LANDSCAPE CONTEXT AND REGIONAL PATTERNS IN ARKANSAS' FORESTS

Victor A. Rudis[1]

Abstract—Recent results from Forest Inventory and Analysis (FIA) surveys provided an opportunity to explore the spatial and temporal context for Arkansas' forests, including associated range, recreation, water, and wildlife habitat resources. Noted were damage agents and multipurpose resource indicators: evidence of human-associated activities (harvesting, hunting, livestock grazing, restricted activity signs, trash dumping, etc.), land cover, forest ownership, forest fragmentation, forest type and stand-diameter class, and proximity to nonforest features. For comparison purposes, analysis was by ecological subregion (province and section): Mississippi Alluvial Basin, Western Mid-Coastal Plains, Arkansas Valley, Ouachita Mountains, Boston Mountains, and Ozark Highlands. I illustrated patterns in areas with maps of their location, tabular statistics of area frequency and change over time, and tree statistics relevant to wildlife habitat concerns. Findings noted pasture land dominating to the north, cropland uses to the east, and forest land to the west. Since the 1978 survey, continuing losses of shortleaf and increases in loblolly suggested the increased importance of remaining shortleaf stands. Some locales were prone to forest damage or more likely harvested, fragmented, grazed by livestock, disturbed by other human uses, or associated with specific forest-community types. Trash was most evident near roaded areas. Signs restricting activities associated with forests occurred in dense concentrations between extensively and sparsely forested regions. A cumulative habitat value index based on the proportion of earth (land and water) cover by community type, and weighted by 1988- to 1995 area change and community type replacement cost (in years), summarized the status, change, and landscape context. Since the 1988 survey, evidence suggested increased restricted access was the most important change. Tabular statistics summarized these and other differences by ecological subregion and selected multipurpose resource attributes.

INTRODUCTION

Like most land-based resources, nonmarket uses and income-generating opportunities from forest land depend heavily on their location. Forest land not suited for sustainable timber production often occurs in areas uneconomical to harvest. Forest resource inventories provide location information, direct measures of timber value, and indirect measures of their suitability and availability as range, recreation, and wildlife habitat resources. Together with periodic monitoring and mapping at the landscape (500- to 50,000- acre) and regional (100,000- to 10 million-acre) scale, coincident sample observations of human and other uses furnish clues to associated values and processes.

Ecological processes, such as weather shaped historic forest resource distributions, still dominate today's landscape patterns. Though rarely under individual owner control, many of these processes influence owner decision-making. Ice storms, insect outbreaks, and even animal damage seemingly occur at random within the lifetime of a forest owner's tenure but may be recurring risks in specific locales when aggregated to coarser scales. Local markets for commodities influence forest uses such as occasional livestock grazing near cattle processing plants and pine plantation establishment near wood processing plants. Indirect effects, such as sightseeing or urban development along forested travel corridors, affect timber availability, game populations, and quality forest recreation opportunities. Knowing where damage agents, markets, and indirect effects predominate, decision-makers may take steps to minimize risk or alter the mix of planned resource outputs. Knowledge of the landscape affects selection of damage-resistant species for reforestation, management to minimize negative esthetic impacts, and investment in wood production, silvopastoral operations, recreation development, and other uses.

Though designed chiefly to assess timber resources, forest inventory and monitoring surveys address range, water, wildlife, and recreation resources by evaluating the status, distribution, and change in forested landscapes. Of concern to wildlife conservation interests in forests are (1) older age community types, because they take longer to regenerate than others; (2) frequent or common community types, because they often impact more of the region's faunal populations than others; (3) rapidly changing community types, because they may precipitate an unsustainable change in selected wildlife populations; and (4) regions with a rare or a wide diversity of community types, because they may support more wildlife species and recreational opportunities for wildlife viewing. Occurrence and change in forest plantations, forest fragment size, livestock grazing, timber harvesting, and other human intrusions provide additional indices of the regional character, uses, and trends important to a range of resource users.

Indices of resource value should be technically feasible, regionally aggregated, scientifically valid, and politically important. The proportion of forest land available for production is one such index that varies with time and the surrounding landscape. Forest land in pasture-dominated landscapes is more often a producer of shade than of wood

[1] Research Forester, USDA Forest Service, Southern Research Station, Forest Inventory and Analysis Unit, Starkville, MS.

Citation for proceedings: Guldin, James M., comp. 2001. Proceedings of the symposium on Arkansas forests: a conference on the results of the recent forest survey of Arkansas; 1997 May 30–31; North Little Rock, AR. Gen. Tech. Rep. SRS–41. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 125 p.

products. Forest land in landscapes with better-than-average soil and climate for wood production is often as valuable for game production and the generation of recreational visits. Such areas recover rapidly from human intrusions and quickly produce 20–inch diameter trees needed by large-bodied birds of prey. Forest land in forest-dominated landscapes is more likely to sustain forest-dependent wildlife populations than that in landscapes dominated by nonforest uses.

Timber production may not be feasible in landscapes with small or roadless forest fragments. In larger forest fragments, bird species diversity is greater, and selected bird species are more abundant (Hunter 1990). Animals incompatible with human uses or perceived as threats, such as black bears, benefit from large forests without human access. Hunters and other primitive-oriented recreation users may value southern lowland hardwood community types more if they are part of large, unfragmented forests (Rudis 1995). Easily accessed, small forest fragments may be sufficient for picnics and other convenience-oriented recreation activities but have limited value for hunting large game animals. Criticized for lacking vegetative components essential to some wildlife populations (Allen and others 1996), pine plantations may contain fewer large-diameter trees, potential cavity trees, and food-producing species when compared with natural pine and hardwood forest types.

Changes in earth (land and water) cover and use of landscapes affect wildlife populations, recreation opportunities, and the value of remaining resources. Recently harvested landscapes are valued for fauna that need young-aged stands. Eventually, stands age and their value changes. A forested landscape with reduced access, such as a roadless area, retains greater value for those interested in conserving black bear habitat and wilderness values. Trash occurrence is a major impediment to a satisfying forest recreation experience—more than a clearcut stand or livestock grazing (Rudis 1987). Forests in landscapes dominated by roads may appear unmanaged and are viewed by some segments of the public as “undeveloped wasteland” suited for dumping household garbage.

I present indicators that reflect resource uses, the surrounding landscape context, and changes to both of these. Included are mapped patterns and tabular statistics in natural and man-made disturbances, livestock grazing, recreation opportunities, land cover, use, human use, forest fragmentation, damage agents, and wildlife habitat attributes of forest composition. Additional reports for Arkansas and other South Central States (Devall and Rudis 1991; Rudis 1991, 1993a, 1995, 1998; Rudis and Tansey 1995) provide additional, associated details about these indicators.

METHODS

I used USDA Forest Service, Forest Inventory and Analysis (FIA) survey data, mapped sampled locations with multipurpose indicators of resource value, and assembled other data in tabular form. Maps provided spatial information for a qualitative interpretation of spatially autocorrelated attributes and hypotheses about landscape scale processes.

FIA surveys gathered sample-based information about Arkansas’ earth cover, land use, and forest resources (FIA Research Work Unit 1987, 1994). Included with both 1995 and 1988 surveys was an array of indices about other forest resources. I used data primarily from the 1995 survey, incorporated estimates of change since the 1988 survey, and where possible, comparable data from the 1978 survey.

FIA estimated forest resources in three steps. First, FIA interpreted locations for forest and nonforest land use from 1:58,000 color aerial photographs for 149,300 locations throughout Arkansas. Second, crews verified forest and nonforest photointerpretation with an on-the-ground sample of 8,950 1–acre locations (London 1997). Third, crews observed and recorded land use (Anderson and others 1976) on 5,972 systematically located areas sampled at approximately 3–mile intervals.

FIA calculated area with particular attributes by summing the number of sampled locations and multiplying by the expansion factor (portion of county area that each sampled location represented). Forest land was land with ≤10 percent tree crown cover and land temporarily with <10 percent tree crown cover not developed for other uses, 1 acre in size, and ≤120 feet wide (Anderson and others 1976). Forest land capable of producing ≤20 cubic feet/acre/year of industrial wood was timberland (not reserved from timber production) or reserved forest land (reserved from timber production by public statute). Other forest land (woodland in earlier forest survey reports) did not have the potential to produce 20 cubic feet/acre/year of industrial wood due to adverse site conditions. Area estimates, measurements, and sampling variance by county referenced the 1995 (London 1997), 1988 (Hines and Vissage 1988), and 1978 (Staff of Renewable Resources Evaluation Research Work Unit 1980) surveys.

Crews inventoried forest land characteristics and uses from 1–acre samples and a subsample of trees by species, stem density, and condition. Crews tallied previously surveyed and currently live trees with ten, 37.5–square-foot basal area variable-radius prism sample for trees ≤5.0 inch in diameter at breast (4.5 feet) height (d.b.h.), and three 7.1–foot fixed-radius plots for live trees 1.0 to 4.9 inches d.b.h. Standing dead trees were ≤ 5.0 inches d.b.h., ≤4.5 feet high, and categorized by soundness (<50, ≤50 percent of sound tree volume) and species group (pines, redcedar, baldcypress, hardwoods) from one 0.1–acre fixed-radius plot within the 1–acre sample area.

Mapped and Nontraditional Data

I employed ArcView software (Environmental Systems Research Institute, Inc. 1996) to create plot attribute maps. Each sample plot represented approximately 6,000 acres, the average per-plot expansion factor. Nominal accuracy of plot locations was 1,000 feet (±300 m) for the South Central States (Rudis 1998). Attributes displayed by location permitted a qualitative interpretation of spatially autocorrelated attributes.

I used the National Hierarchical Framework of Ecological Potential (ECOMAP 1993) to compile FIA statistics for Arkansas by subregion (province and section). A province was a region primarily controlled by climatic weather patterns; a section was a subdivision of a province having broad areas of similar geomorphology, drainage patterns, topography, and regional climate (McNab and Avers 1994). Rudis (1998) assigned each ecological subregion by county according to plurality province, and within provinces to a plurality section. Using the resulting six ecological subregions permitted grouping of data with similar ecological relationships and afforded an opportunity to provide more detailed summaries for western Arkansas than was possible using the four traditional FIA Units (fig. 1).

Using recent aerial photos, FIA survey crews tallied forest fragment size associated with each forest plot sampled, proximity to nonforest land ≥10 acres (Anderson and others 1976), and water sources (≥one-eighth acre in size or ≥40 feet in width). Collecting data on forest fragmentation since 1974 in the South Central States, FIA crews indexed the potential for forest size dependent owner assistance and profitable timber harvesting (Wells and others 1974), wilderness recreation (Rudis 1986), wildlife habitat (Rudis and Tansey 1995), and other resource uses (Rudis 1995). A forest fragment was a contiguous forest ≥1 acre, unbroken and bounded by nonforest earth cover ≥120 feet wide. FIA crews estimated size with 1:20,000- and 1:40,000-scale black and white aerial photographs in the 1970s and 1:58,000-scale color aerial photographs since 1986. Crews did not consider a change in ownership, forest type, age class, land use, or nonforest areas <120 feet wide as a break in contiguous forest cover. Fragment size estimates were in broad classes (represented by midpoints in tables and figures): 1 to 10 (5), 11 to 50 (30), 51 to 100 (75), 101 to 500 (300), 501 to 2,500 (1,500), 2,500 to 5,000 (3,750), and >5,000 acres (in calculating averages, arbitrarily set to 8,208). Significant chi-square tests of association ($P(\chi^2)<0.05$) used the Pearson product-moment correlation (r) (SAS Institute Inc. 1990) to determine the association's direction and strength.

