COMPOSITION, POTENTIAL OLD GROWTH, FRAGMENTATION, AND OWNERSHIP OF MISSISSIPPI ALLUVIAL VALLEY BOTTOMLAND HARDWOODS: A REGIONAL ASSESSMENT OF HISTORIC CHANGE

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Abstract—Recent Mississippi River Alluvial Valley (MAV) bottomland hardwood forest surveys revealed a larger proportion of intermittent flood zone (inundated 1 to 2 months), early successional (primarily hackberry-elm-ash), and permanent flood zone (inundated > 6 months annually, primarily baldcypress-water tupelo) community types than in the 1930s. For the same time period, these same surveys showed a smaller proportion of nonpermanent (inundated < 6 months), late-successional community types (overcup oak-water hickory and mixed bottomland hardwood) than in the 1930s. Sporadic flood zone (inundated < 1 month), shade-tolerant community types were less common in the MAV than elsewhere in the South-Central United States (Alabama, Arkansas, Louisiana, Mississippi, east Oklahoma, Tennessee, and east Texas). Most forests with old-growth conditions (site productivity-based minimum basal area, net growth near zero, and no recent commercial harvest activity) were in private ownership and characteristic of select community types. Findings were based on a reexamination of systematic sample-based forest surveys of the region. Annual change in bottomland hardwood area was diminishing (-1.1 percent, 1970s to 1980s; +0.3 percent, 1980s to 1990s), but the frequency of large (> 2,023 ha) forest fragments continued to decline (-2.4 percent, 1970s to 1980s; -4.0 percent, 1980s to 1990s). To reconstruct the historic mix of bottomland hardwood community types, renew forest cover, and retain or enhance associated resource values, this assessment suggests a primary focus on conserving large fragments, shifting nonpermanent flood zone, early successional community types toward late-successional types, and restoring occasional flooding regimes and forest cover adjacent to small remnant bottomland hardwood fragments.

INTRODUCTION

Nonforest cover represents the majority land use in the formerly extensive bottomland hardwood region known as the Mississippi Alluvial Valley (MAV). At present MAV forest communities contain no designated wilderness and few forest plantations. Yet the region's forest cover is comparatively roadless and more closely tied to hunting activities than other regions of the South-Central United States (Alabama, Arkansas, Louisiana, Mississippi, east Oklahoma, Tennessee, and east Texas) (Rudis 1998). Potential wood productivity of MAV forests is greatest among all regions of the South (Rudis 1998). Reforestation goals include timber production with economically valued species, but also the maintenance of threatened black bear and other forest-dependent wildlife populations and primitive recreation opportunities. Other goals include sequestering elemental carbon within species native to the region, conserving forested habitats and flooding regimes for indigenous plant and animal species, and improving water quality and other economically valued forest recreation like ecotourism. Attaching priority to these multiple goals requires an understanding of the region's historic bottomland hardwood communities and anthropogenic threats to current communities.

In the MAV, historic bottomland hardwood composition and old-growth (mature, stable forests unmodified by post-European settlement) forest conditions are not well documented. Bottomland hardwood forests in the MAV were almost certainly extensive, contiguous, undisturbed by modern anthropogenic uses, and a different mix of community types than found today.

The earliest systematic observations on record were from the 1800s Land Office, i.e., land surveyors' field notes of bearing, or witness, trees. Though not necessarily representative of all conditions, surveyors' accounts provide clues to former MAV forest composition. From one such account dated 1821 for West Feliciana, LA, Delcourt (1975) noted that surveyors referenced comparatively few witness trees in swampland. Nevertheless, in ravines and tributary stream bottoms, dominant witness trees were (southern) magnolia, (American) beech and (American) holly, with baldcypress and (water) tupelo in alluvial swamps. In 1975, the surveyed study area had only a few large (American) beech trees (Delcourt 1975). By the 1980s, modern-day surveys (McWilliams and Rosson 1990) reported none but baldcypress and water tupelo among the 14 species with ≥3 percent importance by volume for the MAV region.

Recent systematic, extensive area surveys noted that more than one-half of the 1930s MAV bottomland hardwood forest area has disappeared (McWilliams and Rosson 1990, Rudis and Birdsey 1986), and the majority area converted to agricultural uses (MacDonald and others 1979). A Yazoo River basin report (Anonymous 1944) noted in the 1940s that better drained floodplain forests were cleared first, followed by land clearing of poorly drained areas—a pattern likely repeated through the rest of the MAV. Following land clearing, subsequent agricultural improvements included drainage structure installation, nearby stream channelization, and changes to the regional flooding regime (Turner and others 1981). These changes fragmented bottomland hardwood forests with agricultural fields and roads and indirectly caused soil deposition and reforestation along new stream channels.

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Forests that are no longer contiguous may not sustain a region's existing mix of species and resources, nor improve selected desired resources, such as black bear habitat (Rudis and Tansey 1995) or primitive recreation opportunities (Rudis 1987). Sample-based inventories of forest fragments, i.e., contiguous forests $\geq$ 0.4 ha and unbroken by nonforest cover $\geq$ 37 m wide, noted significant associations by tree species (Rudis 1993), empirical community type and resource indicators for existing bottomland hardwood communities across the south-central region. These studies showed that the smaller the forest fragment, the more likely the forest was an early successional community characteristic of nonpermanent flood zones (inundated $<$ 6 months). The smaller the fragment, the more frequently it had anthropogenic intrusions, e.g., fences, evidence of livestock use, and rubbish, and the closer it was, on average, to developed roads and agricultural and urban land. The larger the fragment, the more likely the forest had evidence of hunting, and the more likely the sampled tree community was characteristic of a permanently wet community type (inundated $>$ 6 months). Fragment size was also directly associated with timber volume. The largest fragments were less likely to have evidence of harvest since the prior survey. These findings suggested that the potential for vegetation disturbance by land-use activities was inversely associated with fragment size. If old-growth conditions were typical of undisturbed conditions, then the probability of finding such conditions was greatest in the largest fragments.

OBJECTIVES AND METHODS

To test the hypothesis that nonpermanent flood zone, bottomland hardwood community types in the MAV were removed or otherwise altered, I summarized published community-type surveys since the 1930s and compiled associated data on forest fragment size and community types since the 1970s, and old growth by owner class for the most recent survey period.

Because community types before European settlement were poorly documented, I compared the current distribution of MAV bottomland hardwood community types with a surrogate for what might have existed from recent surveys for the entire South-Central United States. I also selected old-growth criteria compatible with available forest survey data to suggest the likely distribution of area in remnant old-growth condition by community type and ownership class.

Surveys from the Forest Inventory and Analysis Research Work Unit (FIA) of the U.S. Department of Agriculture Forest Service were the primary data sources. Detailed FIA bottomland hardwood community types for 1932–35 (Eldredge 1938; Stover 1942; Winters 1939a, 1939b; Winters and others 1938) were for a region roughly comparable to the MAV, including west Kentucky, southeast Missouri, and west Tennessee, but excluding southern Illinois. County boundaries in the delta survey units of Arkansas, Louisiana, and Mississippi (fig. 1) were the boundaries in subsequent survey reports (McWilliams and Rosson 1990, Rudis and Birdsey 1986, Sternitzke and Putnam 1956).

The early forest surveys reported summary findings with limited documentation compared to today. Nevertheless, such accounts embody the only detailed extensive area estimates by foresters of the time. Surveys from the 1930s through the 1960s used community-type estimates from systematic field observations and temporary plots (Frayer and Beltz 1985, Sternitzke and Putnam 1956). The FIA community types before the 1970s likely came from ocular estimation of dominant tree species. Between the 1970s and 1990s, FIA calculated community types from sampled tree species equidistant at 20-m intervals, $>$ 10 m inside forest edges at 10 points within a 0.4-ha plot area (5 points and a 0.2-ha area for Louisiana's 1984 survey). Observations were from permanent plots spaced 4.8 km apart that FIA classed as forested (land with $\geq$ 10 percent tree crown cover and land temporarily $<$ 10 percent tree crown cover not developed for other uses, $\geq$ 0.4 ha in size and $\geq$ 37 m wide).

Because the history of sampled areas is often unknown and forests have often been periodically disturbed, many sampled plots are classed as mixed-age class. A surrogate for age class is stand-diameter class, often referenced in timber resource reports as stand-size class, which is a classification of the height and size of trees. Stand-diameter classes are: sawtimber ($\geq$ 50-percent stocked with live trees

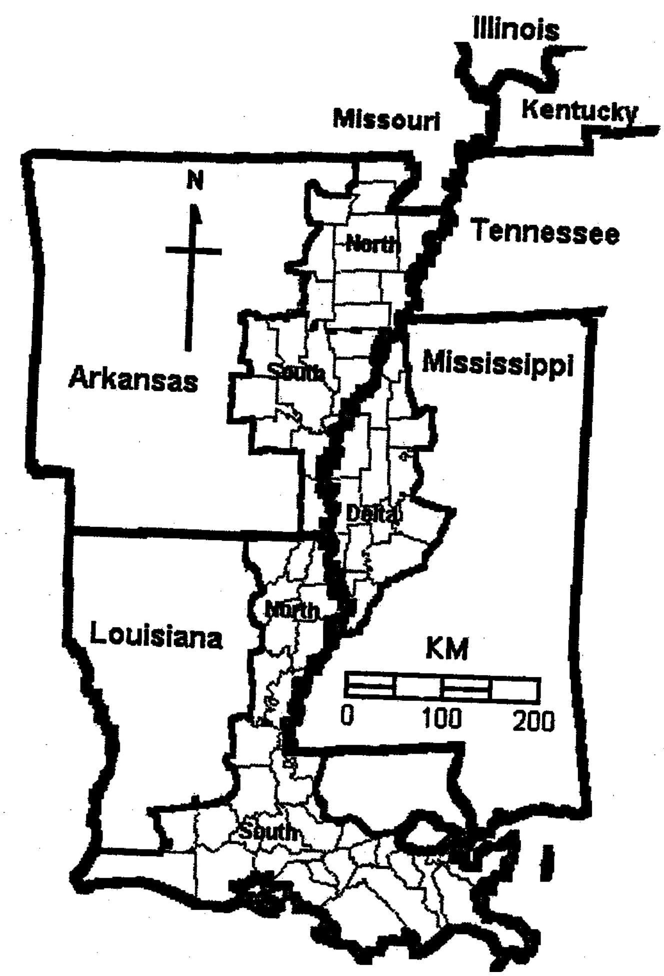

Figure 1—Counties in the Arkansas, Louisiana, and Mississippi Delta survey unit, Mississippi Alluvial Valley.

