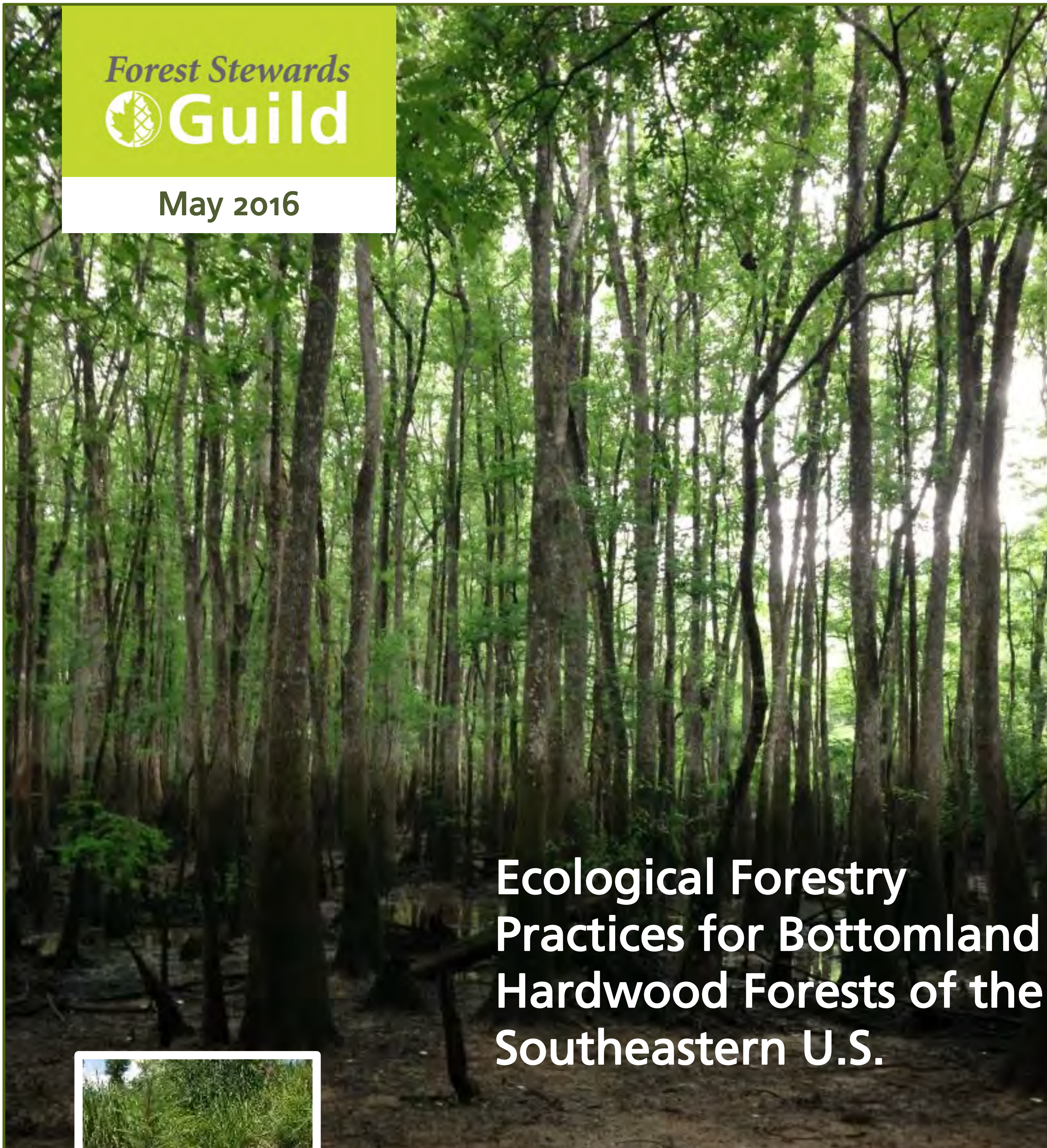

Ecological Forestry Practices for Bottomland Hardwood Forests of the Southeastern U.S.

REPORT

ECOLOGICAL FORESTRY PRACTICES FOR BOTTOMLAND HARDWOOD FORESTS OF THE SOUTHEASTERN U.S.

Amanda Mahaffey and Alexander Evans

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Forest Stewards Guild Mission

The Forest Stewards Guild practices and promotes ecologically, economically, and socially responsible forestry as a means of sustaining the integrity of forest ecosystems and the human communities dependent upon them. Our members are foresters, conservationists, resource managers, scientists, students, policy makers, and land stewards working in forests throughout the United States and Canada. Our research program synthesizes existing knowledge and conducts novel scientific studies as a complement to Guild member's place-based experience.

Summary

Bottomland hardwood forests, floodplain forests that are periodically inundated or saturated during the growing season, are critically important to biodiversity, wildlife, carbon storage, recreation, and clean water in the Southeastern United States. Unfortunately, bottomland hardwood forests are exceptionally threatened by land conversion, altered hydrology, invasive species, more frequent intense storms, and shifting economic drivers. There are opportunities for forest owners, natural resource managers, and communities to protect and enhance the ecological integrity of bottomland hardwood forests through careful management. Conscientious stewardship based on recognition of the complex ecology of bottomland hardwood forests can provide a full suite of benefits to these ecosystems and the communities that depend upon them.

This document is intended to help define and communicate a model of ecological forestry for bottomland hardwood forests in the southeastern United States. The content combines scientific knowledge with boots-on-the-ground expertise to produce meaningful, solution-oriented tools that can help improve the stewardship of this resource for the benefit of these unique ecosystems and the human communities that depend upon them. This report includes background information on bottomland hardwood forest ecosystems, general guidelines for management including silvicultural strategies, and information for specific bottomland forest types. Throughout the report, we have included the insights of Forest Stewards Guild members and other project contributors who are listed in the *Acknowledgements* section.

This publication is targeted toward foresters and land managers; however, the authors strove to make the information accessible to a broader audience as well. The final section *Actions* identifies specific steps to improving stewardship of bottomland hardwood forests.

Contents


Amanda Mahaffey

BACKGROUND

This section provides fundamental background knowledge on bottomland hardwood forests of the Southeast including the factors that define this ecosystem, where it can be found, the significance of these systems, and some current threats to their ecological integrity.

Why are bottomland hardwoods important?

Bottomland hardwood forests are the crucial interface between clear, clean water and the forests, farms, towns, and cities of the southeastern United States. As with other wetlands, bottomland forests play a crucial role in protecting downstream communities by storing floodwater and reducing the risk and severity of flooding. Bottomland forests also improve water quality by filtering and flushing nutrients, processing organic wastes, and reducing sediment load in streams. Researchers estimate that each year, forested wetlands provide as much as $4,700 per acre in flood control, $3,479 per acre pollution treatment, and $1,157 in water supply value (Moore et al. 2011). Because of their high productivity, bottomland forests are important stores of carbon and climate change mitigation (Shoch et al. 2009), as well as for generating forest products.

Bottomland hardwood forests are also particularly productive habitats for animals ranging from beetles to black bears (Smith and Linnartz 1980, Rudis and Tansey 1995, Ulyshen et al. 2004). About 70 bird species depend on bottomland hardwood forests in the Southeast (Pashley and Barrow 1992). Bottomland forests are also premium hunting grounds and command high values for leases (Hussain et al. 2007). All these values should drive protection and careful stewardship of bottomland hardwood forests.

Unfortunately, bottomland hardwood forests are exceptionally threatened (for more detail, see the section, *Why are bottomland hardwoods threatened?*). There is a long history of converting bottomland hardwood forests to other land uses. At the same time, there are new pressures on bottomland forests including demand for wood pellets in Europe, an increase in disturbance events driven by a changing climate and human alteration, and an influx of invasive species.

The tremendous value bottomland hardwood forests provide has been largely underappreciated. A recent study in Georgia concluded that they generate relatively little revenue for landowners, but they have very high value in the provision of ecosystem services, i.e., biodiversity, flood protection, carbon storage, recreation, and clean water (Schmidt et al. 2014). This guide aims to help forest owners, natural resource managers, and the communities that depend on bottomland hardwood forests understand the services these forests provide and useful approaches for stewarding them.

Where are bottomland hardwoods?

This report focuses on bottomland hardwoods in the Southeast. For management recommendations for the Upper Mississippi River, see http://www.ncrs.fs.fed.us/fmg/nfmg/bl_hardwood/index.html.

Bottomland hardwood forests are found along major and minor rivers and streams in low-lying lands across the Southeast. The Mississippi Valley Alluvial Plain is home to what may be considered the "varsity" of bottomland hardwood forests, while smaller, but still highly significant, bottomland forests are found throughout the Atlantic and East Gulf Coastal Plains.

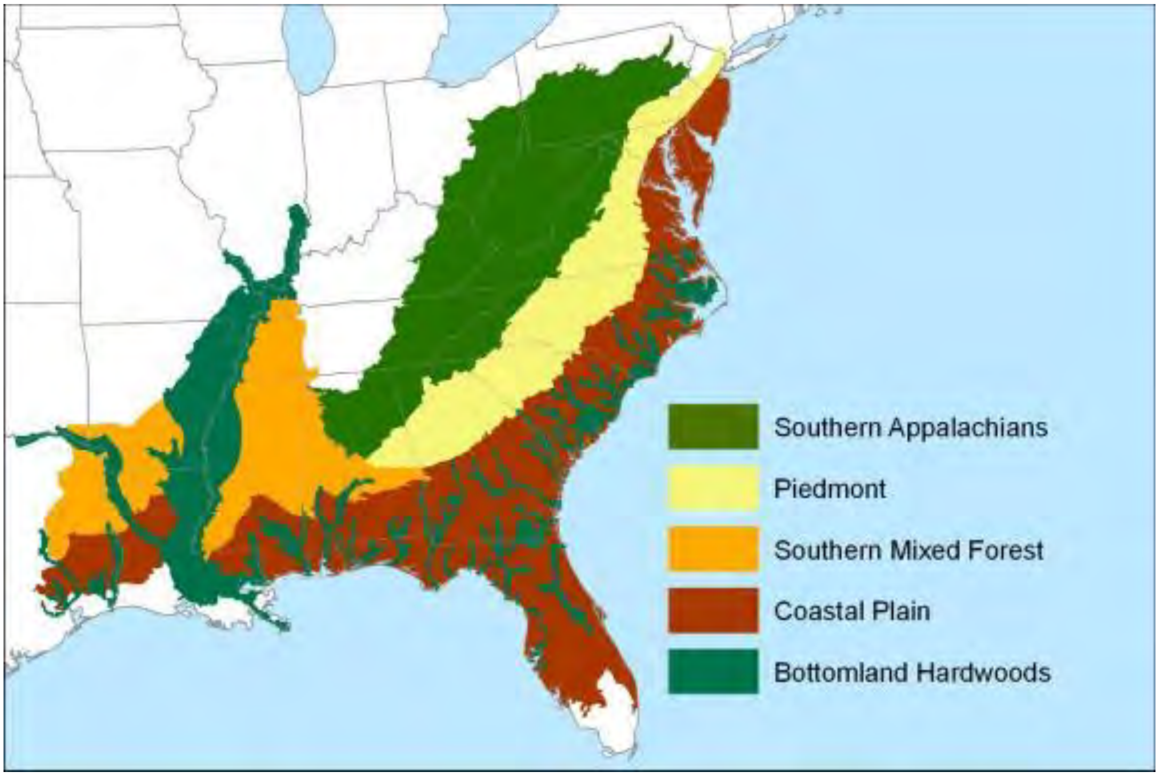


Figure 1 Map of physiographic provinces, with bottomland hardwood areas superimposed. Province data from Cleland et al. 2007 and bottomland hardwood data from Hodges 1995.