Crews recorded occurrence of fences and signs (no hunting, hunt club, hunting restricted, posted, no trespassing, keep out, or other signs indicating restricted activities) and most developed access roads (paved, dirt or gravel roads, or no roads or trails) on the way to forested plots from a nonforest area and within one-quarter mile of the plot. Crews also recorded harvest activity (clearcut, selective cut, salvage), slope (in percent), seasonal water sources, trash (paper, glass, metal, or plastic beverage or food containers; other bottles, cans, glass, or metal containers of unknown contents; discarded machinery and other objects not in use). They based estimates of garbage or trash dumping on the amount and arrangement of trash, fire or recent trail or road use on tire marks and damage to vegetation structure, and tree damage on new growth of overstory stems. For each plot, crews recorded livestock evidence if they observed cattle or other livestock, their tracks, dung, trails, or other physical evidence of livestock occurrence; and hunting evidence if they observed a tree stand, shotgun or rifle shell, or other evidence of hunting activity. I classified plots that were part of a contiguous

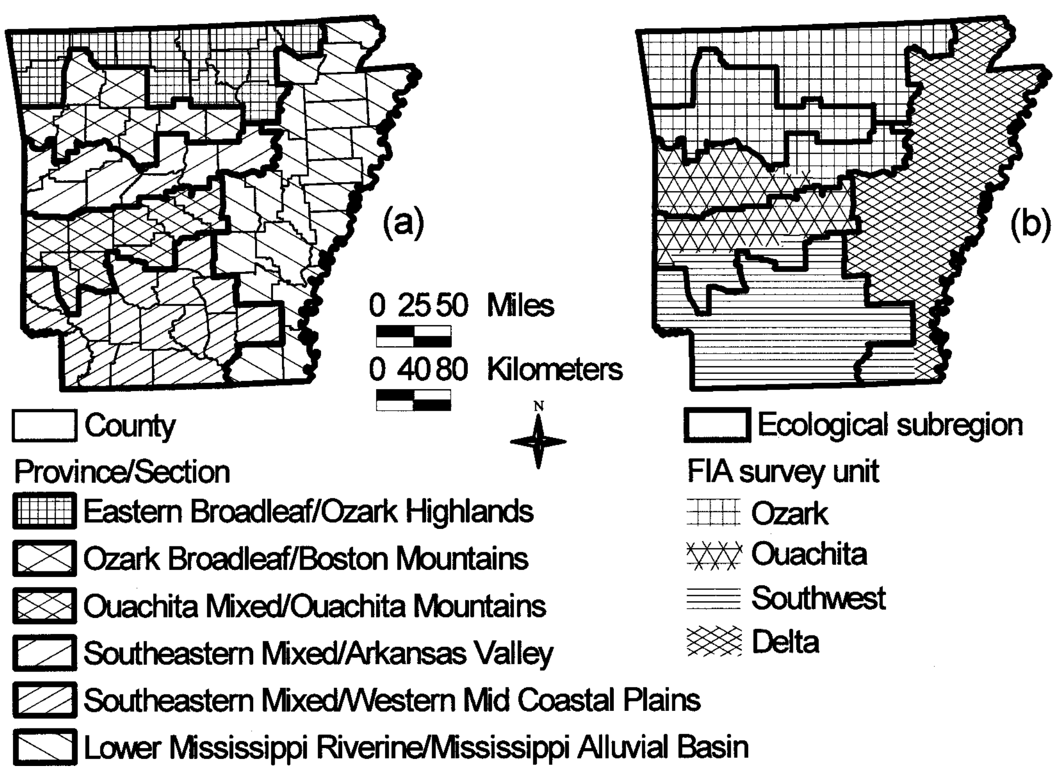

Figure 1—Arkansas divisions by ecological subregion (province and section) and (a) county, (b) Forest Inventory and Analysis survey units.

>2,500–acre forest, one-half mile or more from truck-operable roads, and without trash, as having a primitive recreation opportunity.

I reassembled existing FIA plot and tree information to address important aspects of wildlife habitat in forests. These included FIA area statistics by forest type and stand diameter (stand size in timber-oriented publications) class, and estimates of potential mast producing tree species and dead (potential den) tree stem density by tree condition, species, and diameter class. Other wildlife characterization was lacking, however, as there was no inventory concurrent with the Arkansas FIA survey to account for understory shrubs, vines, herbaceous species, fruit production, or animal populations.

Value Indices

To incorporate the landscape context, I used area and change statistics to create a cumulative habitat evaluation value index (hereinafter value index) that was modeled after Graber and Graber's (1976) and Iverson and others' (1989) assessment of generic bird habitat. Essentially, the largest value indices were in subregions with a large proportion of earth cover in forests and with rapidly declining, older community types; the smallest value indices were in subregions with a small proportion of earth cover in forests with rapidly increasing, older community types. To minimize truncated variability and obtain more normally distributed expected values, I modified calculations of the value index to accept negative sums and used Naperian logarithms (base e) to reduce geometric variability.

The value index was earth cover frequency by community type, weighted by its vulnerability and cost (age, in years) to replace it. A larger weight occurred with a more vulnerable (scarce, declining) and older community type, and a smaller weight to a less vulnerable (common, increasing) and younger community type. Scarcity was the log (total earth cover/community type). To incorporate a frequency term, I used - p(log(p)) where p was the proportion of the subregion's area in a particular type. A subregion's landscape diversity (D) was D = sum(- p(log(p))) .

I used a simplified schedule of the cost, in years, to replace the community type from a clearcut condition. Stand-diameter class (also known as stand-size class in timber-oriented publications) was a proxy for this time period. If forested, I assigned replacement time by forest type and stand-diameter class: sapling-seedling, 10 years; poletimber, 20 years; pine sawtimber plantations, 30 years; oak-pine sawtimber stands, 40 years; and hardwood stands, 50 years. I arbitrarily assigned nontimberland (productive-reserved and other forest land) a 10–year replacement time; nonforest land (agriculture and urban land) a 2–year replacement time; and water a 1–year replacement time.

The forest attribute-neutral index for a region reflected the status and change in forest area by community type. Forest attribute-specific indices reflected forested area with a particular context or disturbance feature. Preliminary assessment suggested a logarithmic distribution for the expected range of value indices. As an interim guide for this report, I defined important attribute-specific value indices as those 80 percent or more different from the attribute-neutral index.

Attributes featured were multipurpose, like forests associated with water, or indicators identified with range, recreation opportunities, and wildlife habitats. Context attributes were: forests that were part of forest fragments >2,500 acres, forests ≤1 mile from urban or built-up land, those ≤one-eighth mile from agricultural land, and those within one-fourth mile of paved roads, water sources, all roads or trails, signs restricting activities, and fences. Other attributes were: forests with livestock use, permanent water, trash, and with recent ≤2 years) fire evidence, logging activity, and trail or road use. A forest area with primitive recreation potential was a forest area with no trash, no recent trail or road use, and part of forest fragments >2,500 acres.

RESULTS

Land Use

Forest land was the majority earth cover in all but the Mississippi Alluvial Basin subregion. Timberland represented 98 percent of Arkansas' forest land. Reserved forest land and other forest land each represented about 1 percent of the forest land, with most in the north and western subregions (table 1). Nonforest land was primarily cropland to the east and pastureland to the north and west (fig. 2).

On forest land, slopes averaged 10 percent statewide. The Mississippi Alluvial Basin (MAB) and Western Mid-Coastal Plains (WMCP) subregions had the most level terrain (≤4 percent slope) and the greatest average potential wood productivity (≥100 cubic feet/acre/year). Representing averages for up to nine plots, mapped data on potential wood productivity illustrate the spatial detail (fig. 3).

Pine plantations represented more of the forest land in the WMCP (20 percent) and Ouachita Mountains (30 percent) than in other subregions. Most planted stands were loblolly pine, situated in southwest Arkansas (fig. 4) and in landscapes dominated by forest industry ownership (fig. 5). Results corroborated a 1988 report (Beltz and others 1992) that noted 69 percent of Arkansas's pine plantations on forest industry land.

Livestock evidence occurred on 9 percent of the forest land, with greatest concentration in the Ozark Highlands (23 percent) subregion. Much of the standing timber may have been incidental to livestock feeding operations, as the majority of forest land with livestock evidence was in landscapes dominated by nearby pastureland (fig. 6) and low potential wood productivity (fig. 3). These landscapes had extensive areas of farm ownership (fig. 5) and limited evidence of recent commercial harvest or timber management activity. Most (90 percent) forest land area with livestock evidence was in upland forests, with more than half in oak-hickory forest type.

Table 1—Area of earth (land use and water) cover, forest land-use class, and percent reserved by ecological subregion, Arkansas 1995

Ecological subregion	Earth cover	All forest land	Unreserved forest land: Timberland	Unreserved forest land: Other forest[a]	Reserved forest land: Area	Reserved forest land: Proportion
	1,000 acres					*Percent*
Mississippi Alluvial Basin	10,088	2,502	2,498	0	4	0.2
Western Mid-Coastal Plains	7,142	5,600	5,597	0	3	.0
Arkansas Valley	3,813	2,313	2,273	19	22	1.0
Ouachita Mountains	3,691	2,679	2,632	11	37	1.3
Boston Mountains	3,657	2,523	2,407	24	92	3.8
Ozark Highlands	5,646	3,173	2,986	113	75	2.5
Statewide	34,037	18,790	18,392	167	231	1.3

Rows and columns may not sum to totals due to rounding.
[a] < 20 ft^3/acre/year, a.k.a. woodland in prior reports.

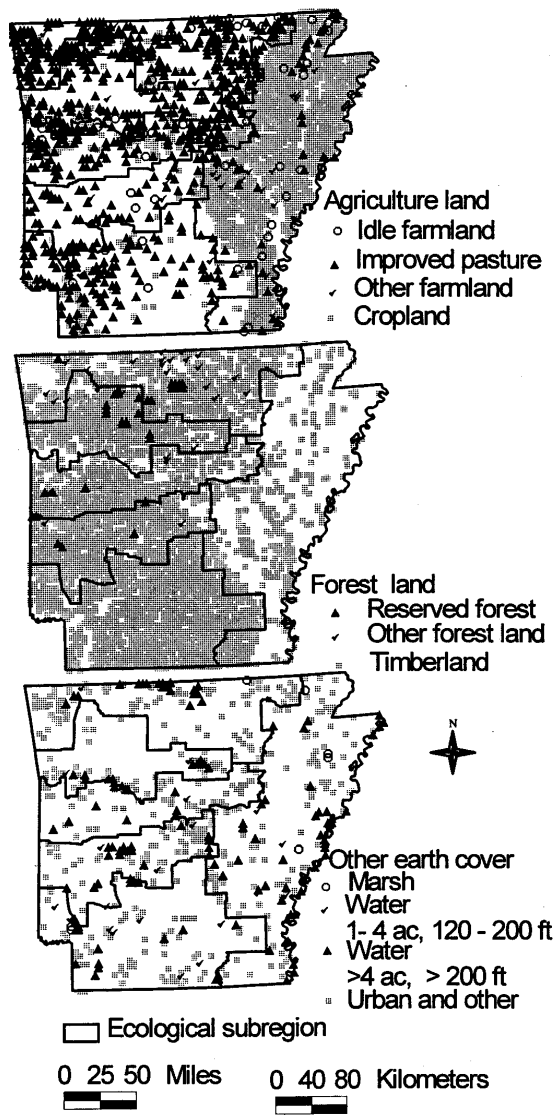

Figure 2—Land and water area by land use class, Arkansas 1995.

Hunting evidence occurred on 10 percent of the forests statewide, with the greatest concentration in the more wood-productive MAB subregion (24 percent). Areas with the most potential for active agroforestry operations (occasional livestock grazing with active timber production and limited hunting activity) were most likely on the few pine-growing areas with nearby pastures.

Comparing classifications between the six ecological subregions and the traditional four survey units (Delta, Southwest, Ouachita, and Ozark) showed ecological subregions afforded a more detailed portrait of land in west central and northwest Arkansas (table 2, fig. 7a, b). Area statistics tabulated from the 1995 survey by either classification method were similar when estimated by forest land or timberland, because forested nontimberland area represented only a small fraction (2 percent) of the forest land (table 2).

Selected Human Uses on Forest Land

A qualitative examination of spatial patterns by harvest activity suggested that partial cutting was the dominant activity for the 1978 to 1988 and 1988 to 1995 periods (fig. 8). The WMCP and Ouachita Mountains received the most harvest activity for both periods. Areas in Howard, Pike, and Saline Counties (Ouachita Mountains) in 1988 had a notably dense pattern of clearcut harvests that was absent by the time of the 1995 survey.

Crews found trash (miscellaneous litter of human origin) on 37 percent of forest land throughout Arkansas forests in 1995, up from 29 percent in 1988. Garbage or trash dumping—a subset of trash based on a field interpretation of abundant and dense concentration of litter of human origin occurred on 6 percent of the forest land in 1995. Garbage or trash dumping occurrence patterns appeared to follow the road network (fig. 9).