≥ 12.7 cm d.b.h. and ≥ 50-percent stocked with live trees ≥ 22.9 cm softwood, and ≥ 27.9 cm hardwoods; poletimber (≥ 50-percent stocked with live trees ≥ 12.7 cm, and < 50-percent stocked with sawtimber trees); and smaller (< 50-percent stocked with live trees < 12.7 cm).

This study examined only sampled plots characterized as bottomland-community type (< 25 percent pine stocking, judged by field crews to be in a wetland physiographic class, or having ≥ 50 percent overstory in bottomland species). Tree sampling recorded live tree stems ≥ 12.7 cm (1.4 m) d.b.h., on variable radius (8.6-m^2 factor) prism plots and live tree stems 2.5 to 12.6 cm on fixed (2.2-m radius) plots around three points. Additional details are provided elsewhere (Faulkner and others 1995, Rosson 1995, Rudis 1995).[2] Definitions for these and other common FIA terms are in the appendix.

Numerical FIA estimates are typically most reliable for a large proportion of the sampled population and least reliable for a smaller one. Louisiana's 1991 survey (Rosson 1995), for example, noted 67-percent confidence that a 502 000-ha estimate was within 5000 ha (1 percent of 502 000 ha) of the actual amount; and 67-percent confidence that an 810-ha estimate was within 200 ha (25 percent of 810 ha) of the actual amount. Because technology, field procedures, and forest-type estimation may change between surveys, care is advised in interpreting results. Shifts in forest-type area may be a result of procedural changes before 1974. Readers should refer to the original survey reports for further documentation. Because one cannot avoid procedural differences, caution is advised in concluding that forest-type classification, areal adjustments, and sample area expansion procedures are comparable to those used today.

Composition

I estimated the likelihood of finding forest land within a range of flood zones, shade tolerances, and empirical community types. This forest occurrence probability used forest-plot information on flood zone and shade tolerance selected at random for an approximately equal number of nonforest plots.

For forest plots, flood zone, shade tolerance, and community type were the dominant species by importance (average occurrence frequency, basal area, and number of stems per plot) value derived from trees tallied on sampled plots. Flood zone values were averaged by plot, with ordinal values assigned by species typical of flood zones inundated (1) permanently, (2) periodically, (3) intermittently, (4) sporadically, and (5) inundated only in wet years, after Wharton and others (1982). Shade tolerance values were averaged by plot, with ordinal values assigned by species as: (1) very tolerant, (2) tolerant, (3) intermediate, (4) intolerant, and (5) very intolerant, after Burns and Honkala (1990).

I cross-referenced these results with an earlier study of plots classed by ordinal flood zone and shade tolerance values for the South-Central United States. The earlier study (Rudis 1995) established 32 empirical community types for that region's 2,666 bottomland hardwood plots with distinctive and internally similar tree species importance. [The process employed hierarchical clustering to minimize the residual (error) sum of squares using FASTCLUS and Ward's method (SAS Institute Inc. 1990).]

For the MAV region, I used flood zone and shade tolerance estimates from the forest plots that occurred in the MAV (Rudis 1995). Because half of the region's bottomland hardwood forests had been cleared since the 1930s, I conservatively assumed that there was at least an equal area (represented by about an equal number of plots) of nonforest land today that was formerly in bottomland hardwood forests. I combined the sample of flood zone and shade-tolerance values from forested plots with the random array of values from nonforest plots to calculate occurrence probabilities. I also applied identical procedures to calculate occurrence probabilities for bottomland hardwood forests of the South-Central United States.

Occurrence probability was 1.00 (100 percent) at a flood zone and shade-tolerance location represented by a forested sample and 0.00 (0 percent) otherwise. G3GRID (SAS Institute Inc. 1991) generated grid patterns that afforded visual comparisons of forest occurrence probability distributions calculated from both regions. Grid patterns were interpolated linearly, between 0.00 and 1.00 in 0.02-percent increments, between flood zone 2, shade value 1 (permanently flooded, very shade tolerant) and flood zone 6, shade value 5 (inundated only in wet years, very shade intolerant). Occurrence probability was set to 0.00 for values outside that range.

Potential Old Growth

To date, no systematic survey of old-growth conditions has been attempted for the entire MAV. I estimated area of potential old growth from an *a posteriori* analysis of an existing database, namely sample-based FIA surveys. There is no one, widely agreed definition of old growth that one can generally accept from an *a posteriori* analysis. Unlike Frelich's (1995) reexamination of North-Central United States from FIA data, FIA surveys in the South-Central United States classed age as mixed if ≥ 2 strata with a > 10-year age difference existed. Other criteria used in old-growth assessments, i.e., a standing dead tree tally, live-to-dead tree ratio, and other disturbances (Devall and Rudis 1991), were not available for all plots.

I selected two types of old-growth criteria: one based on size, the second based on biological maturity. The first used the ratio of basal area of trees ≥ 50 cm diameter at 1.4 m (d.b.h.) divided by basal area of trees ≥ 12.7 cm d.b.h. to provide estimates of forest land with large trees. The second used three progressively restrictive biological maturity criteria designed to estimate forests: (1) likely to be old or mature, (2) having net growth approximately zero, and (3) having no recent harvest evidence. The first biologically mature criteria selected samples with basal area equal to or greater than that averaged for 45- to 65-year-old bottomland

[2] U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis Research Work Unit. 1993. Forest survey inventory work plan, Mississippi 1993-1994. 128 p. On file with USDA, Forest Service, Southern Research Station, P.O. Box 928, Starkville, MS 39760–0928.

hardwood forests. (Age and basal-area data came from the east Texas' 1986 forest survey. I used this region to characterize bottomland hardwood stand age, as that region used precise estimates from a special survey of dominant tree age.[3] Other States and years used 10-year and mixed age classes.) The second criterion selected samples with net growth (current minus past volume from the prior survey a decade earlier) close to zero. The third selected samples with no commercial harvest or cutting activity since the previous survey.

Fragmentation

Between 1974 and 1995, FIA surveys defined the areal extent, i.e., forest fragment size, associated with each 0.4-ha forested plot in south-central States as contiguous, $\geq$0.4 ha, unbroken by nonforest cover $\geq$37 m wide. Each forest fragment was inventoried by size class: 0.4 to 4; 5 to 20; 21 to 40; 41 to 202; 203 to 1012; 1013 to 2023; and $\geq$2023 ha. The FIA field crews estimated forest fragment area from aerial photography and field observations. Image and scale of aerial photographs varied from black and white, 1:20,000 or 40,000 in the 1970s and early 1980s, to color infrared, 1:58,000 after 1986.

RESULTS AND DISCUSSION

Forest Surveys

Conducted in the 1930s, the first extensive forest surveys of the MAV recorded 9 percent of the 5 190 500 ha of forests as old growth, and an additional 18 percent as having been cut but with some old-growth conditions (table 1). Forests near New Orleans and other development centers had already experienced extensive cutting for wood products by the mid-1930s. Remnant uncut old growth at the time was chiefly on poorly drained and clay-dominated soils. Many species became commercially important only after World War I, e.g., trees in sweetgum-water oak communities, or had no commercial value, trees in overcup oak-water hickory community type (table 1).

Table 1—Bottomland forest area by type and condition, Mississippi Alluvial Valley, 1932–35

Forest type	All conditions	Second growth[a]	Old growth[b] Partial[c]	Old growth[b] Uncut[d]	
	- - - - - - - - - - - - - 1000 ha			*- - - - - - - - - - - -*	*%*
Baldcypress-water tupelo	684.9	521.4	131.4	32.1	5
Overcup oak-water hickory	857.0	331.6	285.4	239.9	28
Cottonwood and willow[e]	558.0	558.0	—	—	—
Mixed bottomland hardwood					
Sweetgum-mixed	1,017.3	794.0	129.3	93.9	9
Hackberry-elm-ash	814.0	571.8	199.6	42.6	5
Water oaks[f]	422.6	320.6	88.7	13.3	3
Other mixtures	836.7	729.0	86.1	21.6	3
Total	5,190.5	3,826.5	920.6	443.4	9

[a] Vegetative growth habits typical of abandoned clearings, recent catastrophic disturbances, or new riverbank soil deposits (Winters and others 1938).
[b] Stands composed of sawtimber trees with the characteristics of the original mature trees of the region (Eldredge 1937).
[c] = 10 percent volume removed but characterized by residual trees from the old-growth forest (Eldredge 1937).
[d] < 10 percent volume removed (Eldredge 1937).
[e] Early successional types defined in the 1930s as transitional, having no maturity potential (Winters and others 1938).
[f] Water, Nuttall, and willow oak.
Sources: Eldredge 1938; Stover 1942; Winters 1939a, 1939b; Winters and others 1938.

[3] U.S. Department of Agriculture, Forest Service, Southern Research Station, Forest Inventory and Analysis Research Work Unit. 1985. Forest survey inventory work plan, 1985. 56 p. Administrative report. On file with: U.S. Department of Agriculture, Forest Service, Southern Research Station, Starkville, MS 39762–6124.

These early surveys recorded a paucity of old growth in southeastern Arkansas and points north (table 2) and east in Mississippi (table 3). The MAV maps of the period also indicated extensive land described as formerly forested but cleared for agricultural crops for the area north of the Arkansas River. Most uncut old growth, primarily overcup oak-water hickory was in Louisiana (table 4).