The distribution of bottomland hardwood forest varies by state across the Southeast. Many similarities exist between bottomland hardwood management in the Mississippi Delta and the Atlantic Coastal Plain, and a guide to bottomland hardwood management in the Southeast would be remiss to omit lessons learned in the Mississippi Delta. However, distinctions exist between land use histories, forest successional patterns, forest product markets, and other attributes of the two regions. The Lower Mississippi Alluvial Valley historically supported approximately 8.5 million hectares of bottomland hardwood forests, of which all but 2.5 million hectares have been lost over the past 200 years. Bottomland hardwoods make up about 13% of North Carolina's timberland or about 2.4 million acres (Bardon et al. 2010). The majority of North Carolina's bottomland hardwoods are found in the coastal plain. 2014 USDA Forest Service Forest Inventory and Analysis data in Figure 2 below show the prevalence of bottomland hardwood forest found in coastal southern states. The next section describes where bottomland hardwood forests occur at the local level.

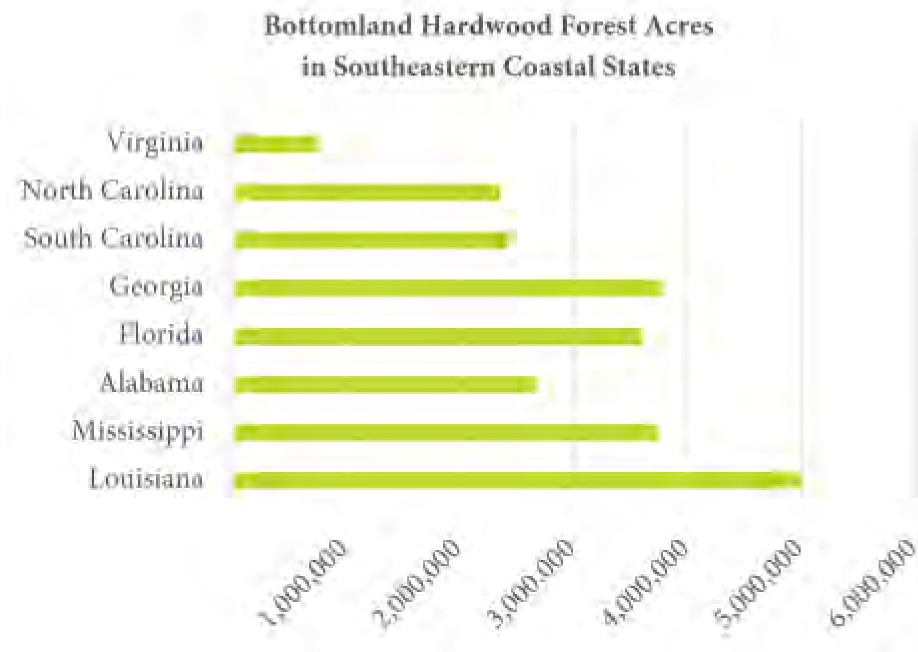


Figure 2 Bottomland hardwood forest acres in Southeast coastal states. USDA Forest Service 2014 FIA data.

What are bottomland hardwood forests?

This section provides a synopsis of the major characteristics of bottomland hardwood forests. The seminal paper on bottomland hardwood forests is John Hodges' 1997 publication, *Development and ecology of bottomland hardwood sites*. Additionally, *Regenerating and Managing Natural Stands of Bottomland Hardwoods* by Kellison, Martin, Hansen and Lea captures the fundamentals of southeastern bottomland hardwood forest management (1988). The 1960 publication by Putnam et al, *Management and Inventory of Southern Hardwoods,* is considered a "bible" of southern hardwoods and articulates ecological principals still relevant today. These papers are strongly recommended reading for forest managers in bottomland hardwood systems.

Bottomland hardwood forests are forested wetlands found in broad, river and stream floodplains of the southeastern coastal state plains and the Midwest. Bottomland hardwood forests occur primarily in alluvial (water-borne soil) floodplains and are also described as floodplain forests. They are included under a variety of names in forest classification systems such as deciduous freshwater palustrine forested wetlands in U.S. Fish and Wildlife Service's Wetland Classification System (Haynes 1988), as well as 16 forest cover types in the Society of American Foresters forest cover type classification system (Allen et al. 2004). Bottomland hardwood forests are seasonally or permanently inundated by water and support plant species and associated wildlife that are well-adapted to these conditions. Water and gradients of flooding (from perennially wet to rarely flooded) help determine the arrangement of species (Smith and Linnartz 1980).The soils can range from clay to sand depending on geomorphologic origin. From herbaceous plants to trees to wildlife, the living components in these ecosystems are driven by the hydrology that continually changes and shapes the bottomland landscape.

Geomorphology and soils

The landforms in which bottomland forests are found, such as fronts, flats, sloughs, and ridges, are molded by the velocity of flowing water and the size and origin of the sediment it carries (Wharton et al. 1982). Floodplains form as moving water slows; first, the coarse sedimentary particles drop out, then the fine sands, and eventually loams and fine clays. The velocity of the water and the distribution of particles across the floodplain create a diverse, ever-changing landscape of landforms, each with its own unique characteristics tied to runoff during the glacial period, in which bottomland hardwood forest communities take root. Soils in the Mississippi Alluvial Floodplain were shaped by glaciation; the large volume of water and sediment resulted in today's broad floodplain. In contrast, the Atlantic Coastal Plain was shaped primarily by marine influences (Hodges 1997). Runoff from the Piedmont carries older soils and silt, while watersheds that originate within the coastal plain tend to be less nutrient-rich (Moorehead 1994). The soils and the seasonal flow of water through these bottomlands help determine the types of forests that develop. Generally speaking, the higher the relative elevation within the floodplain (e.g. front or ridge vs. flat or slough), the greater the productivity and species diversity (Hodges 1997). Elevational differences of mere inches or feet can lead to significant differences in site conditions (Meadows and Hodges 1997).

Hydrology as a driving factor

Hydrology is a constant force of change in bottomland hardwood ecosystems. Therefore, forest management decisions must be founded upon an understanding of the flow of water in the dynamic growth and ecological function of these systems. The manipulation of vegetation, either for forest management or for other land uses, can significantly affect hydrologic flow in these systems (Lockaby et al. 1997, Kolka et al. 2001). This will be discussed in greater detail later in this report.

Climate is a significant factor in determining the hydrology (Wharton 1982, Sun 2001, Dai 2013). Increased precipitation, more intense weather events such as Hurricanes Hugo and Joaquin, and changes in seasonality affect the flow of water through bottomland hardwood forests of the Southeast (Jayakaran et al. 2014). The volume and intensity of water flow affect sediment deposition. Over time, the factors of where sediment is deposited, how much, and what size causes the meander of streams to shift and landforms to evolve. In turn, this affects the natural disturbance patterns to which bottomland hardwood forest ecosystems are accustomed. Scientific research suggests the impact of hurricanes in the Southeast may increase in the near future. These impacts will occur in the form of sea level rise driven by the warming climate, hurricane and wind speed intensification, and increased storm surges and flood elevation, all of which have the potential to affect bottomland hardwood forests (Mousavi et al. 2011). Precipitation patterns are also predicated to change increasing the likelihood of heavy rain events (Carter et al. 2014). The shifting climate means forest managers should be prepared for changing hydrologic dynamics of bottomland hardwood forests.

Tree Species and Natural Communities

Bottomland hardwoods are complex gradients of environmental conditions that support a wide array of tree species including maple, elm, sycamore, ash, cottonwood, sweet gum, and oaks (Smith and Linnartz 1980). Species lists for the Lower Mississippi Alluvial Valley and Coastal Plain bottomlands can be found in Figures 3 and 4 below. Stand development is driven by local processes and disturbance regimes. In baldcypress swamps where little deposition occurs, hurricanes may drive stand initiation on the order of hundreds of years (Hodges 1997). On ridges and other higher elevation sites, pioneering cottonwood may be followed by sugarberry and hackberry. If advanced regeneration is present, sycamore, pecan, or elms may dominate the site (Stanturf et al. 2001). Oaks, such as cherry bark or pin oak, may be part of the stand on better drained soils. Without natural disturbances such as windstorms or salt water intrusion, bottomland forest community types and successional patterns can persist for hundreds of years. Successional pathways in bottomland hardwoods are complex, and Hodges (1997) provides a comprehensive description.

At the macro level, the natural state of these ecosystems is an old, uneven-aged tree structure with relatively small canopy gaps and heterogeneous forest composition. Flooding and windstorms are the major disturbances in bottomland hardwood forests (Smith and Linnartz 1980, King and Antrobus 2001). Historically, wind disturbances would generate small canopy gaps caused by blowdown of individual or small group of trees, while hurricanes would create larger openings more perceptible at the landscape level. The frequency and intensity of tropical cyclones and wind events is increasing over time with the changing climate (Knight and Davis 2009). While fire has not been widely acknowledged as a major disturbance factor, a recent review of disturbance ecology literature shows that fire may have played a larger role historically in shaping floodplain ecosystems than has been recognized in recent restoration efforts (Gagnon 2009). Drought conditions more extreme than those to which bottomlands are adapted can also impact ecosystem stability. One report contributor noted that although ice storms are not common in the southeastern United States, the impact of ice storms is extremely important as far as creating canopy gaps to for the establishment of regeneration, which may be capitalized during silvicultural planning and treatments. While bottomland hardwood forests have historically been shaped by fire, flood, drought, and wind, anthropogenic disturbances such as drainage projects, road construction, timber harvesting, and the conversion of land to non-forest uses have an increasing influence on the evolution of these natural communities. In a flat landscape, hydrologic alterations such as road construction, clogged culverts, levees, and agriculture-related ditching can significantly impact these ecosystems.