Twenty-six percent of Arkansas' forest land had restricted-activity signs in 1995. Many signs in 1995 occurred near the border between the MAB and the largely upland ecological

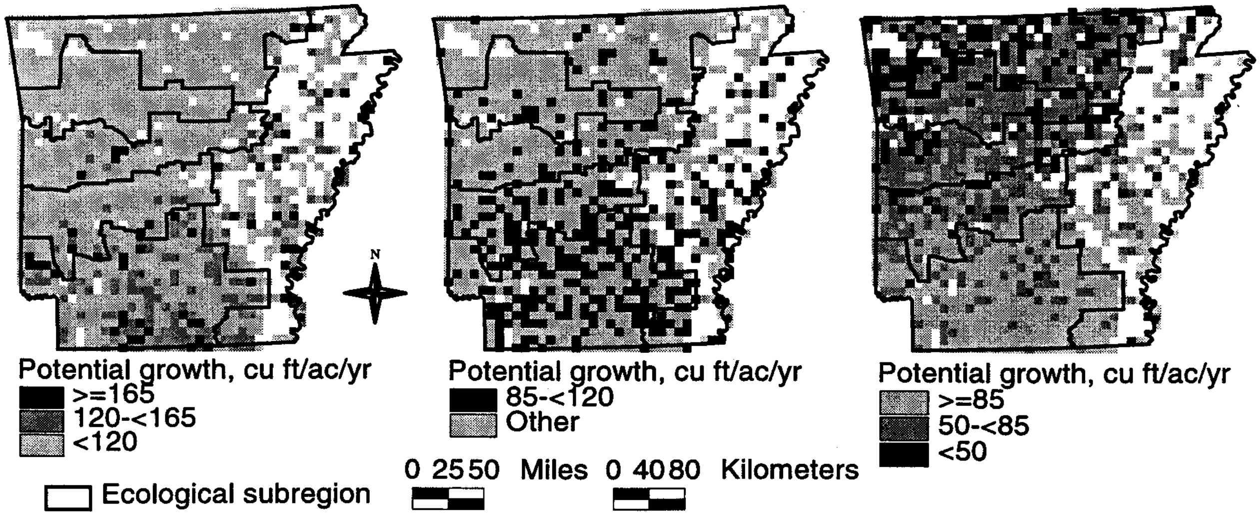

Figure 3—Average forest site productivity class, Arkansas 1995. Each 9-mile by 9-mile cell had a value representing the plurality site productivity class from up to nine adjacent forested plots.

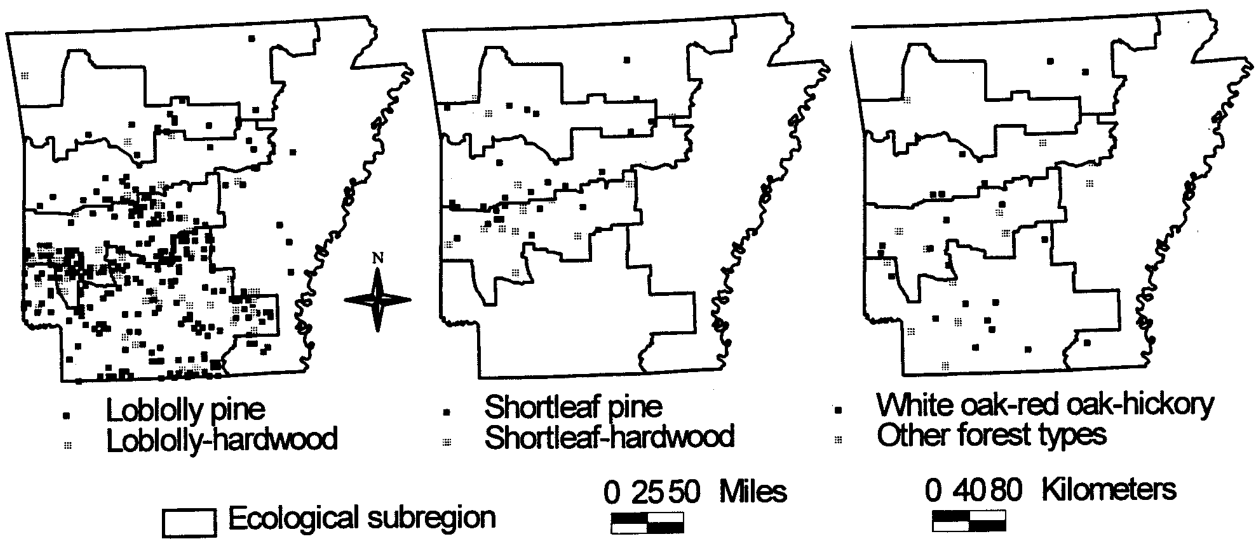

Figure 4—Forest plots in plantations by forest type, Arkansas 1995.

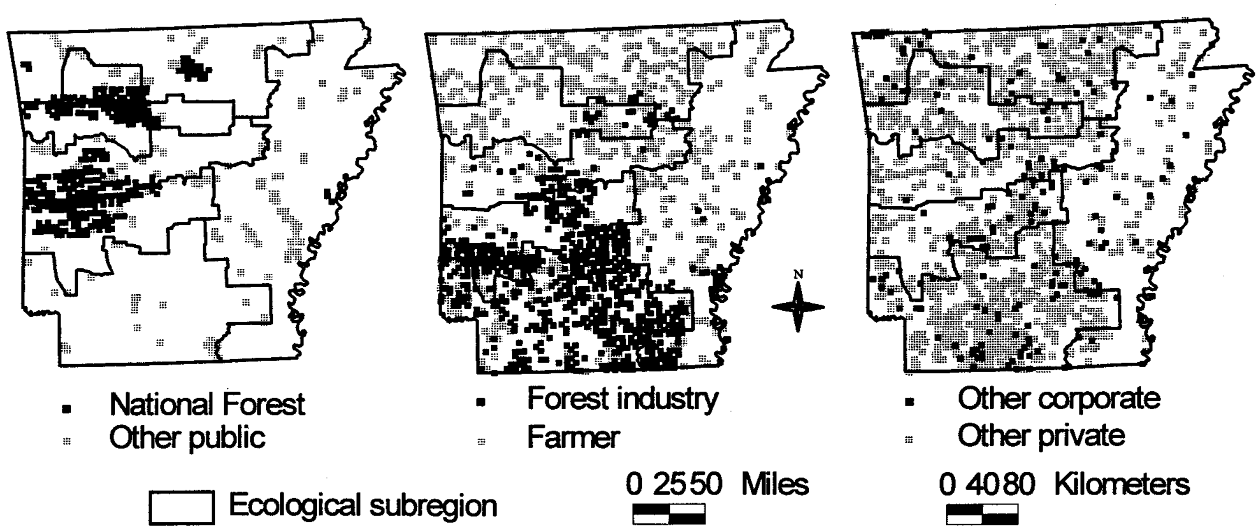

Figure 5—Forest plots by ownership class, Arkansas 1995.

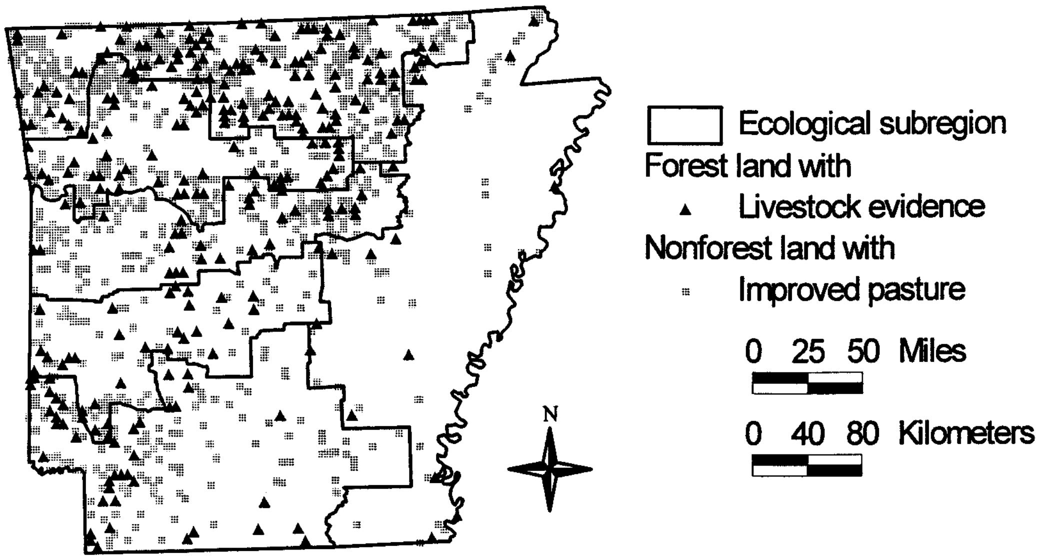

Figure 6—Forest plots with livestock grazing evidence and nonforest land with improved pasture, Arkansas 1995.

Table 2—Proportion of earth cover and average potential productivity and slope, and proportion in planted stands, with livestock evidence, and with hunting evidence by ecological subregion and Forest Inventory and Analysis Unit, Arkansas forest land (timberland), 1995

		Average		Proportion		
Group and subgroup	Proportion of earth cover	Potential productivity	Slope	Planted stands	Livestock evidence	Hunting evidence
	Percent	*Ft³/ac/yr*	*Percent*			
Ecological subregion						
Mississippi Alluvial Basin	25 (25)	110 (110)	3 (3)	5 (5)	4 (4)	24 (24)
Western Mid-Coastal Plain	78 (78)	115 (116)	4 (4)	20 (20)	4 (4)	9 (9)
Arkansas Valley	61 (60)	73 (73)	12 (12)	9 (10)	7 (7)	7 (7)
Ouachita Mountains	73 (71)	84 (85)	14 (14)	30 (30)	7 (7)	7 (7)
Boston Mountains	70 (66)	61 (62)	19 (18)	5 (5)	13 (13)	6 (6)
Ozark Highlands	56 (53)	56 (58)	17 (16)	2 (2)	23 (23)	8 (8)
Forest Inventory and Analysis (FIA) Unit						
Delta	22 (22)	108 (108)	3 (3)	4 (4)	5 (5)	27 (27)
Southwest	77 (77)	114 (114)	4 (4)	22 (22)	4 (4)	9 (9)
Ouachita	71 (70)	75 (76)	15 (15)	17 (17)	6 (6)	5 (5)
Ozark	59 (56)	59 (61)	16 (16)	4 (4)	18 (18)	8 (8)
Statewide						
Forest land (timberland)	55 (54)	88 (89)	10 (10)	13 (13)	9 (9)	10 (10)

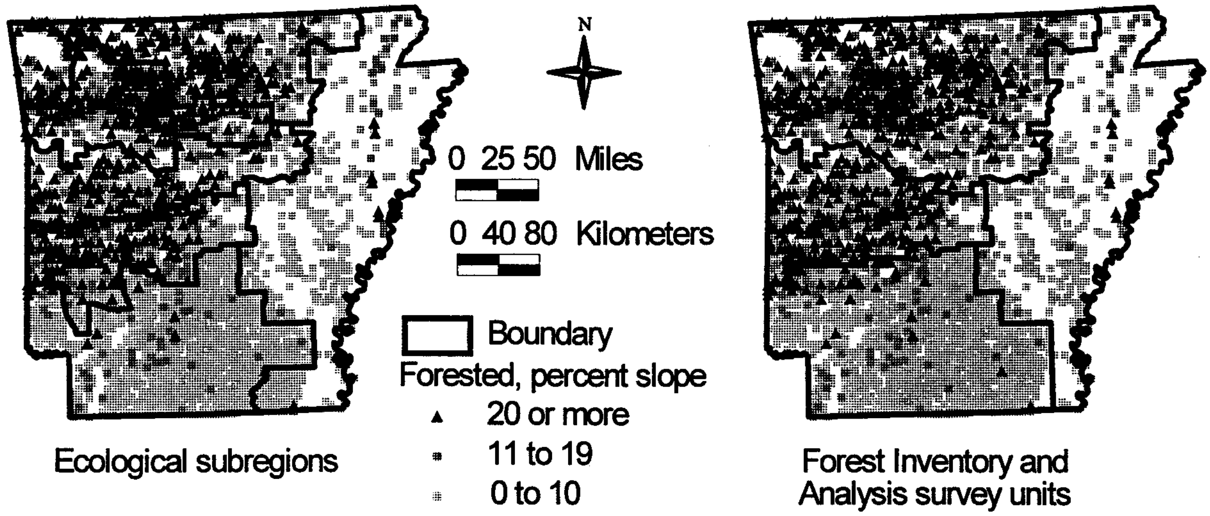

Figure 7—Forest plots by percent slope, Arkansas 1995, by ecological subregion and Forest Inventory and Analysis survey unit.