Apart from the steep declines since the 1930s, community-type comparisons reveal a greater proportion of hackberry-elm-ash and baldcypress-water tupelo and a lesser proportion of overcup oak-water hickory and mixed bottomland hardwood types represented today (fig. 2). Changes between the 1930s and 1990s show that the loss of bottomland hardwood area slowed only in the past

Table 2—Mississippi Alluvial Valley bottomland forest area by type and condition, east Arkansas, west Kentucky, southeast Missouri, and west Tennessee, 1935

Survey region and forest type	All conditions	Second growth[a]	Old growth[b]		
			Partial[c]	Uncut[d]	
	1000 ha				%
Southeast Arkansas					
Baldcypress-water tupelo	36.6	24.8	9.3	2.6	7
Overcup oak-water hickory	136.8	72.2	42.7	21.9	16
Cottonwood and willow[e]	81.9	81.9	—	—	—
Mixed bottomland hardwood					
Sweetgum-water oaks[f]	184.3	150.0	24.1	10.3	9
Hackberry-elm-ash	169.2	116.6	44.0	8.7	5
Water oaks[f]	129.1	104.1	21.5	3.5	3
Other mixtures	351.0	297.0	42.4	11.6	3
Total	1,089.1	846.6	184.0	58.5	5
Northeast Arkansas, west Kentucky, southeast Missouri, and west Tennessee					
Baldcypress-water tupelo	109.5	91.7	15.6	2.2	2
Overcup oak-water hickory	67.0	52.0	11.2	3.8	6
Cottonwood and willow[e]	106.3	106.3	—	—	—
Mixed bottomland hardwood					
Sweetgum-water oaks[f]	177.1	153.2	10.5	13.4	8
Hackberry-elm-ash	191.2	164.7	20.4	6.1	3
Water oaks[f]	107.9	101.5	5.7	0.6	1
Other mixtures	209.7	195.7	12.5	1.6	1
Total	968.8	865.1	76.0	27.8	3

[a] Vegetative growth habits typical of abandoned clearings, recent catastrophic disturbances, or new riverbank soil deposits (Winters and others 1938).
[b] Stands composed of sawtimber trees with the characteristics of the original mature trees of the region (Eldredge 1937).
[c] = 10 percent volume removed but characterized by residual trees from the old-growth forest (Eldredge 1937).
[d] <10 percent volume removed (Eldredge 1937).
[e] Early successional types defined in the 1930s as transitional, having no maturity potential (Winters and others 1938).
[f] Water, Nuttall, and willow oak.
Sources: Eldredge 1938, Winters 1939a.

Table 3—Mississippi Alluvial Valley bottomland forest area by type and condition, Mississippi, 1932

Forest type	All conditions	Second growth[a]	Old growth[b] Partial[c]	Old growth[b] Uncut[d]	
	- - - - - - - - - - *1000 ha*	- - - - - - - - - -			%
Baldcypress-water tupelo	58.3	31.2	25.6	1.5	3
Overcup oak-water hickory	182.4	82.7	83.0	16.7	9
Cottonwood and willow[e]	87.9	87.9	—	—	—
Mixed bottomland hardwood					
Hackberry-elm-ash	126.5	93.5	31.2	1.9	1
Water oaks[f]	50.0	36.7	11.1	2.1	4
Other mixtures	54.6	49.7	4.9	—	—
Total	705.7	495.3	179.6	30.9	4

[a] Vegetative growth habits typical of abandoned clearings, recent catastrophic disturbances, or new riverbank soil deposits (Winters and others 1938).
[b] Stands composed of sawtimber trees with the characteristics of the original mature trees of the region (Eldredge 1937).
[c] = 10 percent volume removed but characterized by residual trees from the old-growth forest (Eldredge 1937).
[d] < 10 percent volume removed (Eldredge 1937).
[e] Early successional types defined in the 1930s as transitional, having no maturity potential (Winters and others 1938).
[f] Water, Nuttall, and willow oak.
Source: Stover 1942.

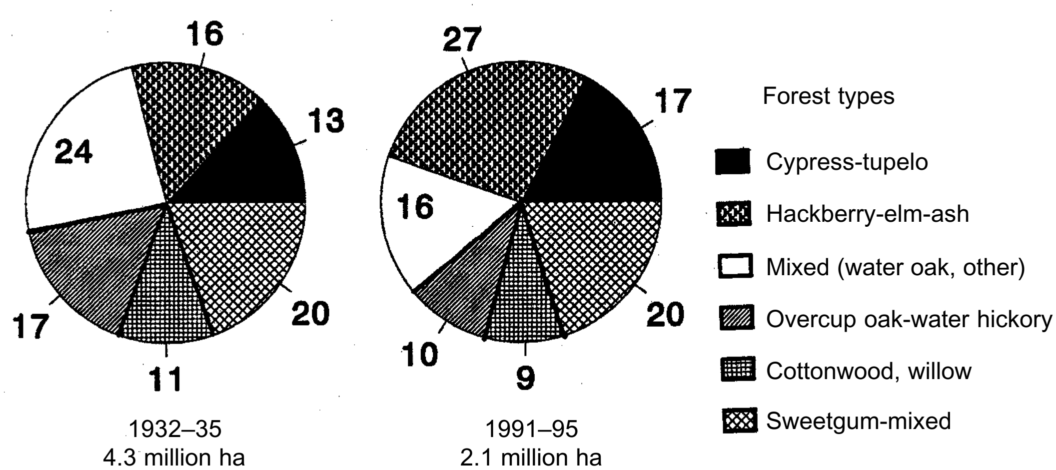

Figure 2—Percent bottomland-hardwood forest area by forest type and total forest area of Arkansas, Louisiana, and Mississippi Delta survey units, 1932–35 and 1991–95.

Table 4—Mississippi Alluvial Valley bottomland forest area by type and condition, Louisiana, 1934–1935

Survey region and forest type	All conditions	Second growth[a]	Old growth[b] Partial[c]	Old growth[b] Uncut[d]	
	- - - - - - - - - - 1000 ha	*- - - - - - - - - - -*			*%*
Northeast Louisiana, 1934					
Baldcypress-water tupelo	38.5	24.0	8.5	6.0	16
Overcup oak-water hickory	328.7	71.4	107.8	149.5	45
Cottonwood and willow[e]	88.6	88.6	—	—	—
Mixed bottomland hardwood					
Sweetgum-water oaks[f]	276.0	186.2	42.4	47.5	17
Hackberry-elm-ash	163.5	64.9	75.4	23.2	8
Water oaks[f]	78.9	42.3	30.0	6.6	17
Other mixtures	99.9	76.7	22.1	1.0	1
Total	1,074.1	554.1	286.2	233.8	22
South Louisiana Delta, 1935					
Baldcypress-water tupelo	442.0	349.7	72.4	19.8	14
Overcup oak-water hickory	142.0	53.3	40.6	48.0	22
Cottonwood and willow[e]	193.2	193.2	—	—	—
Mixed bottomland hardwood					
Sweetgum-water oaks[f]	233.9	191.1	28.6	14.1	6
Hackberry-elm-ash	163.6	132.1	28.6	2.8	2
Water oaks[f]	44.2	36.0	7.8	0.4	1
Other mixtures	133.9	109.9	16.6	7.4	6
Total	1,352.8	1,065.3	194.6	92.6	7

[a] Vegetative growth habits typical of abandoned clearings, recent catastrophic disturbances, or new riverbank soil deposits (Winters and others 1938).
[b] Stands composed of sawtimber trees with the characteristics of the original mature trees of the region (Eldredge 1937).
[c] = 10 percent volume removed but characterized by residual trees from the old-growth forest (Eldredge 1937).
[d] < 10 percent volume removed (Eldredge 1937).
[e] Early successional types defined in the 1930s as transitional, having no maturity potential (Winters and others 1938).
[f] Water, Nuttall, and willow oak.
Sources: Winters 1939b, Winters and others 1938.

decade (table 5). Since the 1970s, only baldcypress-water tupelo and willow community types have increased.

The 1967 delta survey unit in Mississippi documented that two-thirds of its forest land, about 170 000 ha, were soybean fields cleared since the 1957 survey (Beltz and Christopher 1967). Forests cleared for agriculture between 1957 and 1967 were about 28 percent overcup oak-water hickory, 37 percent sweetgum-mixed oaks, 13 percent hackberry-elm-ash, and 22 percent other community types (Beltz and Christopher 1967). Overcup oak-water hickory—characteristic of poorly drained clay flats—was preferentially removed, i.e., the proportion of area removed was larger by 8 percent than what existed in the Mississippi 1946–48 survey (Sternitzke and Putnam 1956).

Though Sternitzke and Putnam (1956) attributed much of the change in the MAV's forest composition to clearing of forests in areas suitable for agricultural production, they also noted heavy cutting during World War II for selected species. Overcup oak and the then undifferentiated tupelo, i.e., today's blackgum, swamp tupelo, or water tupelo, sawtimber

Table 5—Bottomland forest area by type and survey period, Arkansas, Louisiana, and Mississippi Delta survey units, 1930s to 1990s

Forest type	Change since the 1930s	Survey period					
		1991–1995	1984–1988	1974–1978	1964–1969	1947–1954	1932–1935[a]
	Percent	*1000 ha*					
Baldcypress-water tupelo	-34	380.4	412.9	363.4	NA	439.8	573.5
Overcup oak-water hickory	-71	210.4	217.7	286.8	NA	549.6	717.6
Cottonwood-willow	-59[b]					327.8	467.2
Willow		146.3	135.4	127.7	NA	NA	NA
Cottonwood		43.9	42.7	57.1	NA	NA	NA
Mixed bottomland hardwood						2,239.0[c]	
Sweetgum-mixed	-53	402.1	399.3	494.7	NA	NA	851.8
Hackberry-elm-ash	-9	565.4	545.1	590.2	NA	NA	618.6
Other mixtures	-69		287.4	366.0	NA	NA	1,054.4
Total	-52	2,080.1	2,040.5	2,285.9	2,702.2	3,556.2	4,346.1

NA = not available.
[a] 1932–35 adjusted to this three-State region by multiplying Mississippi Alluvial area estimates in table 1 by 0.84 (4,364.1 divided by 5,190.5).
[b] Cottonwood and willow.
[c] Sweetgum-mixed, hackberry-elm-ash, and other mixtures; no details available.

volume declined 27 percent between the 1930s and 1947–54 survey period (Sternitzke and Putnam 1956), which is limited evidence suggesting that the 1930s remnant old-growth forests dominated by these species were extensively logged. During the same period, baldcypress sawtimber volume increased by 33 percent—limited evidence suggesting the 1930s remnant old-growth forests dominated by baldcypress were not extensively logged.

By the 1947–54 surveys, poletimber and smaller diameter class area represented 45 percent of bottomland hardwood communities, and almost one-half were in the mixed types. Sternitzke and Putnam (1956) ascribed the predominance of younger age conditions to extensive cutting and some to reversion to forest after farm abandonment during the Depression and World War II.