Major bottomland hardwood systems

Hodges, Rousseau, and others have similarly summarized site-species relationships common to the bottomland hardwood systems based on physiographic site position, site and soil characteristics, and dominant tree species as replicated in the tables below (Rousseau 2009, Rousseau 2004, Hodges 1997).

Note the differences in tree species and species-site relationships in major and minor stream bottoms in the Mississippi Delta and the Coastal Plain; due to the differences in parent soil and other factors, dominant tree species and successional patterns vary between the two regions. On permanently flooded sites, succession occurs slowly; cypress-tupelo forests can dominate for hundreds of years. In major stream bottoms, both low-elevation and better-drained sites will eventually evolve toward the elm-ash-sugarberry type; in the Atlantic Coastal Plain, this system may contain significant amounts of red oaks and sweetgum. As sediment deposition slows and soils mature, bottomland hardwood forests progress toward an oak-hickory climax, which, if the system remains relatively undisturbed, can take over 200 years (Hodges 1997).

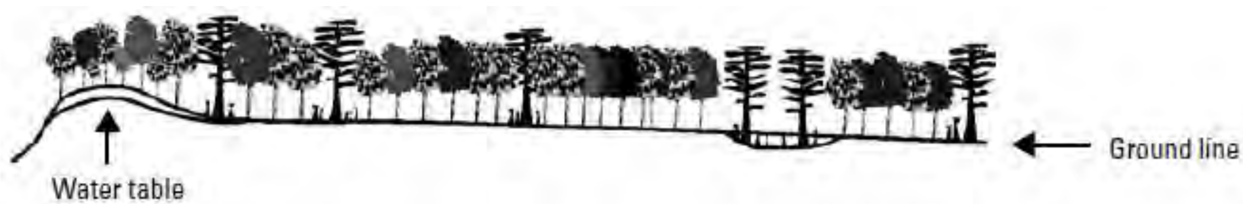
	Mississippi Valley Alluvial Floodplain													
	Major River Bottoms							**Minor Stream Bottoms**						
Desirable/Suitable Species	**Bars**	**Fronts**	**Ridges**	**High Flats**	**Low Flats**	**Sloughs**	**Swamps**	**Bars**	**Fronts**	**Ridges**	**High Flats**	**Low Flats**	**Sloughs**	**Swamps**
Cottonwood	■	■												
Black willow	■					■		■						
River birch								■						
Sycamore		■	■						■					
Sweetgum		■	■						■					
Sweet pecan		■												
Green ash		■	■	■	■							■		
Water oak		■	■						■		■			
Cherrybark oak		■	■							■	■			
Swamp chestnut oak		■	■							■	■			
Shumard oak									■	■	■			
Yellow poplar									■					
Willow oak			■	■							■	■		
Nuttall oak				■										
Sugarberry				■	■									
Overcup oak					■	■						■	■	
Water hickory					■	■								
Persimmon					■							■	■	
Baldcypress							■							■
Water tupelo							■							■
Swamp tupelo														■

Figure 3 Site-species relationships in the Mississippi Valley Alluvial Floodplain per Rousseau and others.

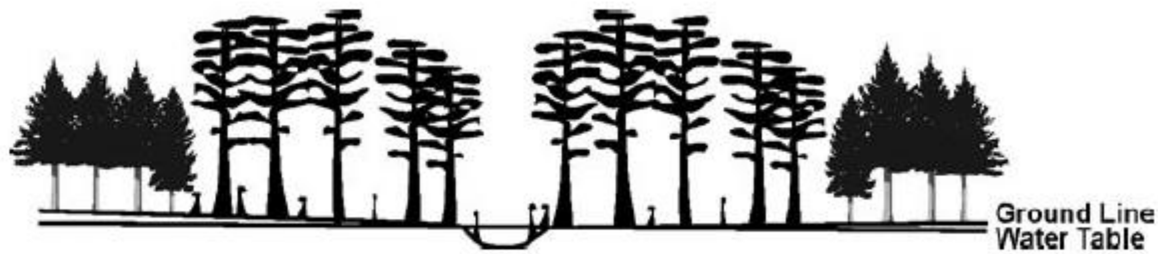
	Coastal Plain															
	Major Stream Valleys										**Minor Stream Valleys**					
	Floodplain							**Terrace**			**Distance from river →**					
Suitable Species	**Bars**	**Fronts**	**Flat**	**Slough**	**Ridge**	**Flat**	**Swamps**	**Ridge**	**Flat**	**Slough**	**Bars**	**Levee**	**Flat**	**Slough**	**Flat**	**Terrace**
Willow	■		■													
Cottonwood	■															
Elm		■	■													
Sycamore		■														
Pecan		■														
Sugarberry		■	■													
Nuttall oak			■						■						■	
Green ash			■		■				■							
Red maple			■													
Overcup oak				■		■				■					■	
Water hickory				■		■				■						
Sweetgum					■			■	■			■	■			■
Water oak					■				■						■	
Willow oak					■				■							
Baldcypress							■							■		
Water tupelo							■							■		
Hickory								■					■			
Red oak								■								■
Swamp chestnut oak								■								
Winged elm								■					■			
Blackgum								■					■			
River birch											■					
American beech												■				
Sycamore												■				
Yellow-poplar												■				■
Spruce pine												■				
Oaks												■	■			
White oak																■
Loblolly pine																■

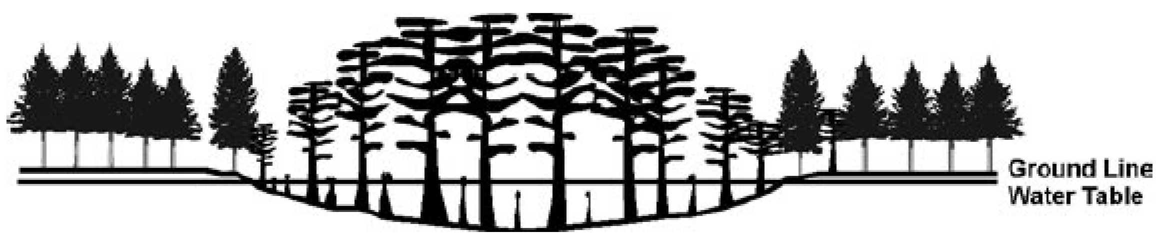
Figure 4 Site-species relationships in major and minor stream valleys of the Coastal Plain per Hodges and others.

Kellison and others characterized seven bottomland hardwood site types in the Southern Atlantic States Coastal Plain by hydrology and indicator tree species: muck swamp, red river bottom, black river bottom, branch bottom, cypress strand, cypress dome, and piedmont bottomland (Kellison et al. 1988). The site-species relationships of these types are summarized nicely in Appendix E of the publication, *A Guide to Bottomland Hardwood Restoration* and replicated here with permission (Allen et al. 2004).

<table>
<tr><th>Hardwood Site Type</th><th>Surface Water Classification</th><th>Indicator Species</th></tr>
<tr><td>Muck Swamp
Broad expanses between tidewater and upstream runs and along black rivers and branch bottom stands, also in areas of organic matter accumulation in red rivers and branch bottoms.</td><td>Flooded 10 to 12 months</td><td>Baldcypress, tupelo</td></tr>
<tr><td colspan="3">
</td></tr>
<tr><td>Red river bottom
Floodplain of major drainage system originating in the Piedmont or Mountains.</td><td>Flooded winter, spring</td><td>Sycamore, sweetgum, cherrybark oak</td></tr>
<tr><td colspan="3">
</td></tr>
<tr><td>Black river bottom
Floodplain of major water system originating in the Coastal Plain.</td><td>Flooded winter, spring</td><td>Tupelo, swamp black gum</td></tr>
<tr><td colspan="3">
</td></tr>
<tr><td>Branch bottom
Relatively flat, alluvial land along minor drainage system which is subject to minor overflow.</td><td>Boggy throughout year</td><td>Swamp black gum</td></tr>
<tr><td colspan="3">
</td></tr>
</table>

<table>
<tr><td>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. Cypress forests in these strands are usually open with sedges beneath. The values for pH and available nutrients are generally low.</td><td>Flooded winter, spring, summer</td><td>Baldcypress</td></tr>
<tr><td colspan="3">
</td></tr>
<tr><td>Cypress dome

Isolated peaty acid depression (dome) usually found in Florida, which is moist or inundated for weeks or months at a time. Ground cover is usually absent except on hummocks, and the tallest trees occur in the center of the domes.</td><td>Flooded throughout year</td><td>Pondcypress, baldcypress</td></tr>
<tr><td colspan="3">
</td></tr>
<tr><td>Piedmont bottomland

In lower Piedmont, identical to red river bottom; upstream, however, features decrease in frequency and area until only well-drained bottomland is encountered.</td><td>Flooded winter</td><td>Yellow-poplar, sweetgum</td></tr>
<tr><td colspan="3">
</td></tr>
</table>

Figure 5 bottomland hardwood site types in the Southern Atlantic States Coastal Plain per Kellison and others

Why are bottomland hardwoods threatened?

The chief threats to bottomland hardwood forests are caused by humans and human decisions. Land conversion, development, and fragmentation have so altered the landscape that many people have forgotten how very significant these ecosystems once were. Forest products markets through time have resulted in high-graded forests growing less economically-desirable trees. Changes in local hydrology coupled with extreme weather patterns disrupt the natural dynamics of these ecosystems and increase vulnerability to invasive species. Because southern forests are largely in non-industrial private forest ownership, much of the landscape is shaped by a diversity of landowner objectives, which presents a challenge to prescribing science-based silvicultural treatments (Meadows and Hodges 1997). Management decisions are often based on beliefs formed from the landowner's experience and perceptions, which in turn must be addressed by land managers when presenting management options that could result in a healthier forest (Hicks et al. 2004). The attitudes of landowners and resource managers must be better understood to help ensure successful conservation, reforestation, and afforestation efforts (Gordon and Barton 2015). Several of our contributors noted that the silvicultural and harvesting operational systems in which foresters are trained often apply better to upland forests than bottomland forests. A basic understanding of these threats can help determine priorities for addressing them and the role of silviculture, restoration, and conservation practices in sustaining bottomland hardwood forests of the Southeast.