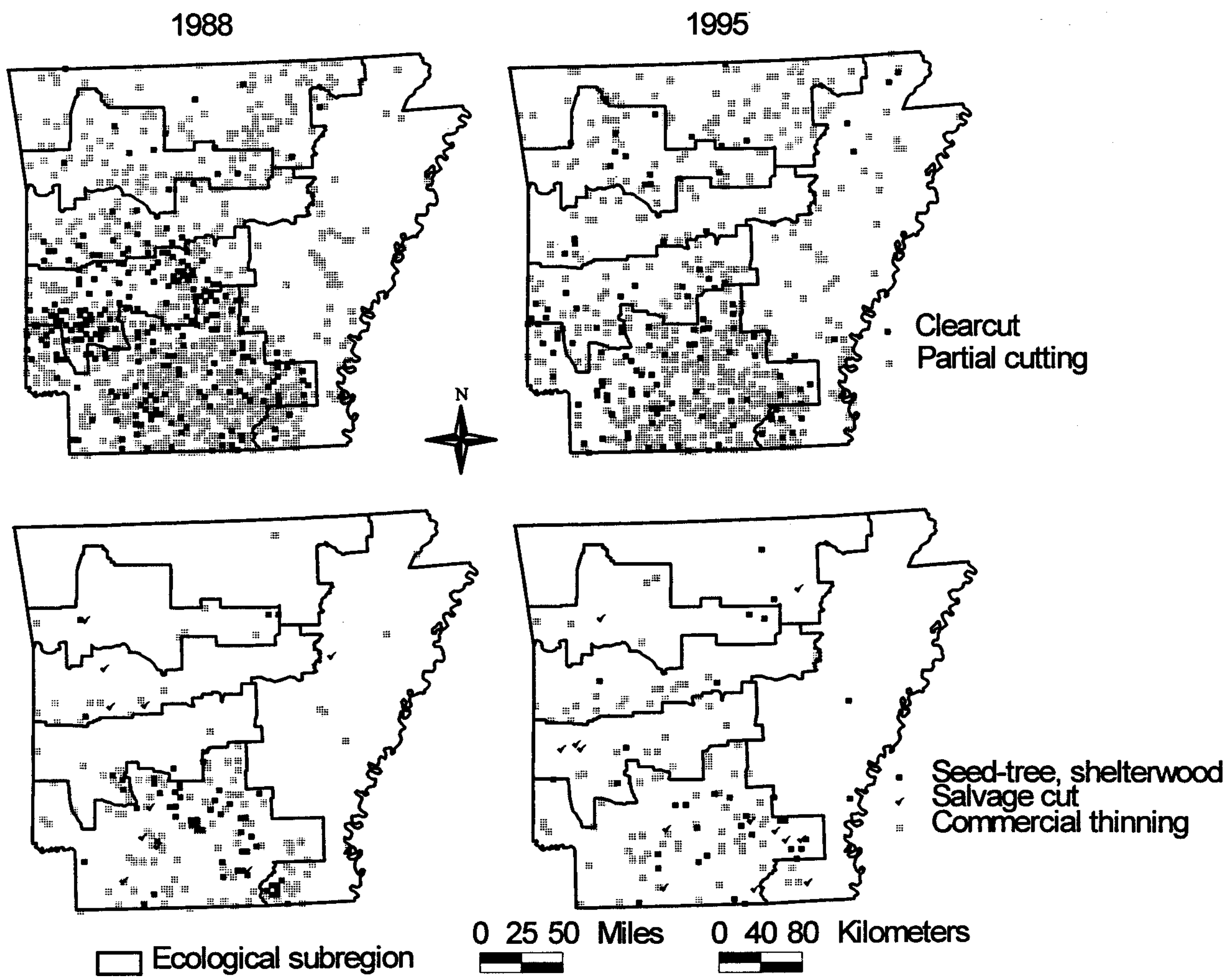

Figure 8—Forest plots with harvest activity by type of activity since the previous survey, Arkansas 1988 (period 1978–88) and 1995 (period 1988–95).

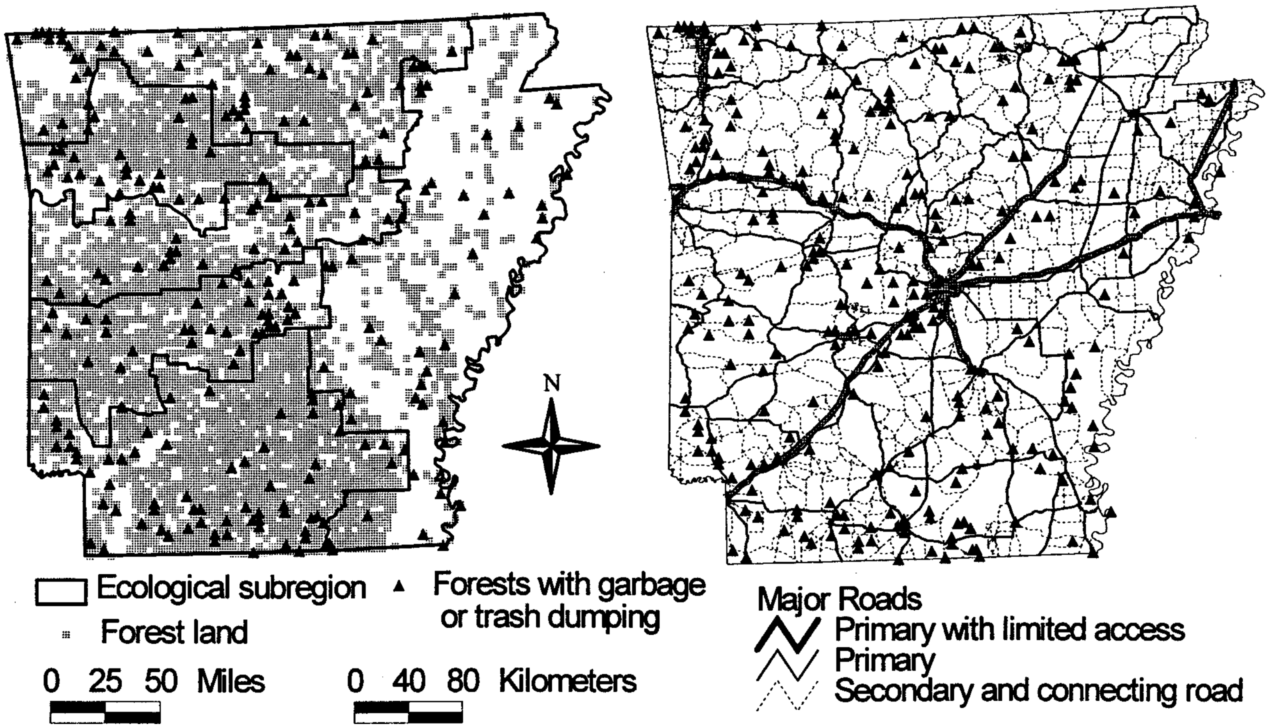

Figure 9—Forest plots with garbage or trash dumping evidence, Arkansas 1995, with forest plots and major connecting roads.

subregions to the west. The 1995 estimate was two times the percentage of the 1988 survey (fig. 10). Dense concentrations were in the WMCP south of Little Rock in both 1988 and 1995. The recent widespread use of purple paint as an indicator of posted land, rather than lettered signs, may have contributed to some of the increase between surveys. Nevertheless, patterns in this indicator suggested increasing owner interest in private, or fee-paid hunting, and trespass concerns in selected locales. Implicit in this finding is the suggestion that there was a reduction in the supply of publicly-accessible recreation opportunities on private land.

Hunting activity evidence was widespread (fig. 11a, b). Hunting evidence increased from 7 to 10 percent of the forest land since the 1988 survey. Areas with a dense

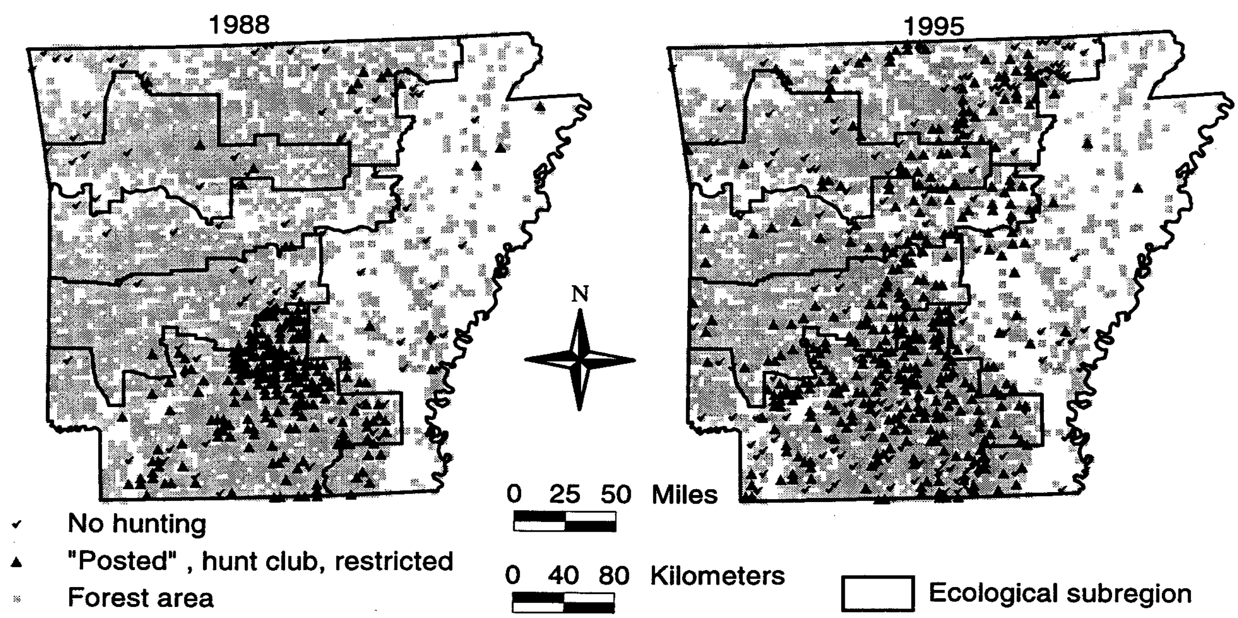

Figure 10—Forest plots within one-quarter mile of hunting activity restricted signs (posted, no hunting, hunt club), Arkansas 1988 and 1995.

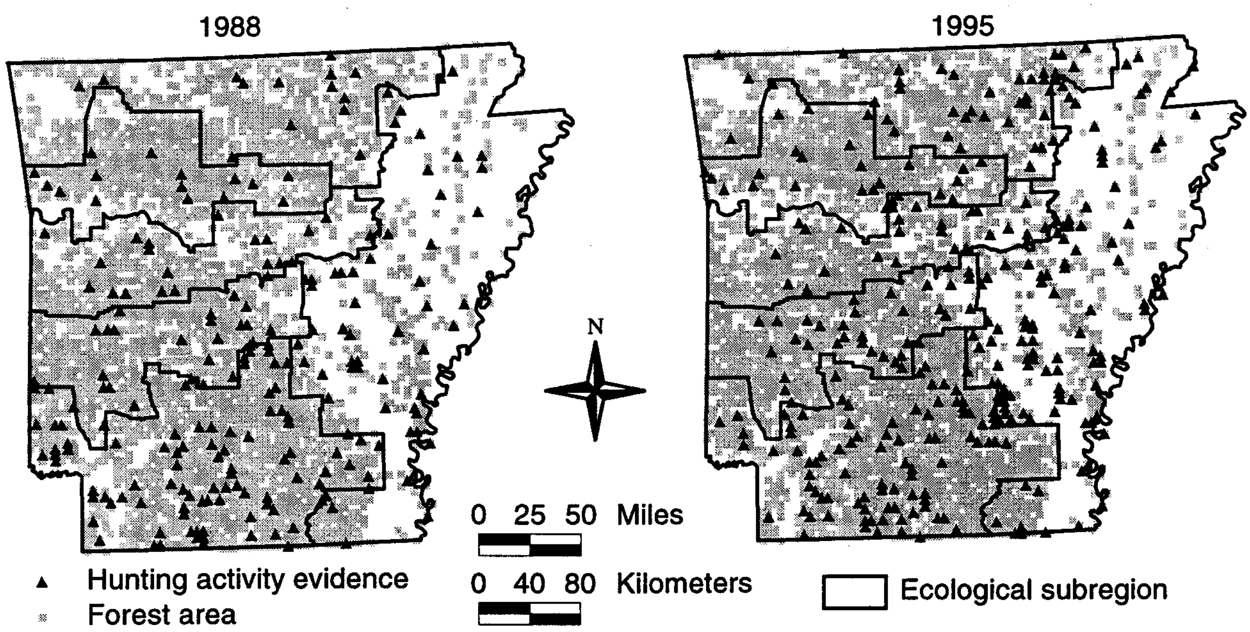

Figure 11—Forest plots and locations with hunting evidence (tree stands, shells, or other evidence), Arkansas 1988 and 1995.

concentration of hunting evidence were between areas of large, forested and large, nonforested landscapes. Comparisons between areas with dense hunting evidence (fig. 11) and restricted-activity signs (fig. 10) suggested that forest land able to satisfy hunter demand was increasingly becoming accessible only on a fee-paid or specific-permission basis.