Area in poletimber and smaller diameter class was greater for the 1947–54 survey period than subsequent years (fig. 3). Baldcypress-water tupelo area in sawtimber diameter class increased between the 1947–54 period and 1990s. With this exception, area in sawtimber diameter class was also greater for the 1947–54 period than in subsequent years. Later surveys showed declines in nearly all bottomland hardwood community types classed as poletimber and smaller diameter class, and a slower, smaller increase in the sawtimber diameter class (fig. 3).

Comparisons of Bottomland Hardwood Community Type in the South-Central United States

Based on an ocular comparison of a forest occurrence probability grid by flood zones and shade tolerance, community types today appear to occupy more of the grid in South-Central United States' bottomland hardwoods (fig. 4A) than in the MAV (fig. 4B). To gain a better understanding of the community types depicted in the above grids, I cross-referenced Rudis's (1995) empirically defined community types with FIA community types. Lines in figure 5 join empirical community types containing at least 50 percent of each FIA community type. For the most part, FIA community types represented a narrow range of flood zones. Exceptions were sweetbay-swamp tupelo-red maple type which occupied a broad range of flood zones, and swamp chestnut oak-cherrybark oak type, which was in the sporadic flood zone but had no majority affiliation with any empirical community type.

Closer inspection of the forest occurrence probability grids for the South-Central United States (fig. 4A) and MAV (fig. 4B) show a gap around flood code 5, shade code 2.5, which corresponds to blackgum (NY) and American holly (IO) empirical community types, and swamp chestnut oak-cherrybark oak FIA community type in figure 5. A second, smaller gap in the MAV grid occurs around flood code 3, shade code 3.5, which corresponds to the swamp tupelo

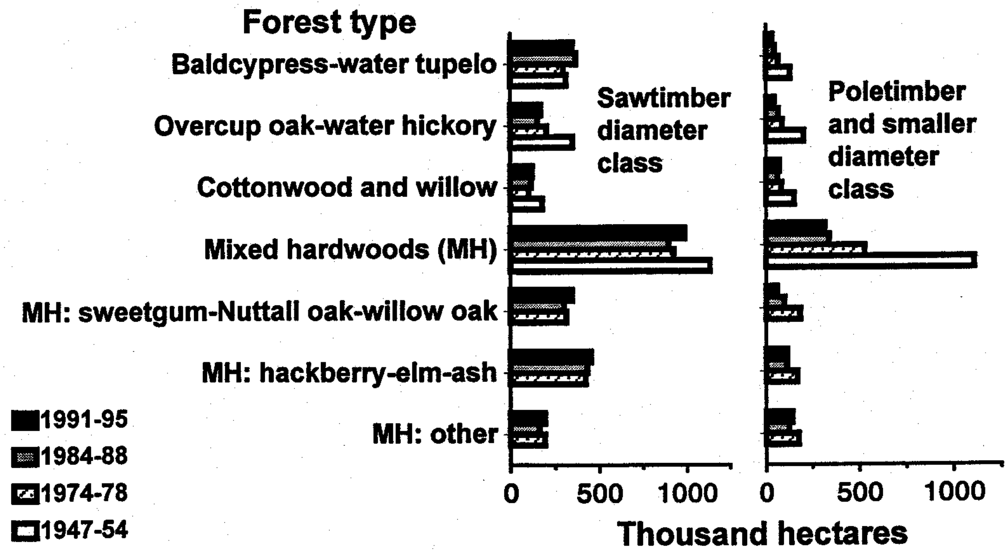

Figure 3—Forest area by diameter class for Arkansas, Louisiana, and Mississippi Delta survey units, 1947–95. For 1947–54 surveys, no data within mixed hardwood (MH) types. Sawtimber diameter class, 1947–54: forests with hardwood trees ≥ 27.9 cm, softwoods ≥ 22.9 cm, and net volume > 1,500 board feet (*sic*, no metric equivalent); 1974 and later: ≥ 50-percent stocked with trees ≥ 12.7 cm diameter, and ≥ 50-percent stocked with trees > 27.9 cm (hardwoods), > 22.9 cm (softwoods). Poletimber and smaller-diameter class: forests with trees not meeting sawtimber-diameter class criteria.

Table 6—Bottomland hardwood forest area by forest type and proportion of large tree basal area in the Arkansas, Louisiana, and Mississippi Delta survey units, 1991–1995

Forest type	All areas	None	Percent large tree basal area[a]			
			>0.1	0.1–20	21–40	>40
	1000 ha					
Baldcypress-water tupelo	380.4	39.0	341.4	188.9	111.9	40.7
Overcup oak-water hickory	210.4	14.9	195.5	60.0	76.5	59.1
Willow	146.3	60.3	90.0	30.9	14.8	40.3
Cottonwood	43.9	8.0	35.9	7.6	5.2	23.1
Sweetgum-Nuttall oak-willow oak	402.1	19.0	383.1	120.7	135.5	126.9
Hackberry-elm-ash	565.4	58.1	507.4	127.1	224.3	156.0
Sweetbay-swamp tupelo-red maple	47.7	11.8	36.0	17.2	14.8	3.9
Sycamore-pecan-elm	60.0	16.2	43.8	16.9	15.5	11.4
Other mixed	221.0	38.8	185.2	74.6	63.2	47.4
Total	2,080.1	266.0	1,814.2	643.8	661.6	508.7

[a] Basal area of live trees ≥ 50 cm diameter at 1.4 m (d.b.h.) divided by basal area of live trees ≥ 12.7 cm d.b.h.

(NB) empirical community type, or the FIA swamp tupelo-sweetbay community type (fig. 5).

Quantitative species-based comparisons corroborate these qualitative comparisons. Species representing ≥3 percent dry weight importance in the east or west south-central Gulf Coastal Plain, but not the MAV, include: blackgum, cherrybark oak, hickory, laurel oak, loblolly pine, sweetbay, swamp tupelo, and yellow-poplar (McWilliams and Rosson 1990).

Old-Growth Potential

By selecting only sampled forests with > 0.05 percent basal area from trees > 50 cm d.b.h. (table 6), one obtains estimates from forests visually perceived as older stands. Community distribution along the flood zone-shade

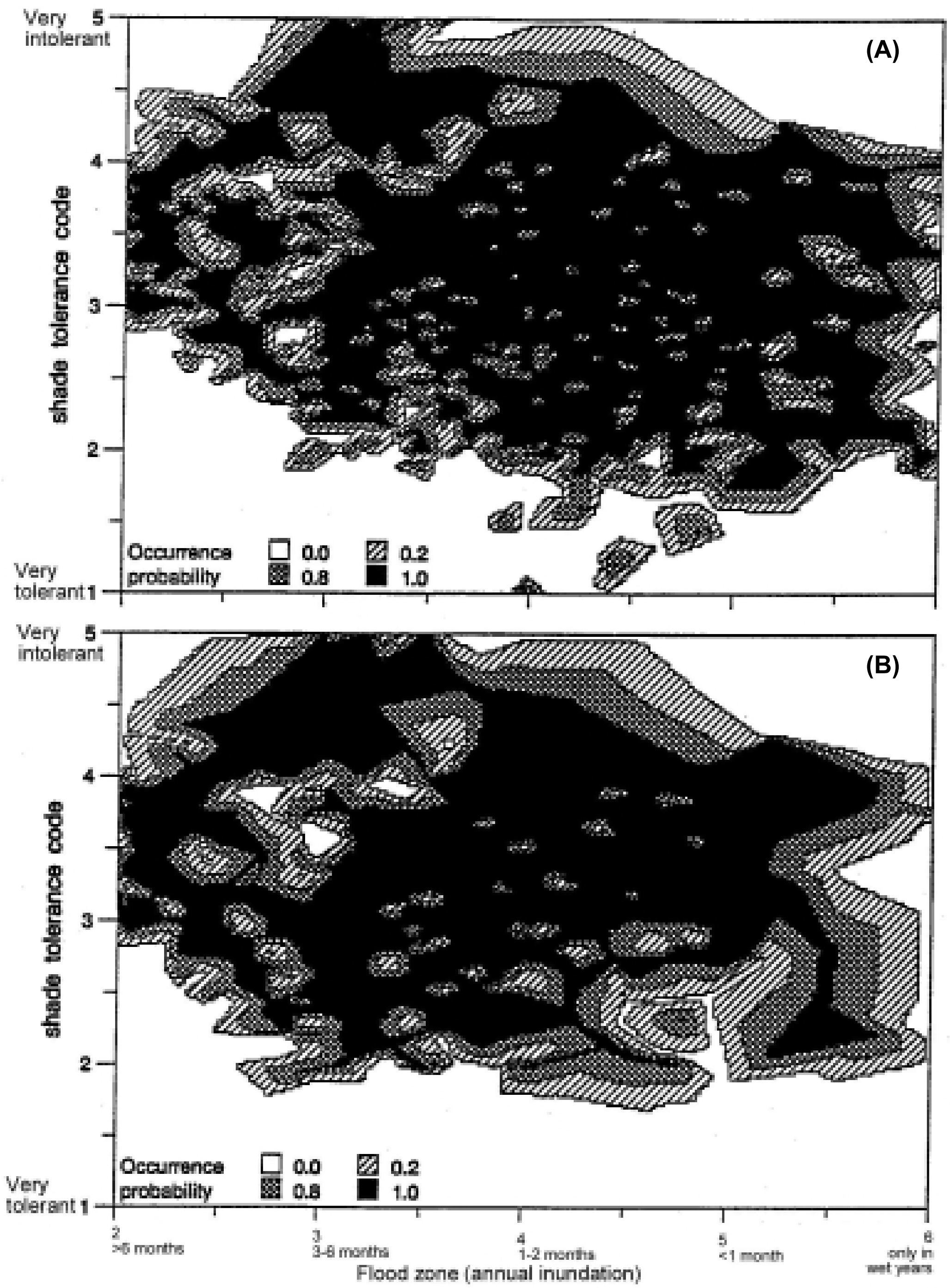

Figure 4—Predicted bottomland-hardwood occurrence by average flood zone and shade tolerance: (A) South-Central United States bottomland hardwoods, 1986–91. (Sample size: 5,366, i.e., 2,666 estimates from forest area samples based on tree importance values and 2,700 randomly assigned estimates representing nonforested, former bottomland hardwood forests; (B) Arkansas, Louisiana, and Mississippi Delta survey units, 1987–91. (Sample size: 1,724, i.e., 824 estimates from forest area samples based on tree importance values and 900 randomly assigned estimates representing nonforested, former bottomland hardwood forests).