Land conversion

A central threat to bottomland hardwood forests is type conversion. By the 1930s, flood control and conversion to agriculture had dramatically reduced the acreage of bottomland hardwood forest and replaced it with a very different landscape that has come to be accepted as the norm today. The expansion of agriculture and river channelization has reduced the area covered by bottomland hardwood forests significantly over the last century (King et al. 2005). The threat of conversion was greatest in the previous century, but continues today. In Mississippi, the conversion of forests to agriculture has been especially significant; by the early 1980s, 60 percent of bottomland hardwood forests had been replaced by crops such as soybeans (Wharton et al. 1982). As a contributor noted, "Removing water from the site, whether draining (ditches)or preventing water from reaching a site (levees) have a huge impact on which species can survive or be regenerated on that site."

Land conversion, deforestation, and fragmentation became rampant across the Lower Mississippi Alluvial Valley since European settlement (Gardiner and Oliver 2005). Bottomland hardwood forests are currently less likely than other forests in the Southeast to be protected from development through easements or other mechanisms (Hanson et al. 2010). While wetlands and inundated forests should be protected by Clean Water Act and state best management practices, in reality, these restrictions are often insufficient. For example, an investigation of cypress swamps identified that some developers misuse the silviculture permit exemption and employ it to convert cypress forests into developments (Fabrizio et al. 2012).


Amanda Mahaffey

A 2007 remote sensing analysis of Georgia's wetlands by Kramer et al. showed that an average of 26,700 acres of wetlands per year were converted to other uses from 1974 to 2001, or 16 percent of Georgia's wetland acres (Kramer et al. 2007). Historical records dating back to the eighteenth century place the loss as high as 25 percent. Significantly, much of the recent conversion occurred in the Atlantic Coastal Plain between 1982 and 1995 as forested wetlands, including bottomland hardwood forests, were methodically converted to intensively-managed pine plantations (Kramer et al. 2007). Georgia's 2015 State Wildlife Action Plan notes that conversion of forests to agriculture is less of a threat than it was historically, and Georgia's Southeastern Plains and Southern Coastal Plain ecoregion wetlands once heavily impacted by ditching, draining, and conversion appeared to show no significant loss of acres in 2006-2011 (Georgia Department of Natural Resources 2015). However, concerns still exist over the conversion of bottomland forests to pine plantations as woody biomass markets put increasing demand on the forest resource.

North Carolina's 2005 State Wildlife Action Plan cites forest fragmentation and type conversion as threats to the state's terrestrial habitats. It highlights a statistic that half of North Carolina's original wetlands have been lost to conversion to cropland (North Carolina Wildlife Resources Commission 2005). In contrast, a 2015 study of the six million-acre Albemarle Sound watershed in North Carolina and Virginia showed no change in acreage of bottomland hardwood forest between 1984 and 2012 (Lorber and Rose 2015). However, the age, structure, species composition, and live tree volume have changed over the last few decades. Today's young forests (i.e. the future forest) show a lower proportion of cypress, ash, tupelo, and black gum than mature forests and a higher proportion of shortleaf and loblolly pine. Most species declined in volume per acre over time, but oak and ash have increased by 57 and 41 percent, respectively. Some of these changes could be attributed to natural succession; however, timber harvesting, inadequate forest management and planning, and other factors may be responsible for the small amount of cypress and tupelo in young stands and the increase in loblolly pine. Periodic growth to harvest ratios indicate sustainable rates of harvest with the exception of 2007 (Lorber and Rose 2015).


Nicholas Biemiller

Economic drivers

Past land-use and timber harvesting can have a detrimental effect on current stand conditions and merchantability of mature trees. High grading has left poorly-formed trees that dominate the stand on many sites. Throughout the Southeast, there are ample opportunities for these areas to be salvaged and restored to a condition in which ecologically and economically valuable species are favored.

Wood product markets ebb and flow. Recently, new demand for wood pellets in Europe has led to intensive harvests of bottomland hardwood forests in North Carolina (Evans et al. 2013). This increase in harvests was driven in part by a backlog of hardwood harvesting following the closure of local hardwood pulp mills. As of 2014, the Southeast as a region became the largest exporter of wood pellets to the European Union, and hotspots of bottomland forest harvesting are predicted to arise in the woodsheds of major pellet mills (NRDC 2015). It is uncertain whether pellet markets encourage harvesting where it had not been economically feasible previously, for example, in low-value tupelo stands. Pellet and biomass markets might also create opportunities to harvest low-grade products and reallocate growing space to higher-quality trees. As new markets emerge, it is important to consider the ecological sustainability of the overall ecosystem in balance with these broader economic forces. Wherever possible, silviculture should be used to promote the right product on the right site. High-value hardwoods take longer to grow, but deliver a greater economic return than pellets and chips. At the same time, specialized products such as cypress mulch can put undue pressure on specific bottomland forest resources in Georgia and other states (Fabrizio et al. 2012).

In the Lower Mississippi Alluvial Valley, robust pulpwood markets currently support forest management that helps restore ecological function and structure to degraded stands. Landowners derive income from these intermediate treatments, as well as from hunting leases prized in bottomland hardwood forests with

older, more complex structure favorable to wildlife. Hunting leases can be a significant economic driver of good silviculture, in combination with the availability of low-grade wood markets and other factors. In Southeast Coastal Plain states, contributors report that hardwood pulp markets have greatly diminished, and sawlog markets are off as well. Market conditions are constantly in flux; from a long-term, big-picture perspective, it would be worth considering what bottomland forests of the Southeast Coastal Plain might look like with the right wood product market conditions. With the right economic driver, the ecological integrity of bottomland hardwood forests could benefit as well.

Climate change

The southeastern United States is warmer now than in the 1960s, and that trend is likely to continue. The Southern Forest Futures project provides estimates of temperature increases in the Southeast, but the potential change in precipitation is less certain (McNulty et al. 2011). With rising temperatures and the possibly of decreased precipitation, water stress will likely increase for trees in the Southeast over the next century (Lockaby et al. 2013). Climate change is also likely to negatively impact bottomland hardwood forests because of an increase in disturbance events (e.g. intense storms) and more frequent periods of drought (Carter et al. 2014). Report contributors noted that the intensity of winter storms seems to be increasing and having a greater impact on bottomlands than in the past. A recent study on the Santee Experimental Forest shows how the combination of climate change effects can impact a forest (Dai et al. 2013). Single events such as Hurricane Hugo can significantly alter the hydrologic dynamics and forest vegetation of a watershed (Jayakaran et al. 2014). More recently, Hurricane Joaquin demonstrated the same point as a major rain event in contrast to Hugo's epic winds. Approximately 5,000 miles of southern coastline are threatened by sea level rise (Benjamin et al. 2012, Lockaby et al. 2013). Saltwater inundation driven by the predicted increase storm surges would be detrimental to bottomland hardwood forests. In places where levees, dams, and other man-made constructions have altered hydrologic flow, the impacts of saltwater inundation are already evident.

Invasive species

Invasive species are one of the many unknown factors that make bottomland hardwood forest management less predictable. There are risks associated with opening up a stand and increasing the potential for an influx of invasives. Many invasive species can take advantage of extreme climatic events such as hurricanes or floods which facilitate spread into new regions, decrease the resistance of native communities, and can put existing non-native species at a competitive disadvantage (Diez et al. 2012). For example, invasive species may be able to take advantage of increased sunlight in forest gaps faster than can native species. A study in Florida found that nearly 30 percent of the species regenerating after Hurricane Andrew were invasive and that invasive vines negatively affect the regeneration of native plants (Horvitz et al. 1998). Similarly, tufted knotweed (*Polygonum caespitosum*) and mile-a-minute weed (*Persicaria perfoliata*) were able to expand after Hurricane Isabel hit Maryland (though garlic mustard decreased because of the increased light) (Snitzer et al. 2005). Chinese tallow tree (*Triadica sebifera*) is a particularly pernicious invader of bottomland hardwood forests (Wang 2014). Unfortunately, the list of major invasive plants in the Southeast is long and includes mimosa trees (*Albizia julibrissin*), kudzu (*Pueraria lobata*), Asian bittersweet (*Celastrus orbiculatus*), cogon grass (*Imperata cylindrica*), and Japanese stiltgrass (*Microstegium vimineum*) (Miller et al. 2010). A North Carolina-based contributor to this report highlighted the following invasive plant threats to bottomland hardwood forests in order of most to least aggravating as of spring 2016 (Bruce White, pers. comm. 2016):

- Chinese Privet (*Ligustrum sinense*)
- Japanese stiltgrass
- Multiflora rose (*Rosa multiflora*)
- Autumn Olive (*Eleagnus umbellata*)
- Wisteria (*Wisteria sinensis* and *Wisteria floribunda*)
- Bradford Pear (*Pyrus calleryana*)
- Tallow Tree/Popcorn Tree (*Traidisca sebifera*)

Additionally, a project contributor in Florida noted that camphor trees (*Cinnamomum camphora*) once found in plantations have escaped into creek bottoms and once there, are difficult to eradicate.

An invasive insect, the emerald ash borer (EAB) also threatens ash trees throughout the southeast (Poland and McCullough 2006). EAB is rapidly spreading and poses a future threat to ash trees. It has been found in Arkansas, Louisiana, Georgia, Tennessee, North Carolina, and Virginia. EAB will have a bigger impact on communities where ash makes up a larger proportion of trees. There are concerns about red river bottoms around the Roanoke and Neuse Rivers. In the Mississippi River Valley, it is common for ten percent of the bottomland forest to be ash, and the loss of these trees would impact ecosystem services such as flood control, wildlife habitat and food sources, as well as timber values; ash logs can be nearly as valuable as oak. Meanwhile, laurel wilt threatens redbay, spicebush and sassafras, all of which can be found in bottomlands, as a contributor noted. Redbay are important to a number of wildlife species, and laurel wilt additionally threatens the existence of two rare plant species in North Carolina, pondspice and pondberry (North Carolina Forest Service 2016). A contributor commented that in Florida, redbay trees may not be around much longer.

The most destructive invasive mammals in bottomland hardwood are feral hogs (*Sus scrofa*). Hogs prefer forested, wet areas with dense cover and hard mast food sources, which makes bottomland hardwood forests ideal habitat (Giuliano 2005). Not only do feral hogs change forest composition by eating seeds and acorns, killing saplings, and affecting soil structure, but, in addition, they can facilitate invasion of Chinese tallow tree

(Siemann et al 2009). Feral hogs can also negatively impact water quality and other ecosystem services (Kaller et al 2007). Another destructive mammal in bottomlands is the beaver. Several report contributors and field forum participants noted the damage to individual trees and more significantly, to the hydrologic flow in bottomlands.