Forest Fragmentation

In Arkansas, many of the fragments were in the range of 501 to 2,500 acres (table 3). Most of the largest fragments were in the Boston Mountains and the WMCP, and the smallest in the MAB, Ouachita Mountains, and Ozark Highlands (fig. 12). Average forest fragment size statewide was 1,985 acres. By subregion, averages were: Boston Mountains, 2,983; Arkansas Valley, 2,103; WMCP, 2,037; Ouachita Mountains, 1,856; MAB 1,554; and Ozark Highlands, 1,463.

There was a net decline in forest fragment size between 1978 and 1995, with increases between 1988 and 1995 primarily in the mid-sized fragment category (table 4, fig. 13). For the MAB, fragment size changes were significant between 1978 and 1995, but the change in direction was

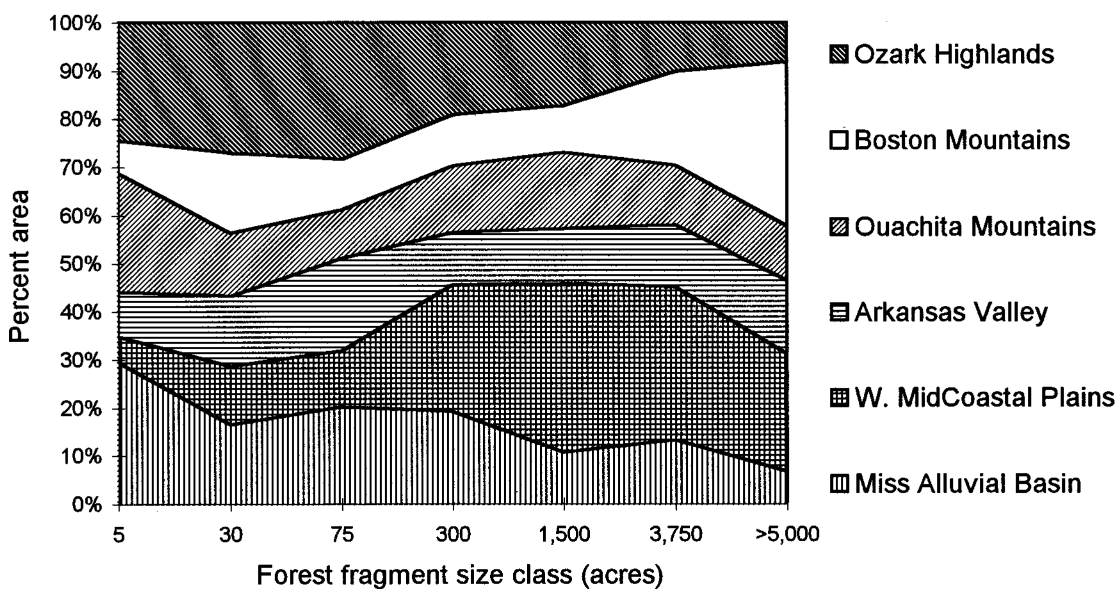

Figure 12—Proportion of forest area by forest fragment size class, Arkansas 1995.

Table 3—Area of forest land and timberland by forest fragment size class and ecological subregion, Arkansas 1995

Land use and size of forest fragment	All subregions	Mississippi Alluvial Basin	Western Mid-Coastal Plains	Arkansas Valley	Mountains		Ozark Highlands
					Ouachita	Boston	
Forest land							
Fragment size	*1,000 acres*						
1–10	202	60	11	19	50	13	50
11–50	708	117	86	103	93	118	192
51–100	1,005	203	117	194	100	106	285
101–500	3,538	676	938	385	489	375	675
501–2,500	9,010	970	3,170	1,020	1,427	863	1,561
2,501–5,000	2,889	381	923	372	359	560	294
>5,000	1,437	96	353	220	162	489	118
All forest land	18,790	2,502	5,600	2,313	2,679	2,523	3,173
Timberland							
Fragment size	*1,000 acres*						
1–10	196	60	11	12	50	13	50
11–50	697	117	86	103	87	112	191
51–100	940	199	117	187	100	91	245
101–500	3,509	676	938	385	489	368	652
501–2,500	8,911	970	3,168	1,015	1,420	843	1,495
2,501–5,000	2,818	381	923	369	351	524	269
>5,000	1,322	96	353	200	135	455	83
All timberland	18,392	2,498	5,597	2,273	2,632	2,407	2,986

Rows and columns may not sum to totals due to rounding.

Table 4—Sample size, tests of association between increasing fragment size class and survey year by ecological subregion, Arkansas timberland

Survey period	All subregions	Mississippi Alluvial Basin	Western Mid-Coastal Plains	Arkansas Valley	Mountains		Ozark Highlands
					Ouachita	Boston	
	Sample size, chi-square, Pearson r (x100)						
1978–88	5995, 49, -7	789, 13, NS	1864, 33, -12	699, 18, NS	909, 23, -14	824, 17, NS	910, 33, -9
1988–95	6195, 41, +3	826, 15, NS	1905, 36, +13	753, 13, NS	915, 13, NS	826, 13, NS	970, 4, NA
1978, 88, 95	9130, 86, -3	1218, 29, NS	2823, 48, NS	1088, 53, NS	1369, 37, -9	1229, 27, NS	1403, 55, -8

$P(X^2>15) = 0.01$, $P(X^2>13) = 0.025$, $P(X^2>11) = 0.05$ with 5 degrees of freedom. Fragment size classes 1–10 and 11–50 acres were combined. Unless otherwise noted, Pearson r ±2 standard errors > 0.
NA = $P(X^2<11) = > 0.05$, Pearson r not applicable. NS = Not significant, Pearson ±2 standard errors include 0.

not significantly different from zero (table 4). Increases occurred in mid-sized classes and declined in the 5,000+ acre class—a pattern similar to that found in the MAB encompassing portions of Arkansas, Louisiana, and Mississippi (Rudis, in press). For the WMCP, fragment size declined between 1978 and 1988 followed by an increase between 1988 and 1995. A net decline in fragment size occurred between 1978 and 1995 for the Ouachita Mountains and Ozark Highlands. In the Arkansas Valley and Boston Mountains, fragment-size distribution was significantly different between 1978 and 1995, but direction was not significantly different from zero.

Landscapes dominated by public ownership retained the largest fragments between 1978 and 1995 (compare fig. 14 with fig. 5). Landscapes dominated by other ownerships varied in fragment size during the period. For areas that declined then increased in fragment size, the temporary

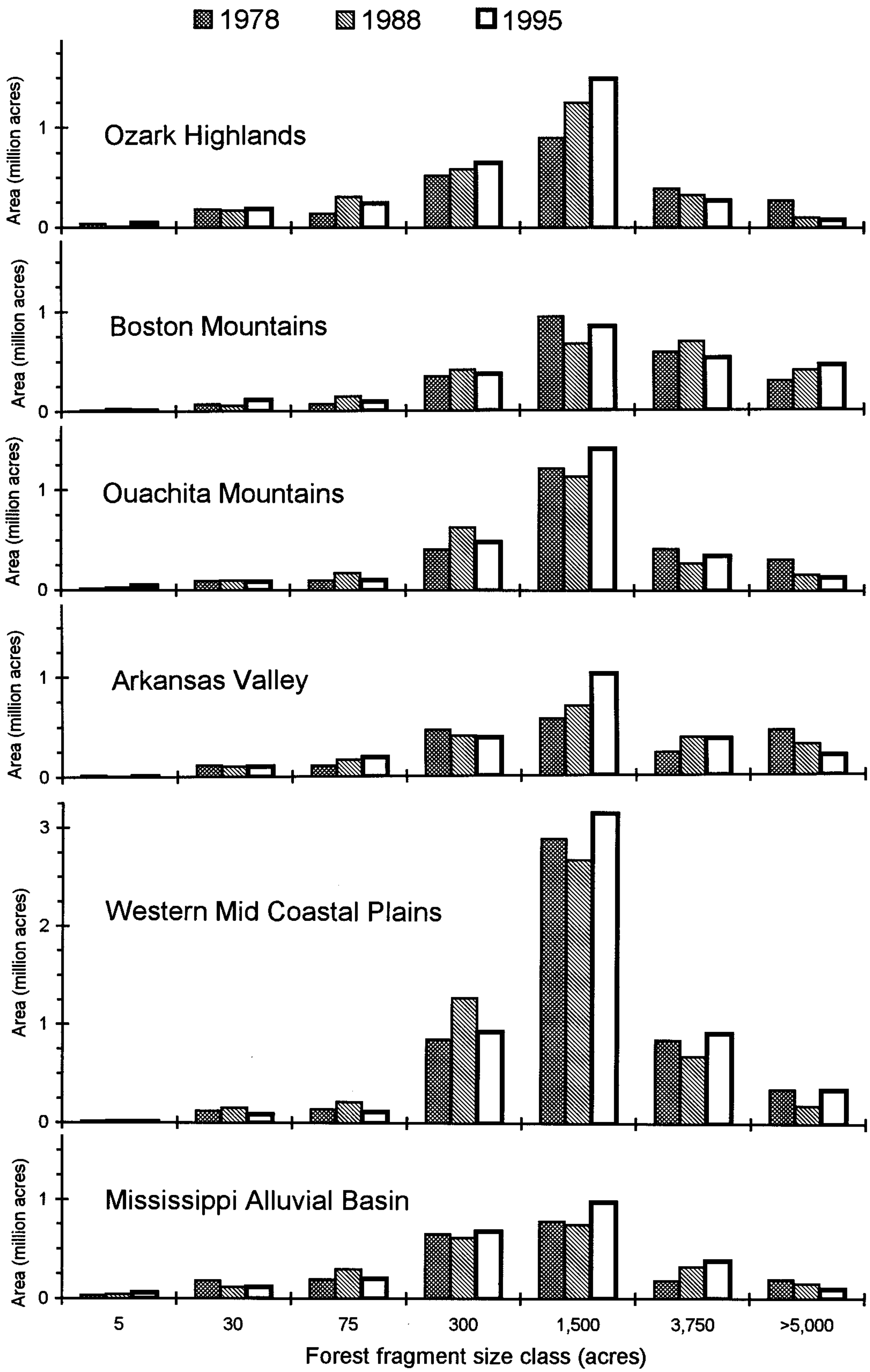

Figure 13—Forest area by forest fragment size class and ecological subregion, Arkansas 1978, 1988, and 1995.