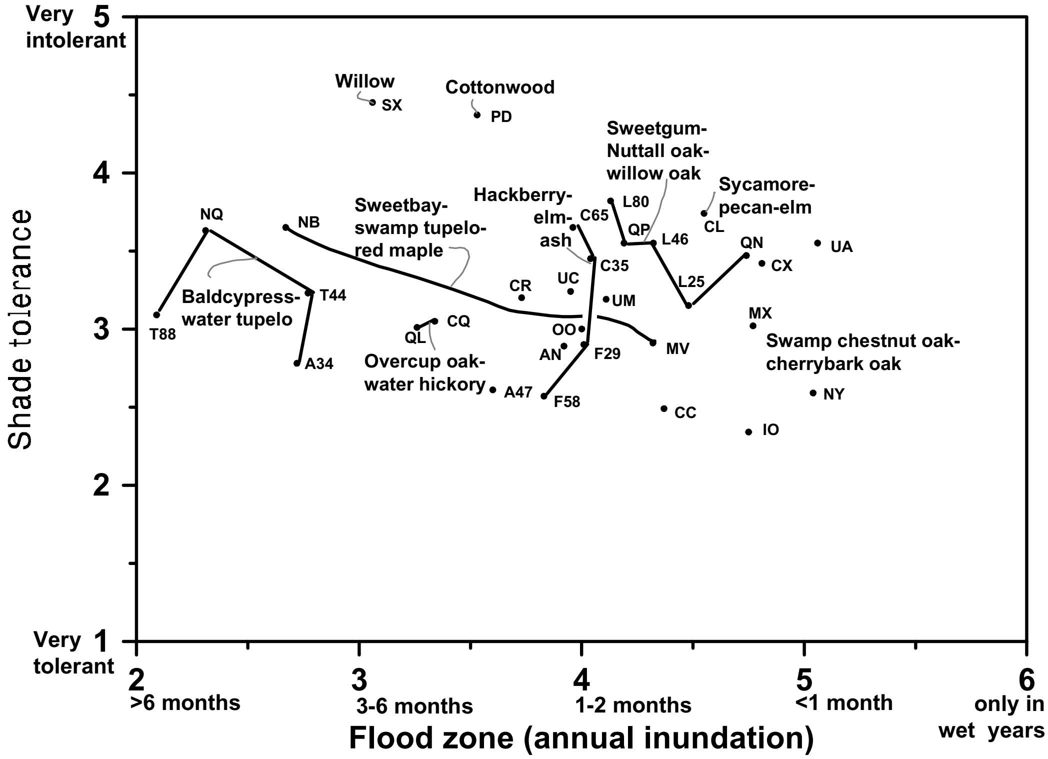

Figure 5—Forest Inventory and Analysis (FIA) community types and empirical-community types by average flood zone and shade tolerance value, South-Central United States bottomland hardwoods. Linked are empirical types that also categorize ≥ 50 percent of the FIA community type. Empirical community type codes by dominant species (additionally coded by percent importance if characteristic of more than one type): A34-red maple, A47-red maple, AN-boxelder, C65-hackberry, C35-hackberry, CC-blue-beech, CL-pecan, CQ-water hickory, CR-hawthorne, CX-other hickories, F58-green ash, F29-green ash, IO-American holly, L80-sweetgum, L46-sweetgum, L25-sweetgum, MV-sweetbay, MX-mixed, importance < 5 percent for any one species, NB-swamp tupelo, NQ-water tupelo, NY-blackgum, OO-no trees, > 2.5 cm at 1.4 m, PD-cottonwood, QL-overcup oak, QN-water oak, QP-willow oak, T44-baldcypress, T88-baldcypress, UA-winged elm, UC-cedar elm, UM-American elm (after Rudis 1995). Sample size = 2,666 plots.

tolerance grid shows a very limited occurrence in flood zone codes 4 through 6 and shade tolerance codes 2 and 3 (fig. 6).

A more conservative distribution of potential old-growth types emerges with the biological maturity criteria (table 7). Most communities in flood zone codes 5 disappear. These correspond to FIA community types like swamp chestnut oak-cherrybark oak and sycamore-pecan-elm. Primarily it is flood codes 2 through 4, i.e., baldcypress-water tupelo, overcup oak-water hickory, cottonwood, and willow, that have basal area equal to or greater than the range associated with mature forests (fig. 6B). Basal area from mature, i.e., 45- to 65-year-old southern bottomland hardwood, forests range from 20.9 to 29.6 m^2 per hectare (table 7). This range compares favorably with one 1990 27.4-m^2-per-hectare estimate from three southern floodplain research natural areas known to contain old-growth trees (Devall and Ramp 1992) and Martin's (1992) 25-m^2-per-hectare minimum for mixed mesophytic, old-growth forests.

Additional criteria [net growth 0$\pm$1.4 m^3 per hectare per year (fig. 7A) and no harvest since the previous survey (fig. 7B)], reveal that the greatest old-growth potential occurs in the wettest community types. Combining the three biological maturity criteria with the size criterion shows that estimates even smaller (table 8).

Ownership is largely in private hands, even when estimating area with old-growth potential (table 9). By forest type, corporate owners—frequently banks, insurance firms, agricultural businesses, and, in Louisiana, companies with oil production interests—control a large percentage of baldcypress-water tupelo area, even when based on the most restrictive old-growth criteria (table 10).

Fragmentation and Changes 1970s to 1990s

If small in area, a forest fragment is more likely than a large forest fragment to show evidence of livestock use and selected human intrusions (beverage, food, and other containers; trash; buildings; foundations; and fences); to be closer to agricultural and urban areas, roads and fences; and to contain less timber growing stock (Rudis 1995). If large, a forest fragment is more likely to have Spanish moss (*Tillandsia usneoides* L.) and signs restricting hunting activities (Rudis 1995). Larger forest fragments are from the permanent flood zone types; smaller fragments are from sporadic, intermittent, and periodic flood zone, early successional community types (Rudis 1995). These indices suggest change in the uses and resource values of remnant

Table 7—Maturity criteria, bottomland forest area, and sample size by potential site productivity and maturity class, Arkansas, Louisiana, and Mississippi Delta survey units, 1991–1995

Potential site productivity class	Maturity criteria[a]		Arkansas, Louisiana, and Mississipppi Delta survey units			
	Basal area	Sample size	All areas		≥Maturity criteria	
m³/ha/yr	*m²/ha*	*Number*	*1000 ha*	*Number*	*1000 ha*	*Number*
15.8 or more	29.6	3	92.0	39	23.1	10
11.6 to 15.7	25.6	10	223.8	94	83.8	35
8.4 to 11.5	23.7	15	381.0	154	179.9	74
6.0 to 8.3	22.6	19	681.0	279	356.6	145
3.5 to 5.9	21.8	17	623.9	253	361.3	146
1.4 to 3.4	20.9	6	78.4	34	37.8	16
Total			2,080.1	853	1,042.5	426

[a] Average stand basal area and sample size for 45- to 65-year-old bottomland forest stands. Stand age represents the mean of five dominant trees spaced ≥20 m within a 0.4-ha area. Source: East Texas 1986 surveys.

Table 8—Bottomland forest area by forest type and growth criteria for the Arkansas, Louisiana, and Mississippi Delta survey units, 1991–1995

Forest type	All areas	Growth criteria[a]			A, B, C, and percent large tree basal area[b]			
		A	A, B	A, B, C	1–100	1–20	21–40	>40
	1000 ha							
Baldcypress-water tupelo	380.4	290.1	75.9	37.5	34.7	14.7	10.2	9.8
Overcup oak-water hickory	210.4	110.6	20.2	13.1	13.1	4.2	2.3	6.6
Willow	146.3	54.3	14.7	4.6	4.6		2.7	1.9
Cottonwood	43.9	12.6	—	—	—	—	—	—
Sweetgum-Nuttall oak-willow oak	402.1	204.5	38.5	15.9	15.9	4.6	5.1	6.2
Hackberry-elm-ash	565.4	264.9	80.0	18.3	18.3	7.3	6.8	4.3
Sweetbay-swamp tupelo-red maple	47.7	25.2	—	—	—	—	—	—
Sycamore-pecan-elm	60.0	15.4	2.6	2.6	2.6	—	2.6	—
Other mixed	221.0	65.0	19.1	14.5	9.3	2.4	6.9	—
Total	2,080.1	1,042.5	209.1	106.5	98.5	33.3	29.5	35.7

[a] A is average basal area of 45- to 65-year-old bottomland hardwood stands (table 7); B is net growth on live trees = 0 ± 1.4 m^3 per hectare per year; C is no evidence of commercial harvest since prior surveys (about 7 years earlier).

[b] Basal area of live trees ≥ 50 cm diameter at 1.4 m (d.b.h.) divided by basal area of live trees ≥ 12.7 d.b.h.