Upland silviculture in bottomlands

While not documented in the scientific literature, several contributors to this report noted that foresters are commonly trained in upland silviculture often geared toward production and plantations. As one project contributor explained, "Forestry schools advocate even-aged management as not just cost-efficient, but ecologically efficient because it regenerates trees that are shade-intolerant." However, the natural disturbance regimes, ecosystem dynamics, and regeneration needs of upland forest communities differ from those characteristic of bottomland hardwood forests; the silvicultural approach to bottomland systems should also be different. Silvicultural guidelines and operational considerations for bottomland hardwood forests are addressed in the next sections of this report.


Amanda Mahaffey

Future direction

Land conversion, changing economic pressures, altered climate patterns, and disruptive invasive species are all increasing the threat to the sustainability of bottomland hardwoods. Closer examination of these and other threats can help land managers establish realistic goals and benchmarks for the future success of these ecosystems. Active stewardship and the time-honored tool of silviculture provide an opportunity to mitigate some of these threats and increase forest resilience. This document will ideally aid foresters in on-the-ground management decisions. Beyond the scope of this document, opportunities abound for foresters and allied professionals in natural resources and conservation to take a landscape view and collaboratively strive toward a brighter future for bottomland hardwood forests.

General Guidelines for Bottomland Hardwoods

This section outlines some general management guidelines applicable to most bottomland hardwood forest types across the Southeast. This section considers silviculture, harvesting and operations, impacts to hydrology, wildlife, site considerations to protect rare forest species, economic goals, and climate change adaptation. The next major section explores considerations for specific bottomland types.

Silviculture

In the *Resources* section, more background on silviculture and bottomland hardwoods in the Southeast can be found. This report summarizes key information; however, we invite our readers to explore these excellent additional resources.

Silviculture, the art and science of forest management, requires knowledge of site properties, stand history, silvics, successional patterns, and many other factors to be successfully applied to bottomland hardwood forests. While these principles are well known to foresters, it is worthwhile to revisit them through the lens of bottomland hardwood forest ecosystems.

Development of a silvicultural prescription for a stand begins with an evaluation of the site and its potential to grow desired tree species. What species are suited to the site? How is this best determined? The current tree species composition tells only part of the story, especially in stands that have been high-graded in the past (Rousseau 2009). Bottomland hardwood forest ecosystems are dynamic, and suitable tree species for a site can change as rapidly as the flow of water or settling of soils. A well-known method of site evaluation was developed by Baker and Broadfoot in the late 1970s and can be summarized as follows (Baker and Broadfoot 1977, 1979):

1. Determine the site quality rating for a particular species by matching the soil-site conditions at your site to the tables in the Baker-Broadfoot guides. These tables capture the major soil factors of physical condition, growing season moisture availability, nutrient availability, and aeration.
2. Determine which of the four major factors limits growth.
3. Estimate productivity at each stage of development.

The Baker-Broadfoot method was developed for 14 hardwood species, including eight species of oak. Even for species not captured in this method, site evaluation should include an assessment of the four major soil factors identified above. Generally speaking, better hardwood sites will have deep, loamy soils with good moisture availability and soil aeration (Rousseau 2009).

Site evaluation should consider the silvics of the species present and the conditions that may be favorable to desirable tree species before and after harvest, including flood and shade tolerances. Tables with such information can be found in the appendices of the U.S. Geological Survey/USDA Forest Service publication, *A Guide to Bottomland Hardwood Restoration* (Allen et al. 2004). Site evaluation should also include an examination of the stand's hydrology and the impacts any changes may have on seed dispersal.

Manuel and others developed a decision-making model to help choose between regeneration and continued management of a stand. In this model, expert foresters examined the stocking level, tree quality and vigor, ownership objectives, and associated factors to determine a manage-or-regenerate threshold (Manuel et al. 1993). While the equations for this model may best fit the study area in Mississippi, a universal lesson is for foresters to assess the landowner's objectives in combination with the quality of sawlog growing stock trees in terms of species class desirability, crown class dominance, merchantable height, butt log grade, and vigor. High-quality stands may be managed, while poor quality stands may be regenerated.

Regeneration treatments

Natural regeneration may not be simple, but it requires less labor than afforestation methods in establishing a future stand. Anecdotally, foresters have expressed that artificial regeneration should be a last resort. However, alternative methods (i.e. planting or seeding) may be needed on sites that have become too degraded or in which a significant shift in species composition is desired. Stanturf and Meadows devised a prediction model to help determine whether sufficient natural regeneration potential exists; the model involves sampling pre-harvest plots and assigning points to stems of various height classes (Stanturf and Meadows 1994). Allen et al. cite a general rule of thumb that natural regeneration will be most successful within two canopy tree-lengths of the existing adjacent mature forest (Allen et al. 2004).

Rousseau (2009) outlines fundamental steps for determining the appropriate silvicultural treatment for bottomland hardwood forest stands. Successful regeneration of a stand requires a seed source, timing the harvest with a seed crop, and appropriate light and hydrologic conditions. If one of these factors is missing, it should be addressed in the pre-harvest preparation. If no seed source is present, planting may be necessary. If a desired species is present, time operations to coincide with a "bumper crop" of seeds. If advanced regeneration is present but shaded, treat or remove competing stems to reduce competition for light. Many bottomland species depend on abundant sunlight for successful regeneration. Consider opportunities for reproduction from sprouts or coppice, especially in Coastal Plain bottomlands. Finally, select a silvicultural treatment based on the species being regenerated (Rousseau 2009). A contributor in North Carolina recommended requiring stumps to be cut low and cleanly to prevent suppression by pre-merchantable stems, and to cut in fall or winter months to maximize sprout vigor. The approaches outlined here can be applied to any bottomland hardwood forest. If unfamiliar with the silvics of a particular species, numerous texts can help provide the necessary background on species requirements.

Hicks and others have captured silvicultural strategies applicable to southern bottomland hardwood forests (Hicks et al. 2004). Widespread high grading in its various forms has shifted the species composition in bottomland hardwood forests toward less-desirable trees; each entry removes the high-quality stems and decreases the economic and ecological value. Restoring ecological function and economic value go hand in hand; properly-implemented silvicultural treatments will maintain natural hydrologic patterns and result in larger, older, more valuable trees that benefit wildlife. The following treatments as described by Hicks and colleagues offer a continuum of silvicultural treatments across a scale of intensity, describing the costs and benefits of each step in the spectrum (2004).

Figure 7 Silvicultural strategies for southern bottomland hardwood forests per Hicks and others

Silvicultural Treatment	Advantages	Disadvantages
Clearcut An even-aged regeneration system in which essentially all the trees in a stand are removed in a single entry. Regeneration may derive from sprouts, advanced regeneration, or seedling reproduction. Shade-intolerant species show fastest initial growth.	(+) Relatively simple to implement operationally (+) Often effective way to "restart" degraded stands with a more desirable species mix (+) Treatment area of 20 acres can balance silvicultural and aesthetic goals	(-) Visual impact (-) Significant alteration to wildlife habitat (-) Potential alteration of hydrologic patterns (-) Great variation in minimum economically-viable clearcut size
Patch clearcut Clearcuts implemented in noncontiguous patches approximately two to five acres in size. Edges limit growth of shade-intolerant trees.	(+) Less visually intrusive than a full clearcut	(-) Requires frequent stand entry (-) May not create optimal wildlife habitat
Shelterwood cut An even-aged regeneration method that reduces the overstory canopy by approximately 50 percent in the first entry and completely within ten years. The high shade that results favors more shade-tolerant seedlings and sprouts.	(+) Less hydrologic alteration (+) In some systems, can be effective for oak regeneration	(-) Appropriate harvesting equipment and operator care are required to implement treatment with minimal disturbance to the residual stand
Seed-tree cut Seed-tree regeneration cuts involve the removal of all but a few trees retained for seed source. Favors light-seeded species establishment.	(+) Seed trees provide wildlife, ecological, and aesthetic values	(-) Most trees in floodplain systems regenerate successfully through means other than gravity-borne seed dispersal (i.e. sprouts, dispersal via water or fauna)
Two-aged system Also called leave-tree cutting, but still considered an even-aged regeneration system. 20-30 square feet per acre of basal area are retained until the end of the following rotation; at that time, 75 percent of the basal area of the regenerated stand is removed along with the leave trees.	(+) An overstory is present through all stages of stand development (+) Crop trees can be retained for the next cutting cycle (+) Requires relatively few entries on wet sites	(-) Leave trees are vulnerable to windthrow and epicormic branching
Group selection This uneven-aged regeneration treatment involves the removal of desirable and undesirable trees of similar age, size, or species within a 0.25-3.0-acre area. Similar to patch clearcuts, but with smaller holes in the canopy.	(+) Limited visual impact (+) Retained forest structure benefits wildlife	(-) Frequent entries may be impractical to implement and/or damaging to sensitive soils (-) May not favor desired shade-intolerant or mid-tolerant species
Single-tree selection Removal of individual trees in a stand to provide growing space for uneven-aged regeneration. Favors shade-tolerant species.	(+) Visually non-intrusive (+) Retained forest structure benefits some wildlife species	(-) Very difficult to apply in practice without increasing potential site damage (-) Often results in a selective or diameter-limit cut

Meadows and Stanturf (1997) highlight additional recommendations for choosing the appropriate silvicultural treatment. Clearcutting has proven successful in regenerating bottomland oak species. Shelterwood cuts can benefit heavy-seeded species under the right conditions. Patch clearcutting allows sufficient light to reach the forest floor to support shade-intolerant species establishment. Intermediate treatments should be part of a silvicultural plan to help ensure the success of the regeneration favored in the initial entry. The table below (Figure 8) is reproduced from this publication and summarizes silvicultural recommendations for eight major species groups in southern bottomland hardwood forests in the Gulf States.