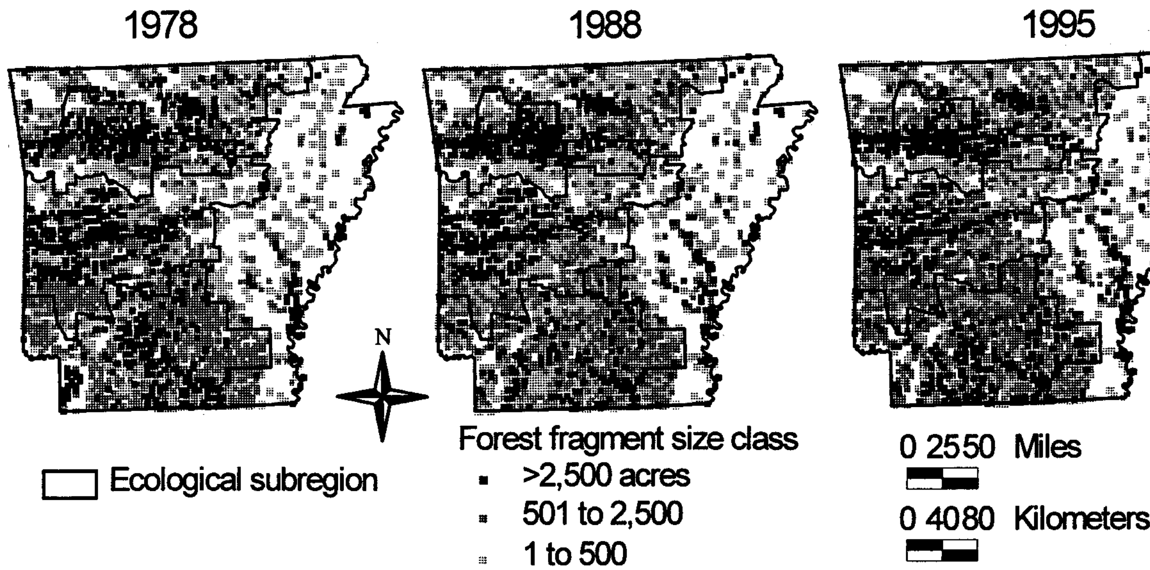

Figure 14—Forest plots by forest fragment size class, Arkansas 1978, 1988, and 1995.

fragmention was probably a result of periodically intense forest management impacts. In areas with young plantations or recently clearcut harvest areas (e.g., landscapes in Howard, Pike, and Saline Counties in 1988), forest fragment boundaries were probably the temporary logging roads used in clearcut harvest operations and narrow access roads used in young plantation management operations. Boundaries became obscured in formerly harvested areas with the passage of time as temporary roads regenerated, nonforest boundary width diminished, and forests (primarily tree branches) covered formerly wider access roads.

Forest Composition

Forest types in Arkansas generally were pine types to the south, oak-hickory type to the north, and lowland hardwood to the east. Figure 15 shows the distribution of food-producing tree species by region and species group. Stem

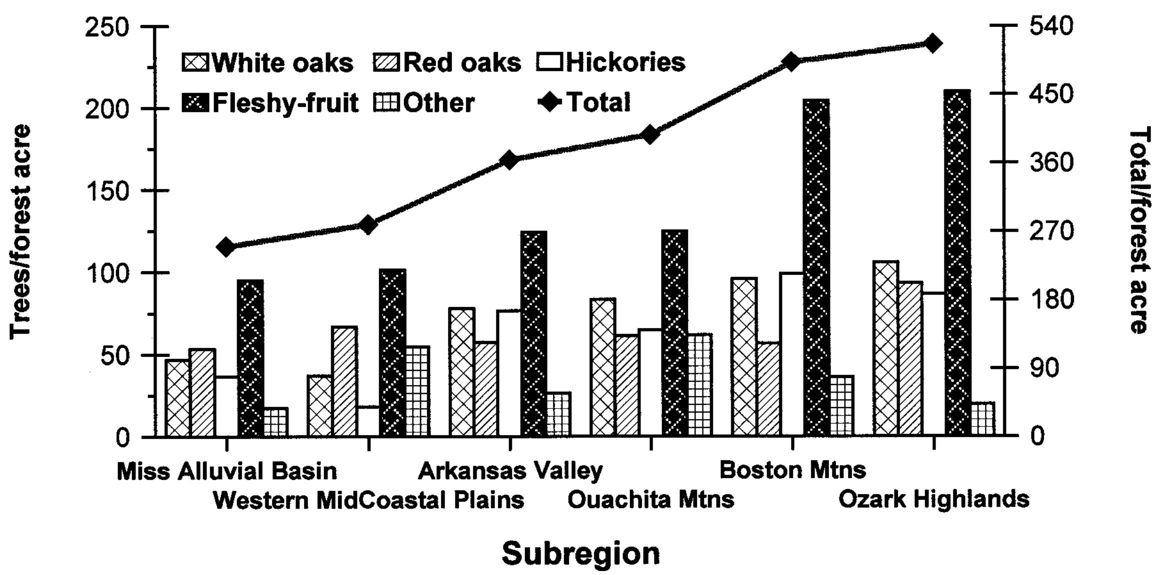

Figure 15—Density of 1.0 inch and larger diameter of food-producing trees by subregion and species group, Arkansas forests, 1995. Within groups, species composition was in descending importance. White oaks: White, post, overcup, chinkapin, swamp chestnut, bur, shingle, Delta post, Durand. Red oaks: Southern red, black, water, Northern red, blackjack, willow, cherrybark, Nuttall, shumard, laurel, pin, bluejack, live. Hickories: Black, mockernut, pignut, shagbark, bitternut, water, pecan, shellbark, nutmeg. Fleshy-fruit species: Flowering dogwood, blackgum, eastern and southern redcedar, common persimmon, American holly, sugarberry and hackberry, sassafras, serviceberry, red mulberry, hawthorn, other cherry and plum species, sparkleberry, water tupelo, white mulberry, swamp tupelo, redbay, apple, chinaberry. Other: Nut-bearing (other than oak and hickory): ironwood, bluebeech, American beech, Black walnut, buckeye, chinkapin, Ohio buckeye, Allegheny chinkapin, butternut; Cone-like: sweetbay, bigleaf magnolia, cucumbertree; Leguminous: honeylocust, black locust, waterlocust, Kentucky coffeetree. Nomenclature follows Little (1979).

density of most food-producing stems, particularly fleshy-fruit species, dominated northern Arkansas.

Wildlife Habitat Attributes—Densities of potential cavity trees, i.e., live trees ≥5 inches d.b.h. and more than one-third of gross volume in a rotten condition, and standing dead trees ≥5 inches d.b.h., were greatest in poletimber and sawtimber hardwood forest-community types (table 5). Large-diameter ≥19.0 inches d.b.h.) density of both live and dead trees was greatest in sawtimber stands (table 5). Planted pine stands had fewer dead trees than natural pine stands, regardless of stand-diameter class.

One-half of potential cavity trees were rotten or dead but ≥50 percent sounds—qualities suggesting greater value for cavity nesters. Tree density varied more by forest type and stand-diameter class than by tree condition, however. Sawtimber- and poletimber-sized stands and hardwood forest types favored an abundance of potential cavity trees. More than three times the density of potential cavity trees occurred in poletimber-sized natural than in plantation pine stands; differences were not as great with other diameter-class stands.

Damage Agents—The 1995 Arkansas survey included damage agents associated with the primary cause of tree

Table 5—Sample size, forest area, and number of live, rotten, and dead trees by diameter at breast height class (d.b.h. in inches) by forest type, stand diameter class, and condition, Arkansas forest land, 1995

Stand diameter and forest type	Sample size	Forest area	Live trees, d.b.h.			Standing dead ≥5.0	
			5.0–18.9	≥19.0	Rotten ≥5.0	≥50% sound	<50% sound
		1,000 acres	*Trees/100 acres*				
Sawtimber stands							
Planted pine	82	467	16,545	154	30	235	97
Natural pine	382	2,212	15,704	268	71	298	237
Oak-pine	204	1,180	14,819	394	168	175	396
Oak-hickory	484	2,764	12,205	541	360	183	527
Lowland hardwood							
Seasonally wet	315	1,886	11,230	988	230	190	535
Permanently wet	28	165	12,829	1,102	324	229	875
Total	1,495	8,673	13,486	538	215	216	420
Poletimber stands							
Planted pine	146	827	29,885	14	13	110	99
Natural pine	99	523	23,472	71	147	411	251
Oak-pine	184	1,079	18,399	125	206	209	343
Oak-hickory	464	2,740	17,056	144	311	169	483
Lowland hardwood							
Seasonally wet	72	440	16,307	277	144	432	390
Permanently wet	3	17	30,788	213	144	0	0
Total	968	5,626	19,777	125	218	211	369
Nonstocked, sapling, and seedling stands							
Planted pine	96	546	6,509	14	43	94	215
Natural pine	103	602	6,280	97	61	192	421
Oak-pine	159	947	6,871	85	74	111	218
Oak-hickory	316	1,856	5,444	71	92	86	214
Lowland hardwood							
Seasonally wet, mixed	87	505	4,135	135	137	52	216
Permanently wet	5	29	3,284	159	74	176	704
Nontyped and nonstocked	1	6	0	0	0	0	0
Total	767	4,491	5,825	78	83	103	246
All types and sizes	3,230	18,790	13,537	305	185	188	363

Rows and columns may not sum to totals due to rounding.

death. Maps of three of these—ice, southern pine beetle, and beavers—suggested spatial dependence of occurrence patterns. Plots with evidence of ice damage were in southeastern Arkansas (fig. 16a). Those with southern pine beetle damage occurred primarily in the WMCP (fig. 16b). Selected areas had plots with beaver damage (fig. 16c), but I had no readily-available information on minor drainage areas to assess associations. The co-occurrence of ice and southern pine beetle damage in southeast Arkansas suggested spatial dependence but was not definitive.

Patterns in Forest Composition—Mapped FIA data on forest composition suggested changes in the distribution of forest types (fig. 17). Between 1978 and 1995 surveys, increases were notable in eastern redcedar-hardwood and oak-hickory types. Most notable, however, were increases in the distribution of loblolly pine and declines in shortleaf pine types between 1978 and 1995. Dominated by forest industry ownership (fig. 5), forest land within the Ouachita Mountains subregion (specifically Howard, Pike, and Saline Counties) underwent a major transformation. In 1978, shortleaf pine dominated these areas. Extensive clearcut harvest activity occurred in these areas for the 1978 to 1988 period (fig. 8). By 1995 many of the same areas were planted in loblolly pine.

Area and Value Indices

Area and percent change, scarcity, frequency, and landscape diversity by community type are straightforward multipurpose indices for a number of interdisciplinary applications. Coupled with these are value indices, which essentially summarize the status, change since the last survey, and landscape context for timberland (table 6) and earth cover (table 7).

Findings based on statewide area change revealed that forest land with fire, primitive recreation opportunities, or livestock evidence or with no trash, nearby fences, or roads was declining (table 8). Forest land near urban areas, permanent water, paved roads, and agricultural land, as well as the occurrence of large forest fragments was increasing. Also increasing was forest land with recent trail or road use, water sources, restrictive activity signs, and with no recent logging activity. The largest value index suggested forests with no trash were rapidly declining among older community types, and the smallest index suggested forests with restrictive activity signs were rapidly increasing among older community types. Restricted-activity signs was the one attribute that had an important (≥80 percent different) shift when compared with the statewide index (table 8).

Contrasts in value indices among subregions by attribute suggested their comparative age, change, and relative frequency in the landscape (table 9). The largest value indices by attribute were in the WMCP with 7 of the 16 top scores: forest land, forests with no trash, no nearby fences, agriculture, and water sources, with fire evidence, and no recent logging activity. Four attributes were greatest in the Arkansas Valley: forests with primitive recreation opportunities, no nearby roads or trails, part of large forest fragments, and near urban areas; two in the Ouachita Mountains: forests with recent trail or road use and with permanent water; and one each in the MAB: forests with signs restricting activities, and Ozark Highlands: forests with livestock grazing. The smallest value indices were in the Ozark Highlands with six of the bottom scores, the MAB with four, the Arkansas Valley with three, the Ouachita Mountains with one, and the WMCP with none.