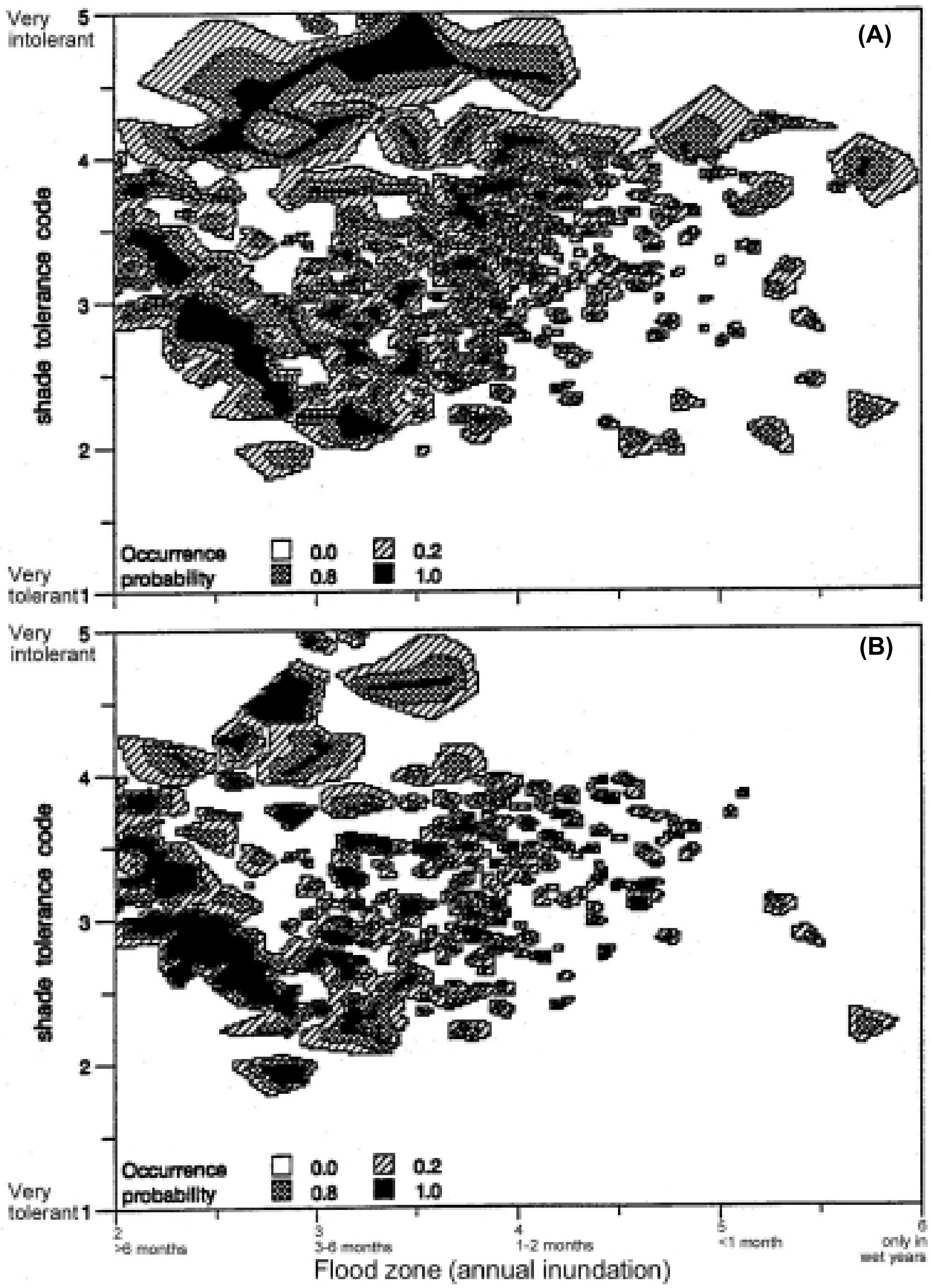

Figure 6—Predicted bottomland-hardwood occurrence, Arkansas, Louisiana, and Mississippi Delta survey units by average flood zone and shade tolerance for forests with: (A) large trees (> 0.1 percent basal ≥ 50 cm diameter at 1.4 m (d.b.h.) divided by basal area of live trees > 12.7 cm d.b.h.; (B) basal area ≥ average for 45- to 65-year-old southern bottomland-hardwood communities by potential site productivity class (20.9 to 29.6 square meters per hectare, productivity classes 1.4 to ≥15.8 cubic meters per hectare per year [see table 7]).

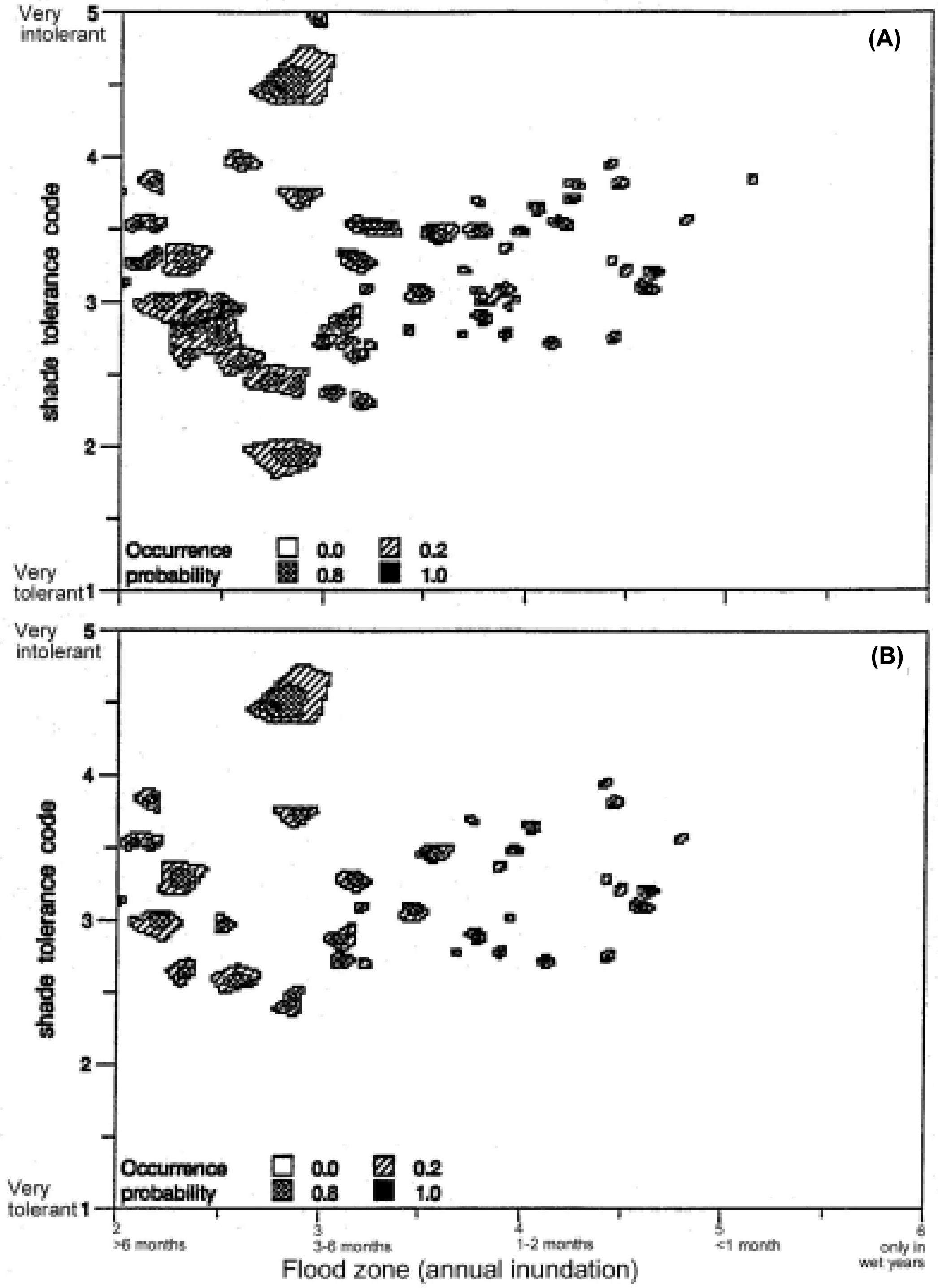

Figure 7—Predicted bottomland-hardwood occurrence, Arkansas, Louisiana, and Mississippi Delta survey units by average flood zone and shade tolerance for (A) forests with basal area >= potential site-productivity averages for 45- to 65-year-old southern bottomland-hardwood communities and net growth = 0 + or - 1.4 cubic meters per hectare per year; (B) forests with conditions listed in (A) and no evidence of commercial harvest activity.

Table 9–Bottomland forest area by forest type and growth criteria in the Arkansas, Louisiana, and Mississippi Delta survey units, 1991–1995

			Growth criteria[a]					
Forest type	All areas		A		A, B		A, B, C	
	1000 ha	*%*	*1000 ha*	*%*	*1000 ha*	*%*	*1000 ha*	*%*
Public	300.6	14	148.4	14	11.9	6	7.7	7
Other corporate[b]	526.9	25	308.9	30	67.1	32	29.9	28
Forest industry	272.3	13	123.5	12	23.4	11	14.4	14
Farmer	405.2	19	171.8	16	46.2	22	25.3	24
Other private[c]	575.1	28	289.9	28	60.6	29	28.6	27
Total	2,080.1	100	1,024.5	100	209.1	100	106.5	100

[a] A is ≥average basal area of 45- to 65-year old bottomland hardwood stands (table 7); B is net growth on live trees = ± 1.4 m^3 per hectare per year; C is no evidence of commercial harvest since prior surveys (about 7 years earlier).
[b] Other than forest industries.
[c] Other than farmers and corporate owners.

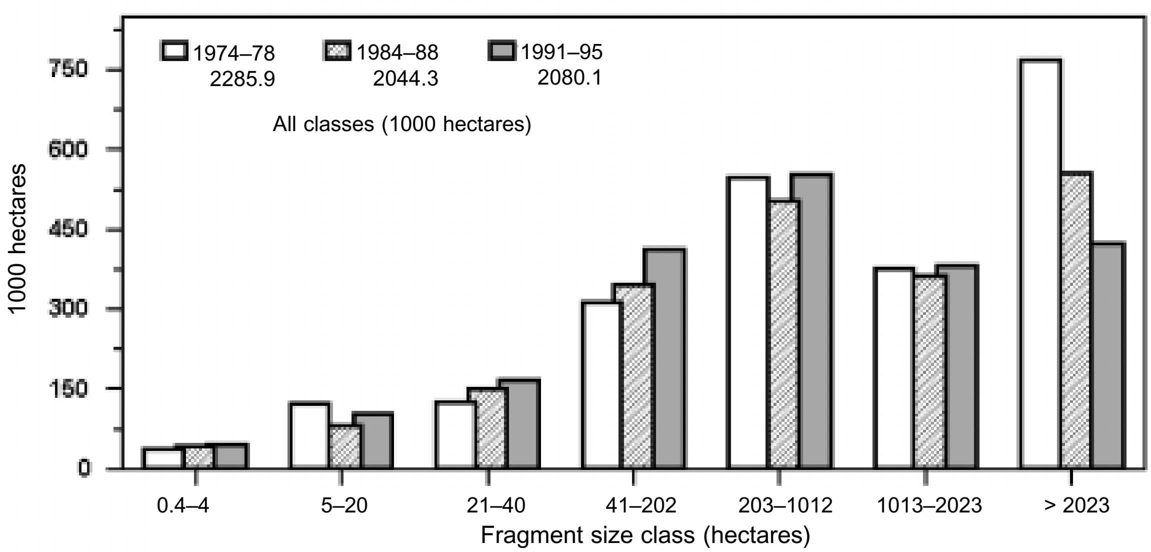

Figure 8—Bottomland-hardwood forest area by fragment size class and survey year, Arkansas, Louisiana, and Mississippi Delta survey units, 1974–78, 1984–88, and 1991–95.

or regenerated forests. On average, fragmented forest cover is less likely to retain or recover the resource values associated with the region's once large, contiguous forests.