Species Association and Site Preference	Silvicultural System	Species Favored
Cottonwood Front (new land) in major bottoms	Seed tree with site preparation	Eastern cottonwood
	Clearcut	Sycamore, sweet pecan, green ash, boxelder
Black willow Bar (new land) in major bottoms	Seed tree with site preparation	Black willow
	Clearcut	Sugarberry, green ash, baldcypress, American elm, overcup oak, bitter pecan, Nuttall oak
Cypress-water tupelo Swamp in major bottoms; slough in minor bottoms	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 in major bottoms	Group selection or clearcut	Sweetgum, red oaks[1], sycamore, sweet pecan, sugarberry, green ash
Elm-ash-sugarberry Wide flats in major bottoms	Clearcut or group selection	Elm, green ash, sugarberry, Nuttall oak, willow oak
Sweetgum-red oaks Ridges in major bottoms; high flats in minor bottoms	Patch clearcut	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] Second bottoms, high ridges in major bottoms; terrace in minor bottoms	Shelterwood or group selection	Red oaks, white oaks, hickory, green ash, sweetgum, American hornbeam
Overcup oak-bitter pecan Low flats, sloughs in major bottoms; flats in minor bottoms	Group selection	Overcup oak, bitter pecan
	Shelterwood	Overcup oak, bitter pecan, Nuttall oak, green ash

Figure 8 Silvicutural systems favoring bottomland hardwood species per Meadows and Stanturf.

[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.

Zander Evans

It is important to note that the method of partial harvesting is not included in these descriptions (Figure 8). To some, the term, "partial harvest" refers to the practice of "taking the best and leaving the rest," also known as high grading. Silviculturally, partial harvesting describes the practice of removing only part of a stand for purposes other than regeneration and is commonly interchanged with the general term, "selective cutting," not to be confused with group selection and other selection methods. In the hydrologic literature, the term "partial harvest" may describe a stand in which only some of the trees were removed, but without specificity as to the silvicultural benefit. "Single-tree selection," when applied in a commercial sense and not silviculturally, can result in selective cutting in its worst form, high grading. Proper single-tree selection is appropriate only for favoring shade-tolerant species over time unless efforts are successful to control shade-tolerant trees to benefit the shade-intolerant trees. The bottom line for bottomland hardwoods is that appropriately applied silviculture can enhance a forest stand.

The silvicultural treatments described above are part of the story of forest management decision-making. This information should be used in combination with site assessment and serious consideration of the impacts of harvesting operations to soils and hydrology as outlined in the section, *Harvesting operations and hydrologic impacts*. For instance, lighter treatments such as group selection or single-tree selection may require more frequent entries with heavy equipment, increasing the potential for damage to the residual stand. Appropriate harvesting equipment and operator care are required to protect the residual stand during harvesting operations.

Intermediate treatments

The Lower Mississippi Alluvial Valley currently supports pulpwood markets that make it economically feasible to conduct intermediate silvicultural treatments; in fact, intermediate treatments were described by contributors to this report as being far more common than even-aged silviculture. Intermediate treatments common to the Lower Mississippi Alluvial Valley include thinnings as well as single-tree combined with small group selection designed to increase light on the forest floor for advanced regeneration and re-allocate growing space to higher-quality hardwood stems. These intermediate treatments allow a land manager to manipulate the stand to improve species diversity, improve understory and midstory diversity and density, increase structural diversity, improve diameter distribution, provide gaps of early successional vegetation, and other measures that enhance the stand. Intermediate treatments also allow a landowner to receive income between establishment and final harvest. The structural conditions created by intermediate treatments are also conducive to wildlife (see *Biodiversity* section below).

Intermediate treatments may not be economically feasible everywhere today in the southern United States, but their benefits are worth considering in the spectrum of management options for bottomland hardwood forests. As one contributor articulated:

"In southern hardwoods, thinnings often become economically feasible at about 30-50 years in an even-aged stand, with a thinning repeated every 10-15 years until rotation harvest at 60-100 years. Good practitioners always use improvement thinnings to achieve the landowner's objectives. Periodic thinnings in both even- and uneven-aged systems provide periodic income to the landowner and cannot be ignored. The intermediate treatments provide land managers with the opportunity to use the culture in silviculture to shape the stand into the desired condition to provide the future benefits being managed for. Growth in timber volume and value, wildlife habitat, and other objectives can be significantly increased with application of improvement thinnings over the life of a stand."

Silvicultural Treatment	Advantages	Disadvantages
Intermediate thinning	(+) Provides periodic economic income (+) Enhances wildlife habitat (+) Increases growth rates of timber and value	(-) Requires expertise to pan and implement (-) Appropriate harvesting equipment and operator care are required to minimize damage to residual stand and site

Figure 9 Intermediate treatments for bottomland hardwood forests as supported by Denman and Karnuth 2005 and Meadows and Goelz 2005.

Field forum participants indicated that intermediate treatments are not currently highly economically feasible in Georgia or North Carolina. At present, many parts of the Southeast lack the logging equipment and experienced operators. To make intermediate treatments feasible there would be a need to mark the trees, and the returns from harvest alone would not justify the cost intermediate treatments. There were also concerns that crop trees may succumb to disturbance or logging damage. At the same time, consideration might be given to intermediate treatments via a hack-and-squirt (an herbicide treatment) operation to reduce competition.

Prescription Design

Silvicultural prescriptions for bottomland hardwood forests should reflect the proper application of a regeneration method and intermediate treatments based upon the landowner objectives, site productivity, current stand conditions, and silvics. The natural disturbance patterns in bottomland hardwood systems are perhaps better mimicked by uneven-aged rather than even-aged management, as bottomland disturbance patterns tended to create small gaps rather than regenerating whole stands. Several report contributors commented that even-aged systems may be more appropriate to pine upland silviculture, perhaps in part because it is the dominate management system in the region and often garners more attention in forestry schools.

The theme of sunlight was prevalent in the field forums and contributor comments: in sum, good silviculture in bottomland hardwood forests manipulates the sunlight to appropriately release advance regeneration and reallocate growing space to desirable trees. Maintaining a diversity of species – not only merchantable trees – facilitates the maintenance of diverse forests structures and age classes and products. A diverse silvicultural strategy can be reflected in the diversity of the forest landscape.

Restoration

When setting a goal of restoration, it is important to consider a few fundamental questions: What are you trying to restore? Structure? Ecological functions? Human values such as pre-settlement conditions? What are the costs and benefits of the available treatment options, and how well will they help achieve your restoration goals? If restoring to a point in time, what point in time in these dynamic bottomland hardwood forest ecosystems? What will you do about climate change and invasives? How will you ensure that the system will sustain itself after your management action? Many field forum participants felt that the key to restoration of a bottomland hardwood forest is the restoration of its natural hydrologic functions.

Restoration of bottomland hardwood systems can often be achieved through silvicultural methods with a focus on natural regeneration. In many situations, however, additional steps such as chemical site preparation and planting may be required to achieve the objectives for a stand. For instance, intermediate treatments as described above can help restore the functionality of bottomland hardwood forest ecosystems. Additionally, direct seeding of oak acorns may be an economically feasible alternative to planting seedlings (Bullard et al. 1992). One report contributor, however, noted that direct seeding can be highly unpredictable. Seed source and dispersal are critical factors in securing natural regeneration. An excellent resource for managers interested in restoring these ecosystems is the 2004 U.S. Geological Survey and USDA Forest Service joint publication, *A Guide to Bottomland Hardwood Restoration*.

As described in previous sections, bottomland hardwood forests throughout the Southeast and Lower Mississippi Alluvial Valley have been degraded over time due to fragmentation, conversion, high grading, and other factors. There is growing interest in restoring the ecological integrity of these ecosystems and in bringing species composition, vertical and horizontal structure, and stand successional and hydrologic patterns back in tune with natural dynamics, as well as with economic sustainability. While the exact balance of economy, ecology, and community needs varies across the region, the opportunity for restorative action is great.

Harvesting operations and hydrologic impacts

This section describes general guidelines for harvesting and operations in bottomland hardwood forests.

Timber harvests in wetlands should extract products while minimizing negative impacts to the bottomland forest ecosystem (North Carolina Forest Service 2006). Because hydrology drives the ecology of bottomland hardwood forests, a central goal in harvesting and operations is to minimize disturbance to natural hydrologic processes. Maintaining hydrologic flow increases the likelihood of securing viable natural regeneration; as one field forum participant articulated, "Poor drainage is a silent killer. Stagnant, hot water can prevent desirable regeneration on a site." Another contributor noted, "Late spring and early summer is the worst time for bottomland species encountering impounded conditions because the impounded water temperature increases, which impedes seed germination, sprout regeneration and plant growth."

Pre-harvest planning should include an examination of the stand's hydrology before, during, and after timber harvest; seasonally; and across multiple years. How does water currently flow through the stand? How might water flow be affected by road construction and other alterations to microsite topography? How might seasonal rains or dry spells affect the flow of water and the dispersal of seeds? How can long-term resilience be factored into alteration of the hydrologic system during harvest operations? Many bottomland species depend on water for seed dispersal; sustaining the natural flow of water is critical to the viability of these species. On some poorly drained sites with limited hydrologic flow, harvesting can compact the soil and make conditions wetter after logging by removing the "natural water pumps."

Timber harvesting in forested wetlands inevitably involves the implementation of Best Management Practices (BMPs) and other measures to protect water quality and soil stability during and after harvest. Links to state BMPs are available in the *Resources* section at the end of this report. Evidence suggests that water quality seems to be protected where BMPs are followed (Sun et al. 2001); however, there is a need to more closely examine factors such as the influence of logging roads on hydroperiod, vegetation productivity, and nutrient cycling (Lockaby 1997). The North Carolina BMP manual lists several practices that can help minimize alterations to hydrologic functions in bottomland hardwood forests, including:

- Work with loggers to plan your harvest and minimize activity in sensitive or exceptionally wet areas.
- Consider laying a temporary shovel-mat trail and employing shove logging techniques to help protect soil structure.
- Concentrate heavy equipment on primary skid trails.
- Protect ditchbanks and ephemeral streambanks.
- Avoid crossing streams wherever possible.
- Where intensive soil disturbance does occur, rehabilitate the soil structure using ripping or tilling without converting wetland to non-wetland.

Additional tips from our contributors for protecting hydrologic function during timber harvest include:

- Consider not harvesting in areas where hydrologic conditions may be altered, impeded or generally made worse.
- Harvesting during dry periods may reduce damage to soil and equipment, and diminish hydrologic impacts. In the Southeast Coastal Plain, the spring may offer dry periods. In the Lower Mississippi Alluvial Valley, autumn (generally August through November) is typically the driest and most reliable to time to harvest.
- The use of shovels will clean out crossings better than conventional equipment.
- Use harvesting equipment built on high-flotation tires to help distribute the weight and reduce soil compaction.
- Assess downstream potential for impact from a harvest.
- Put in culverts, dips, bridges, or box culverts in roads to enable water flow.
- Build in fencing features around culverts and drainage areas to prevent backup of logging slash and debris.
- Harvest smaller areas. Larger harvests inhibit evapotranspiration through trees on a larger scale and create more inundation and saturation on the site; i.e. the pump is removed.
- Maintain residual trees and canopy cover in lower-elevation drainage areas, and buffer these areas outside the harvest. This provides seed source and protects hydrologic functions.