All subregions had attribute-specific indices that were different with their subregion's attribute-neutral index (table 9). Most differences were in the Ozark Highlands, with 12 of 15 rated important. Forest area became the Ozark Highlands' majority earth cover, i.e., 56 percent forested in 1995, an increase of 7 percent since 1988. The increase included a substantial increase in older communities. By contrast, for the 11 attribute-specific indices with important

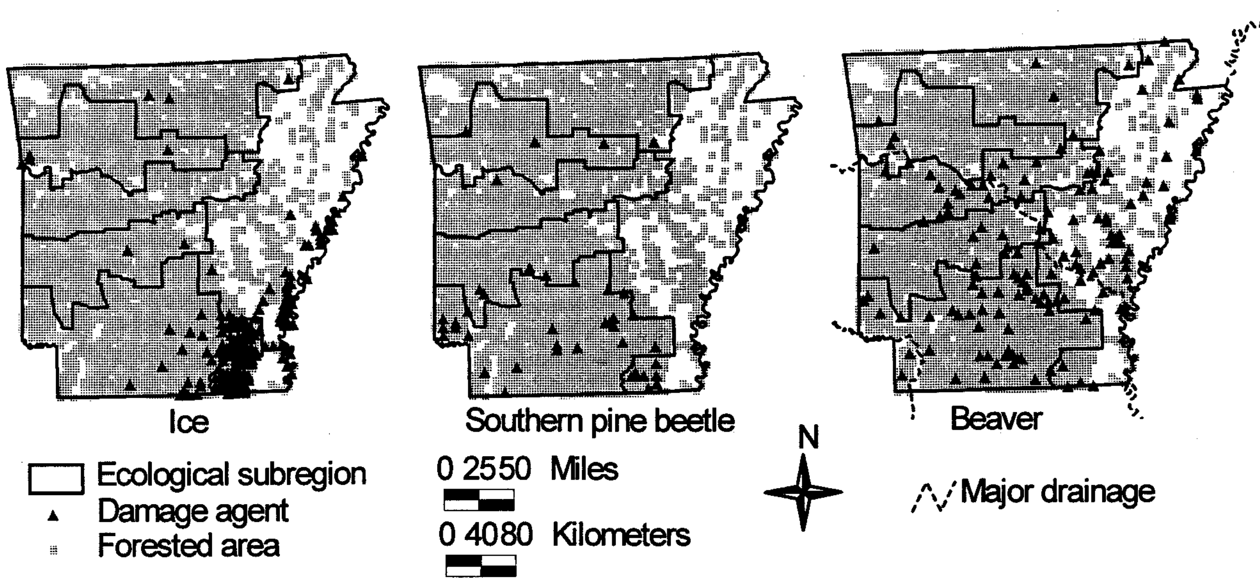

Figure 16—Forest plots and locations with one or more trees damaged by ice, southern pine beetles, and beavers, Arkansas 1995.

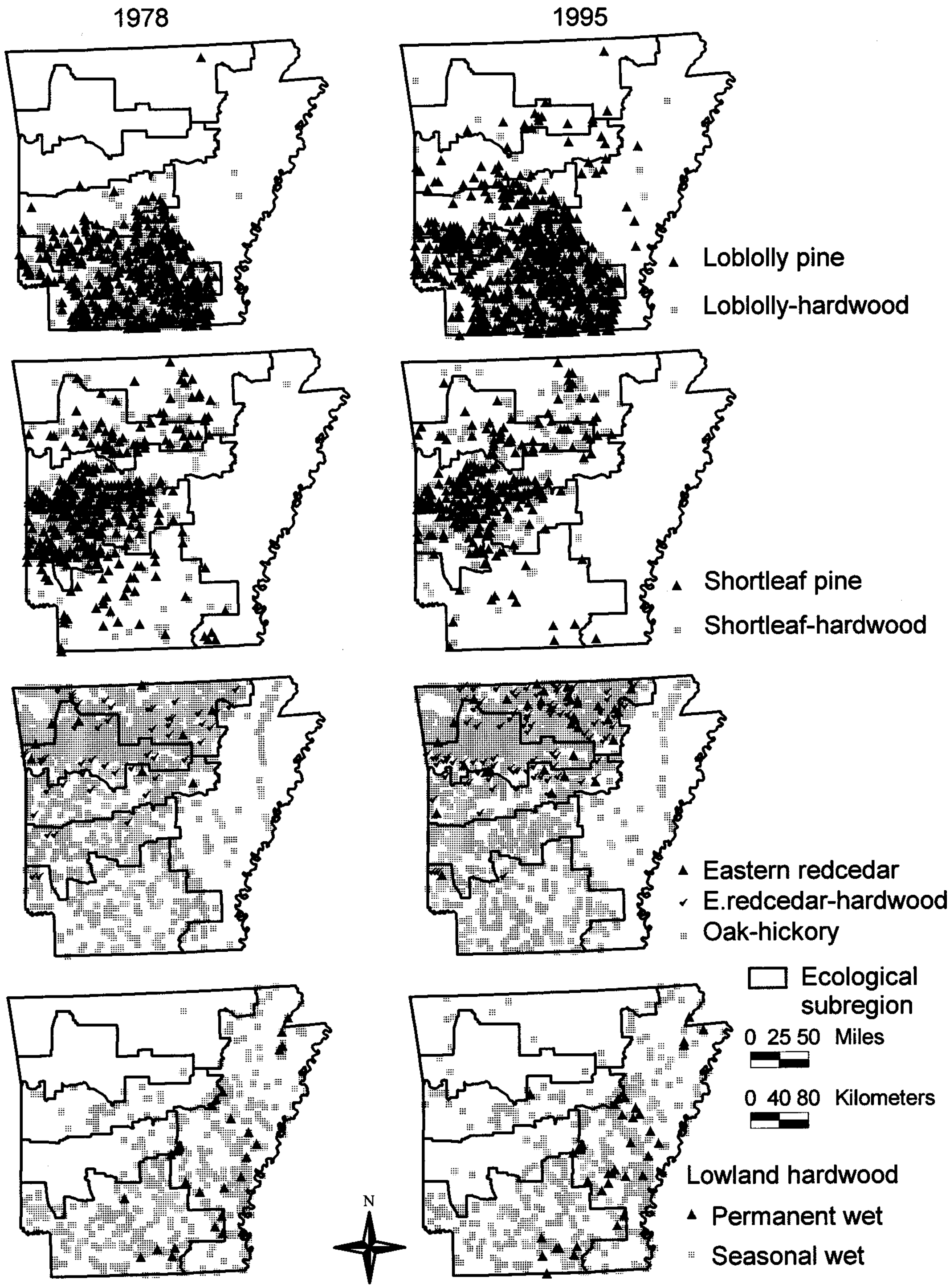

Figure 17—Forest plots by forest type group, Arkansas 1978 and 1995 surveys. Forest type groups above conform to Forest Inventory and Analysis loblolly-shortleaf pine: loblolly pine, shortleaf pine, eastern redcedar; oak-pine: loblolly pine-hardwood, shortleaf pine-hardwood, and eastern redcedar-hardwood. Permanently wet lowland hardwoods are oak-gum-cypress stands dominated by baldcypress-water tupelo and sweetbay-swamp tupelo-red maple. Other lowland hardwoods contain elm-ash-cottonwood and other oak-gum-cypress forest species.

Table 6—Area, scarcity, frequency, and landscape diversity, 1995, and area change and value indices, 1988–1995, Arkansas timberland

Attribute	1995 area	1988–95 change Area	1988–95 change Proportion	1995 Scarcity[a]	1995 Frequency	1995 D[b]	Replacement value	Value index[c]
	Percent	*1,000 acres*	*Percent*		*Percent*		*Years*	
Planted pine								
Sawtimber	467	268	134	4.3	1.37	0.06	30	-1.7
Poletimber	827	542	190	3.7	2.43	.09	20	-3.4
Nonstocked, sapling, and seedling	546	-163	-23	4.1	1.60	.07	10	5.1
Natural pine								
Sawtimber	2,185	235	12	2.7	6.42	.18	40	-0.07
Poletimber	492	-144	-23	4.2	1.45	.06	20	9.4
Nonstocked, sapling, and seedling	567	153	37	4.1	1.67	.07	10	.1
Oak-pine								
Sawtimber	1,157	-46	-4	3.4	3.40	.11	50	29.1
Poletimber	1,052	233	28	3.5	3.09	.11	20	-.5
Nonstocked, sapling, and seedling	928	-89	-9	3.6	2.73	.10	10	6.0
Oak-hickory								
Sawtimber	2,683	463	21	2.5	7.88	.20	50	-8.5
Poletimber	2,624	-183	-6	2.6	7.71	.20	20	18.9
Nonstocked, sapling, and seedling	1,820	-422	-19	2.9	5.35	.16	10	9.7
Bottomland hardwood								
Seasonally inundated, mixed								
Sawtimber	1,882	242	15	2.9	5.53	.16	50	-1.2
Poletimber	440	-70	-14	4.3	1.29	.06	20	8.2
Nonstocked, sapling, and seedling	51	80	19	4.2	1.48	.06	10	.6
Permanently inundated								
Sawtimber	165	22	16	5.3	0.48	.03	50	2.9
Poletimber	17	-5	-22	7.6	.05	.00	20	.8
Nonstocked, sapling and seedling	29	29	2,920	7.0	.09	.01	10	.0
Nontyped, nonstocked	6	1	9	8.5	.02	.00	1	.0
All timberland	18,392	1,148	7	0.6	54.04	1.71	NA	74.9

Rows and columns may not sum to totals due to rounding. NA = non applicable.
Percent change = 100*(area 1995 - area 1988)/(area 1988 + k), where k = 1 if area 1988 = 0, 0 otherwise.
[a] Log(total earth cover area/[area with the attribute]).
[b] D = -p(log(p)) where p = frequency/100 and landscape diversity = sum(-p[log(p)]).
[c] Vulnerability*D* (replacement time) where vulnerability = scarcity - x* log(10* absolute value [percent change/7 years]) and x = -1 if area change is decreasing, +1 otherwise.

Table 7—Area, scarcity, frequency, and landscape diversity, 1995, and area change and value indices,1988–1995, Arkansas earth (land and water) cover

Attribute	1995 area	1988-95 change Area	1988-95 change Proportion	1995 Scarcity[a]	1995 Frequency	1995 D[b]	Replace-ment value	Value index[c]
	Percent	*1,000 acres*	*Percent*		*Percent*		*Years*	
Forest land								
Timberland (from table 6)	18,392	1,148	6	0.6	54.04	1.71	NA	74.9
Nontimberland								
Productive-reserved	231	27	13	5.0	0.68	0.03	10	0.7
Other forest land	167	-69	-29	5.3	.49	.03	10	2.4
All forest land	18,790	1,106	6	.6	55.21	1.77	NA	78.0
Nonforest land and other cover								
Agriculture	11,968	-1,115	-9	1.0	35.16	.37	2	2.6
Urban and other	2,424	99	4	2.6	7.12	.19	2	.3
Marsh	38	8	28	6.8	.11	.01	2	.0
Census water	709	-1	0	3.9	2.08	.08	1	.3
Noncensus water	108	-99	-48	5.7	.32	.02	1	.2
All nonforest and other	15,247	-1,108	-7	.8	44.79	.67	NA	3.4
All earth cover	34,037	-3	0	1	100.00	2.43	NA	81.4

Rows and columns may not sum to totals due to rounding. NA = not applicable.
Percent change = 100*(area1995 - area1988)/(area1988 +k), where k = 1 if area1988 = 0, 0 otherwise.
[a] Log(total earth cover area/[area with the attribute]).
[b] D = -p(log[p]) where p = frequency/100 and landscape diversity = sum(-p(log[p])).
[c] Vulnerability*D* (replacement time) where vulnerability = scarcity - x*log(10*absolute value[percent change/7 years]) and x = -1 if area change is decreasing, +1 otherwise.

larger values than the attribute-neutral index, comparatively fewer older communities increased or increases were in younger-aged communities.

Implications

Knowledge of the spatial distribution and past change in forest land area and resource values are basic to its management. Such information indicates past natural resource management and program activities and can suggest future modifications. To make predictions, however, one must assume subsequent conditions will remain the same.

With these caveats in mind, this report's maps and indices facilitate broad area overviews useful in assessing the relative abundance or rarity of selected resource supplies, uses, or practices. Garbage or trash dumping, for example, appeared greater in specific travel corridors and at the edge of densely forested and urban or built-up landscapes, suggesting priority sites in need of litter clean-up and education efforts.

Analysis of attributes and value indices requires further investigation to assess their relevance to specific wildlife species and recreational opportunities. Some of these are addressed elsewhere, e.g., for black bears (Rudis and Tansey 1995). At the very least, however, the indices suggest increasing restrictions in the public use of largely private forests. This, in turn, may shift the demand for nonfee hunting and other forms of recreation access onto public land.

Livestock grazing on forests is in decline, but the practice persists on a fourth of the Ozark Highlands forests. There could well be an increase in timber management in this subregion if forest industries were to increase their holdings, or if silvicultural programs could accommodate apparent demand for livestock grazing on nonindustrial land.

Intensive timber management, primarily dominated by loblolly pine plantations, continues in west-central Arkansas, particularly in the Ouachita Mountains and WMCP subregions. Greater retention of fruit-bearing tree species and standing dead trees for wildlife needing them in these subregions could alleviate some wildlife conservation concerns. Reforestation efforts might be more effective at satisfying both timber production and apparent hunter demand if centered near the boundary between the MAB and western subregions.