Between the 1970s and 1990s, total forest area in the MAV changed only slightly, from 2.3 to 2.1 million ha, but there was a shift to fragment size classes < 2000 ha (fig. 8), and to baldcypress-water tupelo community types (table 11). For the largest (> 2023 ha) fragment size class, the decline was primarily in mixed hardwoods and hackberry-elm-ash (table 11). Declines in the largest fragment class were 9 percent in baldcypress-water tupelo, and above 30 percent in all other community types examined.

SUMMARY AND IMPLICATIONS

Comparisons with historical MAV data showed that the sporadic flood zone, late-successional community types, especially mixed bottomland hardwoods, were the most

Table 10—Bottomland forest area by forest type, owner, and growth criteria in the Arkansas, Louisiana, and Mississippi Delta survey units, 1991–1995

Forest type and owner class	All areas		Growth criteria[a] A		A, B		A, B, C	
	1000 ha	*%*	*1000 ha*	*%*	*1000 ha*	*%*	*1000 ha*	*%*
Baldcypress-water tupelo								
Public	15.0	4	12.7	4	1.4	2	—	—
Other corporate[b]	166.5	44	133.4	46	35.3	47	15.5	41
Forest industry	39.9	10	34.2	12	7.7	10	7.7	21
Farmer	57.2	15	19.8	7	5.1	7	5.1	14
Other private[c]	101.8	27	90.0	31	26.3	35	9.2	25
Total	380.3	100	290.1	100	75.9	100	37.5	100
Overcup oak-water hickory, cottonwood, and willow								
Public	98.1	26	47.1	27	3.9	11	3.9	22
Other corporate[b]	92.0	22	39.5	22	12.5	36	7.3	41
Forest industry	51.8	13	22.7	13	5.1	15	—	—
Farmer	64.2	17	29.4	17	6.9	20	4.2	24
Other private[c]	94.5	22	38.7	22	6.6	19	2.2	13
Total	400.6	100	177.4	100	35.0	100	17.6	100
Sweetgum-Nuttall oak-willow oak								
Public	60.8	15	33.2	16	—	—	—	—
Other corporate[b]	64.1	16	30.1	15	7.9	21	—	—
Forest industry	42.3	11	20.0	10	6.3	16	4.3	27
Farmer	101.6	25	52.9	26	14.6	38	6.5	41
Other private[c]	133.3	33	68.3	33	9.7	25	5.1	32
Total	402.1	100	204.5	100	38.5	100	15.9	100
Hackberry-elm-ash								
Public	84.3	15	34.9	13	—	—	—	—
Other corporate[b]	144.2	26	79.7	30	6.1	16	2.0	11
Forest industry	104.7	19	40.2	15	2.0	5	—	—
Farmer	86.9	15	40.0	15	17.2	45	9.5	52
Other private[c]	145.4	26	70.0	26	12.8	34	6.9	37
Total	565.4	100	264.9	100	38.0	100	18.3	100
Mixed hardwoods (sycamore-pecan-elm, sweetbay-swamp tupelo-red maple, and other mixed)								
Public	42.4	15	20.5	26	6.5	30	3.9	22
Other corporate[b]	38.4	14	14.3	18	5.3	24	7.3	41
Forest industry	31.7	11	4.4	5	2.4	11	—	—
Farmer	88.4	31	25.0	31	2.4	11	4.2	24
Other private[c]	82.9	22	16.2	20	5.2	24	2.3	13
Total	283.9	100	80.4	100	21.7	100	17.6	100

[a] A is ≥ average basal area of 45- to 65-year old bottomland hardwood stands (table 7), B is net growth on live trees = ± 1.4 m^3 per hectare per year, C is no evidence of commercial harvest since prior surveys (about 7 years earlier).
[b] Other than forest industries.
[c] Other than farmers and corporate owners.

Table 11—Bottomland forest area by forest type, survey period, change since the 1970s, and forest fragment size class in Arkansas, Louisiana, and Mississippi Delta survey units

		Forest fragment size class (hectares)				
Forest type and survey period	All size classes	0.4 to 40	41 to 202	203 to 1,012	1,013 to 2,023	>2,023
	- - - - - - - -	- - - - - - - -	- - - 1000 ha	- - - - - - - -	- - - - - - - -	- - - - - - - -
Baldcypress-water tupelo						
1974–1978	363.4	23.9	19.9	63.7	78.3	177.6
1984–1988	412.9	23.0	48.7	78.0	72.2	190.8
1991–1995	380.4	28.6	58.0	62.6	69.8	161.4
Change	17.0	4.7	38.1	-1.1	-8.5	-16.2
Percent	5	20	2	-2	-11	-9
Overcup oak-water hickory, cottonwood, and willow						
1974–1978	471.6	54.3	71.0	130.1	83.9	132.4
1984–1988	395.8	44.9	62.6	118.5	53.3	118.4
1991–1995	400.6	55.3	82.9	88.1	82.4	92.0
Change	-71.0	1.0	11.9	-42.0	-1.5	-40.4
Percent	-15	2	17	-32	-2	-31
Sweetgum-Nuttall oak-willow oak						
1974–1978	494.7	106.4	90.0	128.7	86.9	82.6
1984–1988	399.3	78.9	95.0	91.7	70.0	64.2
1991–1995	402.1	80.2	87.1	121.4	71.3	42.0
Change	-92.6	-26.2	-2.9	-7.3	-15.6	-33.7
Percent	-19	-25	-3	-6	-18	-41
Hackberry-elm-ash						
1974–1978	590.2	50.7	69.3	150.7	83.8	235.8
1984–1988	545.1	70.4	73.7	147.2	121.4	132.7
1991–1995	565.4	74.4	101.8	167.8	129.1	92.4
Change	-24.8	23.7	32.5	17.1	45.3	-143.4
Percent	-4	47	47	11	54	-61
Mixed hardwoods (sycamore-pecan-elm, sweetbay-swamp-tupelo-red maple, and other mixed)						
1974–1978	366.0	49.8	62.2	72.4	42.4	139.2
1984–1988	287.4	58.6	65.0	66.8	48.8	49.4
1991–1995	331.6	74.0	81.0	112.1	29.1	35.3
Change	-34.4	24.2	18.8	39.7	-13.3	-103.9
Percent	-9	49	30	55	-31	-75
All forest types						
1974–1978	2,285.9	285.1	312.5	545.5	375.2	767.6
1984–1988	2,044.3	275.8	344.9	502.3	365.8	555.6
1991–1995	2,080.1	312.6	410.8	552.0	381.7	423.0
Change	-205.8	27.5	98.3	6.5	6.5	-344.6
Percent	-9	9	31	1	2	-45

vulnerable to anthropogenic intrusions. The permanent flood zone community types typified by baldcypress-water tupelo, and the intermediate flood zone, early successional community types typified by hackberry-elm-ash were the least vulnerable. Since the 1970s, the largest (> 2023 ha) forests have continued to decline, with the nonpermanent flood zone types most affected. Based on old-growth criteria (potential site productivity-based minimum basal area, net growth near zero, and absence of harvest activity), permanent flood zone bottomland community types were associated with the most old-growth potential and large forest fragments and were primarily in private ownership. Nonpermanent flood zone types were associated with small forest fragments and the least old-growth potential. Clewell and Lea (1989) and Zedler and Weller (1989) describe associated forested wetland creation, maintenance, restoration, and research needed.

National reforestation programs to restore forested communities, such as the 1970s Forestry Incentive Program and the 1980s Conservation Reserve Program, have not traditionally focused on regional shifts in species or community types or forest fragmentation. If restoration of historic community types is also a desired future goal, these programs require approaches sensitive to regional changes. Declines in large forest fragments suggest losses in their associated values, e.g., optimal habitat for black bear (Rudis and Tansey 1995) and primitive recreational opportunities (Rudis 1987, 1995). Hoover and Shannon (1995) suggest social and political institutions and processes to maintain regional conservation land corridors and mitigate fragmentation, e.g., formal regional planning, informal adjacent landowner cooperation, and more stakeholder participation in the planning process.

If restoration of the 1930s proportion of MAV bottomland hardwood community types is desired, these programs will require focused efforts that (1) shift area of hackberry-elm-ash toward late-successional types, (2) establish species typical of likely missing bottomland hardwood types, e.g., swamp chestnut oak-cherrybark oak, (3) conserve remaining late-successional, nonpermanent flood zone types, and (4) foster occasional flooding characteristic of sporadic, intermittent, and periodic flood zones. Localized reforestation along rivers and streams and reconnection among existing small bottomland hardwood remnants also improve chances for recovery of landscape and regional scale values, e.g., water quality and habitats for selected wildlife species characteristic of floodplain forests (Hamel 2001).

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LITERATURE CITED

Anon. 1944. Survey of the Yazoo River watershed in Mississippi. House Doc. 564, 78th Congress, 2d session. Washington, DC: U.S. Government Printing Office. 58 p.

Beltz, R.C.; Christopher, J.F. 1967. Land clearing in the delta region of Mississippi, 1957–1967. Research Note SO–69. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 3 p.

Burns, R.M.; Honkala, B.H. 1990. Summary of tree characteristics. In: Silvics of North America. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture, Forest Service: 846–849. Vol. 2.

Clewell, A. F.; Lea, R. 1989. Creation and restoration of forested wetland vegetation in the Southeastern United States. In: Wetland creation and restoration: the status of the science. EPA 600/3-89/038a. Corvallis, OR: U.S. Environmental Protection Agency, Environmental Research Laboratory: 199–237. Vol. 1.

Delcourt, H.R. 1975. Reconstructing the forest primeval, West Feliciana Parish. Melanges 10. Baton Rouge, LA: Louisiana Sate University, Museum of Geosciences. 13 p.

Devall, M.S.; Ramp, P.F. 1992. U.S. Forest Service research natural areas and protection of old growth in the South. Natural Areas Journal. 12:75–85.

Devall, M.S.; Rudis, V.A. 1991. Older stands characterized and estimated from sample-based surveys. In: Henderson, D.; Hedrick, L.D., eds. Restoration of old growth forests in the interior highlands of Arkansas and Oklahoma. Morrilton, AR: Winrock International Institute for Agricultural Development; Hot Springs, AR: U.S. Department of Agriculture, Forest Service, Ouachita National Forest: 121–138.