Relatively inexpensive methods can be used to roughly assess changes in hydrology before and after harvest. Where possible, use LIDAR imagery and consult with hydrologists as needed. Foresters can observe the shallow ground water levels using a manual dipstick well and evaluate water table depth weekly or biweekly. Cheap plastic rain gauges installed in open areas can help capture and assess local rainfall patterns over time. Photographs can help document vegetation, ponding, and surface runoff. Foresters should also note the acres, age, and species of trees harvested within a stand, as well as the proximity of the harvest area to the nearest defined stream; harvests near downstream outlet may have a higher impact than harvests higher in the watershed. Small, but consistent monitoring of site conditions including for pre-harvest period can provide valuable information to help minimize hydrologic impacts during and after a timber harvest compared to the pre-harvest conditions (Amatya pers. comm. 2016). "Most importantly" wrote a contributor, "don't allow harvest activities to block the natural flow of water!"

Some states' BMP guides could be enhanced with practices or guidelines that protect the hydrology of bottomland forests as much as the water quality. For instance, BMPs could address buffer layout in areas lacking defined stream channels, which is common in bottomlands. For example, Florida's Silviculture BMPs provide specific practices for harvesting in wetland flow-ways; a certain proportion of leave trees should be left along the center line or distributed throughout the site (Florida Forest Service 2008). It is also worth noting that while "upland bottomlands" (terraces) may not be considered jurisdictional wetland by the U.S. Army Corps of Engineers, the application of BMPs may be entirely appropriate to protect water quality, soil stability, and hydrologic flow. In the Southeast, "shovel logging" is used to describe a technique of laying logs in front of the feller-buncher to go deeper into the site and removing the trees on the way out. Specifications for shovel logging operations might include recommended trail layouts, opening sizes and shapes, and photos illustrating well-implemented practices. The Florida

Silviculture BMP manual details practices specific to shovel logging, including minimizing mats to less than 20 ft in width and 25 percent of the harvest area (Florida Forest Service 2008).

Following a timber harvest, it takes time for a hydrologic system to adapt to the new "normal." One study of hydrologic impacts following harvesting revealed changes in some of the biogeochemical properties one year after harvest (Lockaby et al. 1997). Another study in the same watershed suggested that partial harvest on an 8-hectare (20-acre) scale had minimal to minor effects on biogeochemistry for three years following harvest (Clawson et al. 1999). Another study in a tupelo-cypress swamp found conditions had nearly returned to those of the reference area 16 years after clearcut logging using skidder and helicopter (Gellerstedt and Aust 2004). Sun and others developed a conceptual model depicting the effects of forest management on hydrology in the southern U.S.; generally speaking, the wetter the topography (bottomland vs. upland) and climate (higher potential evapotranspiration, or PET), the smaller the hydrologic effects of forest management practices. Partial harvesting is depicted as the least hydrologically impactful of practices examined, with increasing impact across the spectrum of bedding, clear-cutting, and ditching (Sun et al. 2001). Wetlands in their natural state have high water storage capacity; however, human alterations and climate can impact hydrologic flow. For instance, soil compaction, rutting, and churning during wet-weather harvesting may be exacerbated by more intense and frequent weather events.

Biodiversity

Bottomland hardwood forests are incredibly rich in biodiversity ranging from microbes to flora to forest-dependent fauna. Bottomland hardwoods are important for a variety of wildlife species, and hunting and other recreation-linked wildlife can be key source of income or reason to own bottomland forests (Hussain et al. 2007; Ober 2016). One contributor to this report estimated hunting lease values in the Lower Mississippi Alluvial Valley at approximately $30 per acre in bottomland hardwood forests versus $10-12 per acre for pinelands. Therefore, managing forests for wildlife can also help achieve additional objectives. For example, management that encourages various-sized canopy gaps provides for a wide gradient of light reaching the forest floor, which in turn produces a complex understory and midstory utilized for browse, nesting cover, escape cover, etc. by native wildlife. Management that encourages mast oaks also provides acorns, which are an important food resource for many different wildlife species. "Wildlife-forestry" practices, which are growing in popularity in the Lower Mississippi Alluvial Valley, refer to silvicultural treatments prescribed to enhance wildlife habitat by increasing structural diversity. Wildlife response may take five to eight years and should be reevaluated every 15 years (Twedt and Somershoe 2009). Clearcut shapes could follow natural contours. Managers could consider accelerating growth of future den trees for bears.

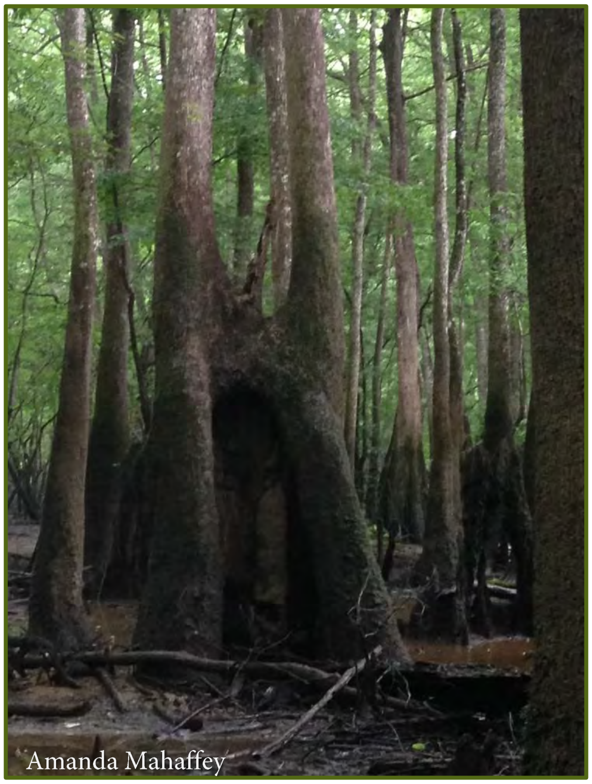
Many species of wildlife flourish in forests diverse in tree species and forest structures and age classes, especially forests in which large, older trees and frequent canopy gaps are common features (Twedt and Wilson 2007). The Lower Mississippi Valley Joint Venture Forest Resource Conservation Working Group recommends that on a landscape (10,000-ac) scale, it is recommended that approximately 70% of the landscape be managed using silviculture that benefits wildlife; of this proportion, regeneration harvests greater than seven acres should occupy less than 10% of the landscape, and approximately 5% of the area should be in early successional habitat. The remainder of the landscape would ideally be unmanaged. Within managed stands, silvicultural prescriptions can benefit wildlife by (1) reducing basal area and tree stocking, recognizing that the forest will regrow quickly; (2) enhancing or creating multi-layered canopies; (3) increasing midstory development; and (4) promoting the development and retention of dominant trees, large-cavity trees, an understory that includes shade-intolerant regeneration. The report includes targets for desired stand conditions to benefit wildlife in forest metrics including overstory canopy cover of 60-70%, 60-70 ft^2/ac BA with at least 25% in older age classes, 60-70% stocking, and midstory and understory cover each at 25-40%, as well as metrics for coarse woody debris and cavity trees (LMVJV Forest Resource Working Group 2007).

Snags, or standing dead trees, play an ecologically significant role in forest ecosystems and can be seen as flagships of biodiversity within a stand. Snags in bottomland hardwood forests, particularly large-diameter oak snags, are important habitat for woodpeckers (Conner et al. 1994, Shackelford and Conner 1997). Trees 36 inches in diameter or greater with visible cavities should be retained in cypress swamps to provide den sites for black bears (LASAF 2015). A study of snag retention in bottomland hardwood forests found that while partial harvesting did not significantly affect snag density, cumulative mortality, or snag recruitment, clearcutting did affect these factors (Lockhart et al. 2010). The Forest Stewards Guild produced recommendations for retention of dead wood in southeastern forest in part to support wildlife (Forest Guild 2012; Evans 2011).

Bottomland hardwood communities provide crucial habitat for neotropical migrant and wintering nearctic birds in addition to year-round residents. The retention of microhabitat features such as Spanish moss, scour channels, canebreaks, and vine tangles are of especial importance to neotropical migratory birds (Pashley and Barrow 1993). One guide to bottomland hardwood management for non-game bird communities recommends harvesting timber as single tree or group tree cuts to mimic natural disturbance (Guilfoyle 2001). Another study notes the benefits to songbirds of small canopy gap sizes and uneven-aged management treatments; notably, diameter-limit cutting or high grading will over time be detrimental to migratory birds through changes in species composition (Pashley and Barrow 1993). To balance the needs of migratory forest songbirds, other wildlife species, economic pressures, and ecological values, communication must increase between professionals in these disciplines (Hamel et al. 2001).

RECOMMENDATIONS FOR SPECIFIC BOTTOMLAND FOREST SYSTEMS

This section addresses management recommendations specific to individual bottomland forest types; specifically red river bottoms, black river bottoms, and cypress swamps. Given the complexity and dynamic nature of bottomland hardwood forest ecosystems, it is safe to say that further research on silvicultural options for bottomland systems will always be welcomed.



Amanda Mahaffey

Conservation as a tool for management

Humans have altered the landscape of bottomland hardwood forests so severely that in some places and natural communities, the highest management priority may be protection through a working forest conservation easement or outright preservation, which would prevent development from claiming those acres. Atlantic white-cedar, for instance, is a globally threatened species susceptible to many of the threats to bottomland hardwood forests (Burke and Sheridan 2005). Carolina bays, pocosins, sweetgum-water oak forests, and cypress-tupelo swamps have also received recent attention as particularly sensitive or vulnerable natural community types (NRDC 2015, Enviva 2016). When considering managing a stand, it can be important to take a step back and consider conservation as a management option. Several field forum participants and report reviewers expressed a sentiment that if certain bottomland forests are left alone, they are more likely to return to natural succession dynamics than if managed too heavily.