Table 8—Percent forest and area, frequency, and landscape diversity, 1995, and area change and value indices, 1988–95, by attribute, Arkansas

Attribute	Forest area	1995 area	1988–95 change	1995 Frequency	1995 Landscape diversity	Value index Actual	Value index Relative to forest
	Percent	*- - 1,000 acres - -*		*Percent*			*Percent*
Earth cover	NA	34,037	-3	100.00	2.43	81.4	NA
Nonforest land and other cover	NA	15,247	-1,108	44.79	0.67	3.4	NA
Forest land	100	18,790	1,106	55.21	1.77	78.0	0
Forest land attribute, decreasing in area							
No trash[a]	63	11,794	-838	34.65	1.27	122.2	57
Livestock use	9	1,730	-210	5.08	.27	37.2	-52
No fences ≤1/4 mi	52	9,784	-160	28.75	1.12	87.0	12
Primitive recreation[b]	15	2,803	-96	8.23	.41	35.5	-54
No roads, trails ≤ 1/4 mi	10	1,881	-53	5.53	.29	39.4	-49
Fire evidence ≤ 2 yrs	3	613	-47	1.80	.12	17.5	-78
Forest land attribute, increasing in area							
Forest fragments >2,500 ac	23	4,326	143	12.71	.58	39.5	-49
Urban, built-up land[c] ≤ 1 mi	11	2,005	194	5.89	.32	30.5	-61
Trail, road use ≤ 2yrs	15	2,785	202	8.18	.42	46.2	-41
Permanent water[d] on plot	10	1,911	275	5.61	.30	23.3	-70
Water[e] sources ≤1/4 mi	34	6,330	353	18.60	.79	45.7	-41
Paved roads ≤ 1/4 mi	13	2,467	481	7.25	.37	32.4	-58
Agriculture[e] ≤ 1/8 mi	31	5,773	552	16.96	.73	33.1	-58
No logging activity ≤ 2 yrs.	74	13,815	1,683	40.59	1.42	30.4	-61
Signs restricting[f]	26	4,942	2,300	14.52	.66	-5.6	-107

Rows and columns may not sum to totals due to rounding. NA = Not applicable.

[a] Garbage dump; beverage, food, or other containers; or discarded machinery, etc.

[b] An area with no trash, no recent trail or road use, and part of forest fragments >2,500 acres.

[c] ≥10 acres and defined by Anderson and others (1976).

[d] Swamp, pond, stream, or small creek.

[e] Water bodies ≥0.13 acres or courses ≥40 feet wide.

[f] No hunting, posted, keep out, no trespass, or other activity restricted.

Table 9—Percent forest and area, 1995, and change and value indices, 1988–95, by attribute and ecological subregion, Arkansas

					Ecological subregion					
								Mountains		
Attribute	Forest area	1995 area	1988–95 change	State	MAB	WMCP	Arkansas Valley	Ouachita	Boston	Ozark Highlands
	Percent	*- - 1,000 acres - -*		*- - - - - - - - - - - - - - - - - - Value index - - - - - - - - - - - - - - - - - -*						
Earth cover	NA	34,037	-3	81	57	132	66	38	47	11
Nonforest land use and water cover	NA	15,247	1,108	3	2	5	4	4	3	3
Forest land	100	18,790	1,106	78	55	127	62	33	45	8
Forest land attribute, decreasing area										
No trash[a]	63	11,794	-841	124	81	183	118*	69*	53	33*
No fences ≤1/4 mi	52	9,784	-217	90	74	118	57	63*	57	37*
Livestock use	9	1,730	-206	37	12	26	19	24	26	47*
Primitive[b] recreation	15	2,803	-119	39	9*	21*	75	34	34	20*
No roads, trails ≤1/4 mi	10	1,881	-56	40	11*	25*	52	-4*	43	24*
Fire evidence ≤ 2 yrs	3	613	-44	17	7*	23*	-1*	6*	4*	3
Forest land attribute, increasing area										
Forest fragments >2,500 ac	24	4,326	143	40	17	23*	98	36	32	36*
Urban, built-up land[c] ≤1 mi	11	2,005	194	31	8*	28	31	22	21	19*
Trail, road use ≤2 yrs	15	2,785	202	46	33	63	17	70*	-6*	15*
Permanent water[d] on plot	10	1,911	275	23	9*	28	7*	34	-3*	19*
Water[e] sources ≤1/4 mi	34	6,330	353	46	40	112	11*	51	37	20*
Paved roads ≤1/4 mi	13	2,467	481	32	17	39	5*	42	24	32*
Agriculture[c] ≤1/8 mi	31	5,773	552	33	32	90	30	43	30	7
No logging activity ≤ 2 yrs.	75	13,815	1,683	30	39	73	15	30	34	2
Signs restricting[f]	27	4,942	2,300	-6*	14	-6*	-7*	-11*	-23*	-26*

Rows and columns may not sum to totals due to rounding. NA = Not applicable.
MAB = Mississippi Alluvial Basin. WMCP = Western Mid-Coastal Plains.
* ≥80 percent different relative to subregion forest land value index.
[a] Garbage dump; beverage, food, or other containers; or discarded machinery, etc.
[b] An area with no trash, no recent trail or road use, and part of forest fragments >2,500 acres.
[c] ≥10 acres and defined by Anderson and others (1976).
[d] Swamp, pond, stream, or small creek.
[e] Water bodies ≥ 13 acres or courses ≥ 40 feet wide.
[f] No hunting, posted, keep out, no trespass, or other activity restricted.

ACKNOWLEDGMENTS

I gratefully acknowledge the assistance of FIA Arkansas field personnel in the collection of the data, office staff in helping to assemble the data base, and comments received after I presented findings at the conference. Dan Nolan, Bill Pepper, and Ray Sheffield reviewed an early draft and offered many constructive suggestions.

LITERATURE CITED

Allen, Arthur W.; Bernal, Yvonne K.; Moulton, Robert J. 1996. Pine plantations and wildlife in the Southeastern United States: an assessment of impacts and opportunities. Inf. and Technol. Rep. 3. Washington, DC: U.S. Department of the Interior, National Biological Service. 32 p.

Anderson, James R.; Hardy, E.E.; Roach, J.T.; Witmer, R.E. 1976. A land use and land cover classification system for use with remote sensor data. U.S. Geol. Surv. Prof. Pap. 964. Washington, DC: Publisher unknown. 28 p.

Beltz, Roy C.; Bertelson, Daniel F.; Faulkner, Joanne L.; May, Dennis M. 1992. Forest resources of Arkansas. Resour. Bull. SO–169. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 48 p.

Devall, Margaret S.; Rudis, Victor 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: Proceedings of the conference; 1990 September 19–20; Morrilton, AR. Morrilton, AR: Winrock International, Hot Springs, AR: U.S. Department of Agriculture, Forest Service, Ouachita National Forest: 121–138.

ECOMAP. 1993. National hierarchical framework of ecological units. Washington, DC: U.S. Department of Agriculture, Forest Service. 20 p.

Environmental Systems Research Institute, Inc. 1996. Using ArcView GIS: the geographic information system for everyone. Redlands, CA: Environmental Systems Research Institute, Inc. 350 p.

Forest Inventory and Analysis Research Work Unit. 1987. Other forest resources work plan: Arkansas 1987: supplement to forest survey inventory work plan. Starkville, MS: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 35 p. [Field manual].

Forest Inventory and Analysis Research Work Unit. 1994. Forest survey inventory work plan: Arkansas 1994–1995. Starkville, MS: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 61 p. plus appendix A (50 p.), appendix B (19 p.). [Field manual].

Graber, J.W.; Graber, R.R. 1976. Environmental evaluations using birds and their habitats. Illinois Nat. Hist. Surv. Biol. Notes 97. Champaign, IL: Illinois Natural History Survey. 39 p.

Hines, F. Dee; Vissage, John S. 1988. Forest statistics for Arkansas counties. Resour. Bull. SO–141. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 68 p.

Hunter, Malcolm L. 1990. Wildlife, forests, and forestry: principles of managing forests for biological diversity. Englewood Cliffs, NJ: Regents/Prentice Hall. 370 p.

Iverson, Louis R.; Oliver, Richard L.; Tucker, Dennis P. [and others]. 1989. Forest resources of Illinois: an atlas and analysis of spatial and temporal trends. Illinois Nat. Hist. Surv. Spec. Pub. 11. Champaign, IL: Illinois Natural History Survey. 181 p.

Little, Elbert 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.

London, Jack D. 1997. Forest statistics for Arkansas Counties—1995. Resour. Bull. SRS–17. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 86 p.

McMinn, James W.; Hardt, Richard A. 1996. Accumulations of coarse woody debris in southern forests. In: McMinn, James W.; Crossley, D.A., Jr., eds. Biodiversity and coarse woody debris in southern forests: Proceedings of the workshop on coarse woody debris in southern forests: effects on biodiversity; 1993 October 18–20; Athens, GA. Gen. Tech. Rep. SE–94. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 1–9.

McNab, W. Henry; Avers, Peter E. 1994. Ecological subregions of the United States: section descriptions. WO-WSA-5. Washington, DC.: U.S. Department of Agriculture, Forest Service. 267 p.

Rudis, Victor A. 1986. Emerging patterns in the distribution of roadless forested areas in the Midsouth. In: Kulhavy, David L.; Conner, Richard N., eds. Wilderness and natural areas in the Eastern United States: a management challenge: Symposium proceedings; 1985 May 13–15; Nacogdoches, TX. Nacogdoches, TX: Stephen F. Austin State University, Center for Applied Studies, School of Forestry: 265–270.

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

Rudis, Victor A. 1988a. Nontimber values of east Texas timberland. Resour. Bull. SO–139. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 34 p.

Rudis, Victor A. 1988b. Nontimber values of Louisiana's timberland. Resour. Bull. SO–132. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 27 p.

Rudis, Victor A. 1991. A recreation and landscape perspective of Alabama's changing forest environment: the human character of forests. In: Jones, R.H., ed. Proceedings: Alabama's forest resources: past, present and future; 1991 May 29–30; Auburn University, AL. Auburn University, AL: Auburn University School of Forestry, Alabama Cooperative Extension Service: 93–114.

Rudis, Victor A. 1993a. Forest fragmentation of Southern United States bottomland hardwoods. In: Brissette, J., ed. The seventh southern silvicultural research conference; 1992 November 17–19; Mobile, AL. Gen. Tech. Rep. SO–93. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 35–46.

Rudis, Victor A. 1993b. The multiple resource inventory decision-making process. In: Lund, H. Gyde; Landis, Eric; Atterbury, Toby, eds. Stand inventory technologies '92: Proceedings of stand inventory technologies: an international multiple resource conference; 1992 September 13–17; Portland, OR. Bethesda, MD: American Society for Photogrammetry and Remote Sensing: 180–192.

Rudis, Victor A. 1993c. Transforming round pegs to fill square holes: facing the challenge of forest inventories as tools of environmental policy for the 21st century. In: Preto, G.; Koch, B., eds. Forest resource inventory and monitoring and remote sensing technology: Proceedings: IUFRO centennial meeting in Berlin; 1992 August 31–September 4; Berlin, Germany. Tokyo, Japan: Japan Society of Forest Planning Press: 51–60.

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

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

Rudis, Victor A. [In press]. Composition, potential old growth, fragmentation, and ownership of Mississippi Alluvial Valley bottomland hardwoods: a regional assessment of historic change. In: Foti, T.; Hamel, P.B., ed. Bottomland hardwoods of the Mississippi Alluvial Valley: characteristics and management of natural function, structure, and composition: Proceedings; 1995 October 28; Fayetteville, AR. Gen. Tech. Rep. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.

Rudis, Victor A.; Skinner, Thomas V. 1991. Fire's importance in South Central U.S. forests: distribution of fire evidence. In: Nodvin, S.C.; Waldrop, T.A., eds. Fire and the environment: ecological and cultural perspectives. Gen. Tech. Rep. SE–69. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 240–251.

Rudis, Victor A.; Tansey, John B. 1995. Regional assessment of remote forests and black bear habitat from forest resource surveys. Journal of Wildlife Management. 59(1): 170–180.

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

Staff of Renewable Resources Evaluation Research Work Unit. 1980. Forest statistics for Arkansas counties. Resour. Bull. SO–76. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 77 p.

Wells, G.R.; Hedlund, A.; Earles, J.M. 1974. Assessment of Tennessee timberland: a guide to implementing the productivity approach. Bull. 527. Knoxville, TN: University of Tennessee, Agricultural Experiment Station. 35 p.