Eldredge, I.F. 1937. Volumes on an average acre in the various units of the pine-hardwood region west of the Mississippi. For. Surv. Release 26. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 29 p.

Eldredge, I.F. 1938. Forest resources of the north Arkansas delta. For. Surv. Release 32. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 21 p.

Faulkner, J.L.; Hartsell, A.J.; London, J.D. 1995. Forest statistics for Mississippi counties—1994. Resour. Bull. SO–189. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 39 p.

Frayer, W.E.; Beltz, R.C. 1985. Loss of bottomland hardwoods in the Mississippi Alluvial Plain. In: Schmid-Haas, P., ed. Inventorying and monitoring endangered forests: Proceedings of the IUFRO conference; 1985 August 19–24; Zurich, Switzerland. Birmensdorf, Switzerland: Swiss Federal Institute for Forestry Research: 307–309.

Frelich, L.E. 1995. Old forest in the Lake States today and before European settlement. Natural Areas Journal. 15: 157–167.

Hamel, Paul, ed. 2001. Bottomland hardwoods of the Mississippi Alluvial Valley: characteristics and management of natural function, structure, and composition; 1995 October 28; Fayetteville, AR. Gen. Tech. Rep. SRS–42. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 109 p.

Hoover, A.P.; Shannon, M.A. 1995. Building greenway policies within a participatory democracy framework. Landscape and Urban Planning. 33: 433–459.

Little, E.L., Jr. 1979. Checklist of United States trees (native and naturalized). Agric. Handb. 541. Washington, DC: U.S. Department of Agriculture, Forest Service. 375 p.

MacDonald, P.O.; Frayer, W.E.; Clauser, J.K. 1979. Documentation, chronology and future projections of bottomland hardwood habitat loss in the lower Mississippi Alluvial Plain. Vicksburg, MS: U.S. Department of the Interior, Fish and Wildlife Service, Ecological Services; basic report. 133 p. Vol. 1.

Martin, W.H. 1992. Characteristics of old-growth mixed mesophytic forests. Natural Areas Journal. 12: 127–135.

McWilliams, W.H.; Rosson, J.F., Jr. 1990. Composition and vulnerability of bottomland hardwood forests of the Coastal Plain province in South Central United States. Forest Ecology and Management. 33/34: 485–501.

Rosson, J.F., Jr. 1995. Forest resources of Louisiana, 1991. Resour. Bull. SO–192. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 71 p.

Rudis. V.A. 1987. Recreational use of forested areas by Alabama residents. Research Pap. SO–237. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 37 p.

Rudis, V.A. 1993. Forest fragmentation of Southern U.S. bottomland hardwoods. In: Brissette, John C., ed. Proceedings of the seventh biennial southern silvicultural research conference; 1992 November 17–19; Mobile, AL. Gen. Tech. Rep. S0–93. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 35–46.

Rudis, V.A. 1995. Regional forest fragmentation effects on bottomland hardwood community types and resource values. Landscape Ecology. 10(5): 291–307.

Rudis, V.A. 1998. Regional forest resource assessment in an ecological framework: the Southern United States. Natural Areas Journal. 18(4): 319–332.

Rudis, V.A.; Birdsey, R.A. 1986. Forest resource trends and current conditions in the lower Mississippi Valley. Resour. Bull. SO–116. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 7 p.

Rudis, V.A.; Tansey, J.B. 1995. Regional assessment of remote forests and black bear habitat from forest resource surveys. Journal of Wildlife Management. 59: 170–180.

SAS Institute Inc. 1990. SAS/STAT user's guide. Version 6. 4th ed. Cary, NC: SAS Institute Inc. 943 p. Vol. 1.

SAS Institute Inc. 1991. SAS/GRAPH software: usage. Version 6. 1st ed. Cary, NC: SAS Institute Inc. 887 p.

Sternitzke, H.S.; Putnam, J.A. 1956. Forests of the Mississippi Delta. For. Surv. Release 78. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 42 p.

Stover, W.S. 1942. Forest resources of the delta section of Mississippi. For. Surv. Release 53. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 28 p.

Turner, R.E.; Forsythe, S.W.; Craig, N.J. 1981. Bottomland hardwood forest land resources of the Southeastern United States. In: Clark, J.R.; Benforado, J., eds. Wetlands of bottomland hardwood forests. New York: Elsevier Scientific Publishing Co.: 13–28.

Wharton, C.H.; Kitchens, W.M.; Sipe, T.W. 1982. The ecology of bottomland hardwood swamps of the Southeast: a community profile. FWS/OBS-81/37. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 133 p.

Winters, R.K. 1939a. Forest resources of the south Arkansas Delta. For. Surv. Release 46. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 24 p.

Winters, R.K. 1939b. Forest resources of the south Louisiana Delta. For. Surv. Release 42. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 20 p.

Winters, R.K.; Putnam, J.A.; Eldredge, I.F. 1938. Forest resources of the north Louisiana Delta. Misc. Publ. 309. Washington, DC: U.S. Department of Agriculture. 49 p. + 1 color map.

Zedler, J.B.; Weller, M.W. 1989. Overview and future directions. In: Wetland creation and restoration: the status of the science. EPA 600/3-89/038a. Corvallis, OR: U.S. Environmental Protection Agency, Environmental Research Laboratory: 465–473. Vol. 1.

APPENDIX A

Common and scientific names as listed in the text (Little 1979):

Common name	Scientific name
Ash	*Fraxinus* spp.
Green ash	*F. pennsylvanica* Marsh.
White ash	*F. americana* L.
Baldcypress	*Taxodium disticum* (l.) Rich. var. *distichum*
American beech	*Fagus grandifolia* Ehrh.
River birch	*Betula nigra* L.
Blackgum	*Nyssa sylvatica* var. *biflora* (Walt.) Sarg.
Blue-beech	*Carpinus caroliniana* Walt.
Boxelder	*Acer negundo* L.
Cottonwood	*Populus tremuloides* Michx.
Elm	*Ulmus* spp.
American elm	*U. americana* L.
Cedar elm	*U. crassifolia* Nutt.
Winged elm	*U. alata* Michx.
Hackberry	*Celtis laevigata* Willd.
	C. occidentalis L.
Hawthorn	*Crataegus* spp.
Hickory	*Carya* spp.
	C. illinoensis (Wangenh.) K. Koch
Water hickory	*C. aquatica* (Michx f.) Nutt.
American holly	*Ilex opaca* Ait
Southern magnolia	*Magnolia grandiflora* L.
Red maple	*Acer rubrum* L.
Oak	*Quercus* spp.
Cherrybark oak	*Q. falcata* var. *pagodifolia* Ell.
Delta post oak	*Q. stellata* var. *paludosa* Sarg.
Laurel oak	*Q. laurifolia* Michx.
Nuttall oak	*Q. nuttallii* Palmer
Overcup oak	*Q. lyrata* Walt.
Shumard oak	*Q. shumardii* Buckl.
Swamp chestnut oak	*Q. michauxii* Nutt.
Water oak	*Q. nigra* L.
White oak	*Q. alba* L.
Willow oak	*Q. phellos* L.
Pecan	*Carya illinoensis* (Wangenh.) K. Koch
Persimmon	*Diospyros virginiana* L.
Loblolly pine	*Pinus taeda* L.
Slash pine	*P. elliottii* Engelm.
Sweetbay	*Magnolia virginiana* L.
Sweetgum	*Liquidambar styraciflua* L.
Sycamore	*Platanus occidentalis* L.
Swamp tupelo	*Nyssa sylvatica* var. *biflora* (Walt.) Sarg.
Water tupelo	*N. aquatica* L.
WIllow	*Salix* spp.
Yellow-poplar	*Liriodendron tulipifera* L.

APPENDIX B

Definition of Terms

Flood zones—Sporadic, intermittent, nonpermanent, permanent zones.

Forest types—Community types recognized by Forest Inventory and Analysis and named by the species that comprise the majority of the stocking. These include: baldcypress-water tupelo associates include green ash, red maple, and sweetgum. This type occurs chiefly on very wet sites where surface water is present throughout the growing season in years of normal rainfall. Cottonwood associates include willow, white ash, green ash, and sycamore. Sites are along stream banks where bare moist soil is available, e.g., along river and stream margins. Hackberry-elm-ash associates include water oak, willow oak, laurel oak, sweetgum, water hickory, and boxelder. Sites are typical of river margins and moist bottoms. Overcup oak-water hickory associates include green ash, hackberry, American elm, red maple, and persimmon. Sites are in low-lying, poorly drained flats with clay or silty-clay soils. Sycamore-pecan-elm associates include boxelder, green ash, hackberry, cottonwood, willow, sweetgum, and river birch. Sites are on alluvial flood plains. Swamp chestnut oak-cherrybark oak associates include white oak, Delta post oak, Shumard oak, white ash, and hickories. Sites are on terraces or ridges in first bottoms. Sweetbay-swamp tupelo-red maple associates include slash pine, and moist site hardwood species. Sites normally have saturated soils throughout the growing season, such as along branch heads, drains, bays, and swamp borders. Sweetgum-Nuttall oak-willow oak associates include cottonwood, green ash, sycamore, pecan, American elm, red maple, and boxelder. This type occurs chiefly on sites with exposed moist soil such as stream banks and pond margins.

Saplings—Live trees with stems 2.5 to < 12.7 cm in d.b.h.

Seedlings—Live trees with stems < 2.5 cm in d.b.h. and > 3.0 cm tall for hardwoods, > 1.5 cm tall for softwoods.

Stand diameter class—A classification of the height and size of trees in a stand. Sawtimber diameter class stands are ≥50 percent stocked with live trees ≥12.7 cm d.b.h. and ≥50 percent stocked with sawtimber (≥22.9 cm softwood and ≥ 27.9 cm hardwood) trees. Poletimber stands are ≥50 percent stocked with live trees ≥12.7 cm and <50 percent stocked with sawtimber trees. Smaller diameter class stands, typically composed of saplings and seedlings, are <50 percent stocked with live trees <12.7 cm.

Stocking—Degree of occupancy of land by live trees. It is measured by basal area or number of trees by size and spacing, or both, as a percent of a specified standard, which is the basal area or number of trees, or both, required to utilize the tree growth potential of the land.