Red river bottoms

On the time scale of forest development, red river bottoms are “a modern invention” resulting in part from erosion from land clearing for agriculture from the early 1800s onward, a process that dramatically altered bottomlands across the Southeast. Forests that grew on these soils were also later cleared for agriculture. Today, the well-drained loams and silt loams support a range of species dominated by sweetgum, ash, elm, and hackberry as well as water hickory, sycamore, red maple, river birch, willow oak, water oak, laurel oak, and overcup oak. In adjacent second bottoms where flooding is less frequent, species include cherrybark oak, swamp chestnut oak, hickories, American beech, and yellow-poplar (Shear et al 1997). As sediment continues to shift, so too do the hydrologic regimes and stand development patterns.

Red river bottoms are valued for their rich soils, which support a variety of oak and other commercially desirable species. To maintain these systems as forests, managers should take extra care to protect soil integrity during timber harvests outlined in the section above on harvesting operations and hydrologic impacts.

Harvesting a mature stand of hardwoods in red river bottoms will favor pioneer species such as sweetgum, sycamore, river birch, green ash, and red maple, even if oaks are present in the overstory. To promote oaks on these sites, plan for longer rotations to allow the shade- and mid-tolerant oaks to gain a competitive advantage. Consider silvicultural treatments such as shelterwood harvests or patch cuts (clearcuts less than five acres in size that maximize shade from edges). Bottomland red oaks given some direct sunlight during early stand development will eventually surpass other species (Lockhart 2005). Contributors to this report have similarly noted the seeming variation in shade tolerance of oak species in the various stages of development. Larger seedlings and stump sprouts in red oak and ash stems will likely compete better than smaller seedlings less than one foot in height (Belli et al. 1999). A project contributor commented that seedlings four feet in height have a chance. Creating openings while retaining shade and forest structure will help maintain hydrologic flow while promoting desired species. As always, consider seed source, existing stand composition and regeneration, and other factors to help ensure a successful harvest.

Black river bottoms

Black river bottoms are less studied than red river bottom systems, and there are differences between the two. Soils in black river bottoms originate in the coastal plain and are less nutrient-rich than those of red river systems. Black river bottoms are dominated by sweetgum, tupelo, red maple, red oaks, and a mix of other species. Similarly to red river bottoms, harvesting will favor pioneer species, and only by allowing sufficient time between harvests will shade-tolerant species become dominant.

Unlike oaks, tupelo reproduces well by coppice. Stands dominated by tupelo gum, swamp blackgum, cypress, Carolina ash, and similar species will regenerate largely by sprout origin. A study of water tupelo stands in Alabama showed that sprouts from stumps cut by chainsaw were significantly denser than sprouts from stumps felled mechanically with a tracked, swing feller (Gardiner et al. 2000). Techniques of cutting stumps low (10 to 14 inches) and harvesting while trees are dormant are also recommended for encouraging coppice (USGS and USFS 2004). Group selection is recommended by Meadows and Stanturf for regenerating stands that include sweetgum or water tupelo (1997). A contributor to this report noted that in practice, larger groups may be needed to regenerate such stands.

Further study is needed of the economics of timber harvesting in black river bottoms. Anecdotally, a recent timber harvest in a black river bottom was found to be operational at 40 acres of harvest with a minimum of two loads per acre in a shovel-logging operation. Exact operational acres will vary. Future research might examine silvicultural and harvesting equipment combinations that produce desires stand conditions in an economically feasible timber harvest.

Cypress swamps

While cypress trees are considered conifers, their management and significance are worth consideration in a report on bottomland hardwood forest management in the Southeast. A 2012 report highlights the need to ensure cypress sustainability in Georgia's forests that echoes many of the themes for bottomland hardwood forests. Among the concerns is a misconception that cypress regenerate successfully from stump sprouts; in fact, seed regeneration and supplemental planting are preferred (Fabrizio et al. 2012). The Louisiana Society of American Foresters corroborates this in a comprehensive report produced in 2015 on sustainable cypress management. This report provides a wealth of information on classifying cypress stands according to sustainability categories and treating stands appropriately. Where natural regeneration is viable, group selection or whole stand clearcuts are recommended, while seed tree and shelterwood treatments are optional but potentially less operationally feasible (LASAF 2015). A report contributor noted the difficulty in having the right combination of conditions to obtain cypress seed regeneration, including a dry period during germination and early growth; these factors that can determine the success of cypress seedlings are not under our control, but are critical to monitor.

Cypress has been described as "down on its luck," and further action will be needed to ensure the viability of cypress and other bottomland forest ecosystems. As one workshop participant expressed, "If ever it's out there and I think it's got a chance, I want to help it."


Zander Evans


Zander Evans

Actions

- BMPs in some states could focus better on hydrology more than the water quality; protecting hydrologic function protects water quality (perhaps moreso in black versus red river bottomlands). Hydrology determines regen establishment. BMPs could be developed specific to maintaining hydrologic function in bottomland hardwoods versus pine sites. Future BMPs could also include practices specific to shovel-logging; see Florida BMPs for examples.

- Convince land managers to conduct a site assessment prior to beginning any operations. Train foresters how to evaluate a stand and determine whether it should be regenerated or not. Advance the recognition that if you have a really mature stand, it may be better to let it be. Increase appreciation of genuine virgin cypress forest because there's not much of it left.

- Evaluate stands to determine whether it should be cut or not to achieve the landowner's objectives. Advance the recognition that if there is a really mature stand, management options to achieve the landowner's objectives can be wide and varied, and need not automatically recommend a commercial timber harvest in the near future.

- The average forester can (1) learn how to better evaluate what they have on the site; and (2) break the misconception that the best approach is to clearcut bottomland hardwood stands in the odd dry year.

- Partner with universities to get students out in the woods learning about bottomland hardwood management. Get professionals out, too! Create teaching units on silviculture and harvesting operations specific to bottomland forests.

- Continue exploring carbon markets. Carbon estimates modeled for bottomland hardwood stands in the Lower Mississippi River Valley were higher than regional estimates used by the U.S. Department of Energy (Shoch et al. 2009).

- Continue exploring payments for ecosystem services. Little has been proven for bottomland hardwood forests of the Southeast; however, a recent study of McIntosh County, Georgia showed that (1) forested wetlands show very high ecosystem service values; (2) compared to residential property, forests contribute rather than absorb services; and (3) ecosystem services and values could be protected by restricting new development in the 500-year floodplain (Schmidt et al. 2014).

- Consider exploring markets for low-grade wood products to inspire investment in lighter logging equipment.

- Where feasible, time bottomland harvests with upland pine harvests to make operations more economically viable overall. Or, use the returns from upland management to conduct harvesting operations in bottomlands.

- Explore options for managing bottomland hardwood forests in the Southeast using “wildlife-forestry” principles to build an ecologically and economically sustainable base for hunting lease income for landowners.

- Educate non-industrial private woodland owners about the beauty of this valuable resource and the importance of protecting its ecological integrity through thoughtful forest management planning.

- Explore the creation of incentive programs for bottomland management. Think about the longleaf pine movement now as an example of how a monetary incentive can encourage landowners to manage bottomland hardwood forests with ecological forestry practices or conservation as appropriate.

Resources and References

Resources

State Best Management Practices

- Alabama's Best Management Practices for Forestry www.forestry.state.al.us/BMPs.aspx
- Arkansas Best Management Practices www.arnatural.org/forestry/bmps.htm
- Florida Silviculture Best Management Practices www.fl-dof.com/forest_management/bmp/index.html
- Georgia Best Management Practices www.gfc.state.ga.us/forestmanagement/bmp.cfm
- Kentucky Forest Practice Guidelines for Water Quality Management www.ca.uky.edu/forestryextension/Publications/FOR_FORFS/FOR67.pdf
- Field Guide to Best Management Practices for Timber Harvesting in Kentucky www.ca.uky.edu/forestryextension/Publications/FOR_FORFS/FOR69.pdf
- Recommended Forestry Best Management Practices for Louisiana www.ldaf.state.la.us/portal/Portals/0/FOR/for%20mgmt/BMP.pdf
- Guidelines for Practicing Forest Environmental Enhancement in Louisiana www.ldaf.state.la.us/portal/Portals/0/FOR/for%20mgmt/BMP.pdf
- North Carolina Best Management Practices ncforestservice.gov/water_quality/bmp_manual.htm
- Oklahoma Best Management Practices Guidelines www.forestry.ok.gov/waterqualitybmp
- South Carolina Best Management Practices www.state.sc.us/forest/refbmp.htm
- Tennessee Forestry Best Management Practices www.tn.gov/agriculture/forestry/bmps.shtml
- Texas Forestry Best Management Practices txforestservice.tamu.edu/main/article.aspx?id=14536
- Virginia's Forestry Best Management Practices for Water Quality www.dof.virginia.gov/wq/resources/ManualBMP/2011_Manual_BMP.pdf
- West Virginia Silvicultural Best Management Practices for Controlling Soil Erosion and Sedimentation from Logging Operations www.wvforestry.com/BMP%20Book%202009.pdf

Extension offices & publications

- Regenerating Hardwoods in Mississippi – Department of Forestry, Mississippi State University http://extension.msstate.edu/sites/default/files/publications/publications/p2470.pdf
- Bottomland Hardwood Management – Mississippi State University Extension Service http://extension.msstate.edu/sites/default/files/publications/publications/p2004_1.pdf
- Forest management in bottomland hardwoods – Louisiana Department of Wildlife and Fisheries www.wlf.louisiana.gov/sites/default/files/pdf/publication/34723-forest-management-bh-low-res/forest_management_in_bh_low-res.pdf

USDA Forest Service resources

- Southern Hardwood Forest Management – U.S.D.A. Forest Service
  http://web.extension.illinois.edu/forestry/publications/pdf/forest_management/USFS_Southern_Hardwood_Mgmt.pdf
- A Guide to Bottomland Hardwood Restoration – USDI, USGS, USDA Forest Service
  www.nwrc.usgs.gov/wdb/pub/diglib/bottomland_hardwood.htm

Forest Stewards Guild Reports

- Forests to Faucets: Protecting upstream forests for clean water downstream
  http://forestguild.org/publications/research/2013/forests-to-faucets-report.pdf
- Forest Biomass Retention and Harvesting Guidelines for the Southeast
  http://www.forestguild.org/publications/research/2012/FG_Biomass_Guidelines_SE.pdf
- Biomass Supply and Carbon Accounting for Southeastern Forests
  http://www.southernenvironment.org/uploads/publications/biomass-carbon-study-FINAL.pdf
- Ecology of Dead Wood in the Southeast
  http://www.forestguild.org/publications/research/2011/ecology_of_dead_wood_SE.pdf

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