Regional Forest Resource Assessment in an Ecological Framework: The Southern United States

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ABSTRACT: Information about forest resources grouped by ecologically homogeneous area can be used to discern relationships between those resources and ecological processes. I used forest resource data from 0.4-ha plots, and data on population and land area (by county), together with a global-to-local hierarchical framework of land areas with similar ecological potential to assess extant forest resources in the southern United States. Because each data source differed in resolution and types of information, I referenced all to a common county land unit. I also characterized and tested the importance of other resource indicators by ecological province. Data were largely from U.S. Forest Service Forest Inventory and Analysis surveys for the southern United States (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, east Oklahoma, South Carolina, Tennessee, east Texas, and Virginia). Findings described differences by province in the proportion of forest types, public land, private land, protected forests, forest plantations, disturbances, and human uses. Analysis of resource value indicators showed significant differences among provinces in livestock grazing, selected recreation, wildlife habitat, timber resources, and vulnerability to urban and agricultural influences. Ecological perspectives suggested a need to tailor forest resource analysis, planning, and incentive programs and focused attention on selected disturbances and complementary and competing uses.

Index terms: ecoregion, forest resources, regional classifications, southern United States.

INTRODUCTION

Natural resource planning and analysis rely upon resource information organized by land types that are likely to respond in a uniform way to management activities and program incentives. Inventory, monitoring, and associated assessments involving comprehensive sampling efforts will more accurately characterize unmonitored sites and discern relationships when samples are stratified according to ecologically similar area. Assessments that rely on post-stratification of systematic samples can maintain the same accuracy with fewer ground plots if information is subgrouped to illustrate underlying functions and relevant processes.

Forest resource surveys typically estimate and report information according to primary resource administrative divisions such as owner class and federal or state forest management district. This permits primary stakeholders to rapidly assess priorities and programs under their control or influence. Stakeholders concerned with multiple resource issues or those whose income derives from a variety of forest resources may be better served with information grouped by areas with similar ecological potential such as land with the potential for periodic wood production and income from livestock grazing or hunting lease sales. County divisions are logical bases for integration, as their boundaries are discipline-neutral, historically established, reinforced through courts of law, defined with minimum error, and form the backbone of a nested hierarchy that frames local, regional, and national planning.

Forest surveys traditionally group and report data by state and then by areas with similar wood resource attributes (e.g., Powell et al. 1993, Thompson and Johnson 1994, Haynes et al. 1995, Rosson 1995). For extensive and diverse areas, analyses often group data first by physiography (i.e., geomorphology, drainage, and elevation) and then by climate and edaphic influences (e.g., Martin et al. 1993, Barrett 1995). Differing from these, Bailey's (1996) classification focuses on ecological potential. That classification framework, formally called the National Framework of Ecological Potential (ECOMAP 1993), begins with a global climate organizational scheme, followed by a global-to-local organizational hierarchy that incorporates physiography and permits secondary organization by political divisions and other resource perspectives.

Terms used in the ECOMAP hierarchy (adapted from McNab and Avers 1994) include: "ecoregion" (a broad area of regional extent, on the scale of subcontinents having similar climate), "province" (a broad vegetation area conforming to subcontinental weather patterns), "section" (part of a province with similar geomorphology, geologic origin, drainage networks, topography, and regional climate), and "subsection" (part of a section with similar surficial geology, soils, subregional climate, and potential natural vegetation communities). Mountain provinces are those exhibiting altitudinal zonation and the climatic regime of adjacent lowlands. As used in this report, a "region" is an area greater than 100,000 ha, and a "subregion" is a province or section based on the framework.

The chief objective of this report is to demonstrate the use of the National Framework of Ecological Potential (ECOMAP 1993) to examine existing information about the abundance, distribution, ownership, wood productivity, protection, and scarcity of forest resources. I also describe and test the significance of differences in selected resource value indicators by province. When combined with the framework, these indicators suggest complementary (agroforest, recreation) and competing (agriculture, urban) uses and disturbances (fire, livestock grazing, timber harvesting, human intrusions) characteristic of subregions. The approach and results enabled generation of other resource perspectives from data examined primarily from national (Powell et al. 1993, Haynes et al. 1995) and state-level timber resource surveys (e.g., Thompson and Johnson 1994, Rosson 1995).

STUDY AREA

The study area comprised the 13-state southern survey region of the United States Forest Service: Kentucky; the southeastern states of Florida, Georgia, North Carolina, South Carolina, and Virginia; and the midsouth states of Alabama, Arkansas, Louisiana, Mississippi, east Oklahoma, Tennessee, and east Texas. In 1924 forests in the South consisted largely of pines (*Pinus* L.) to the south, oaks (*Quercus* L.) to the north, and cypress-tupelo-sweetgum (*Taxodium* Rich.–*Nyssa* L.–*Liquidambar* L.) in river bottoms (Shantz and Zon 1924). Presettlement fires set by lightning and Native Americans, coupled with the South's periodic droughts, were once dominant ecological forces that gave rise to vast areas of southern pine forests (Williams 1989). Later, fire suppression, land clearing, and timber cutting activities reduced the extent of all forests, though some areas regenerated to pine forests after farmland abandonment (Walker 1995). With the widespread use of drainage structures and levees more than a half century ago, many former river bottom forests were cleared to become cropland and homesteads (Turner et al. 1981). Other important competing land uses included human settlement, animal agriculture, and urban and other land use (Healy 1985).

By the 1990s the South's river bottom forests were severely reduced in extent (McWilliams and Rosson 1990). Elsewhere in the coastal portions of the South, pine plantations were on the increase (Powell et al. 1993). Though pine plantations did contain some hardwoods (Rosson 1995), they were intensively managed for commercial wood production, which suggested a potentially negative impact on biodiversity (Boyce and Martin 1993), particularly wildlife habitat (Allen et al. 1996). In interior portions of the south, stands were succeeded to oak-pine (*Quercus* L.-*Pinus* L.) and oak-hickory (*Quercus* L.-*Carya* Nutt.) forest types (e.g., in north Alabama: Rudis 1991). Reforestation effort on cropland and regeneration of cut stands on managed sites favored loblolly (*P. taeda L.*) and slash (*P. elliottii* Engelm.) pines over longleaf (*P. palustris* Mill.) and shortleaf (*P. echinata* Mill.) pines (Kelly and Bechtold 1990, McWilliams et al. 1986, Rudis 1991).

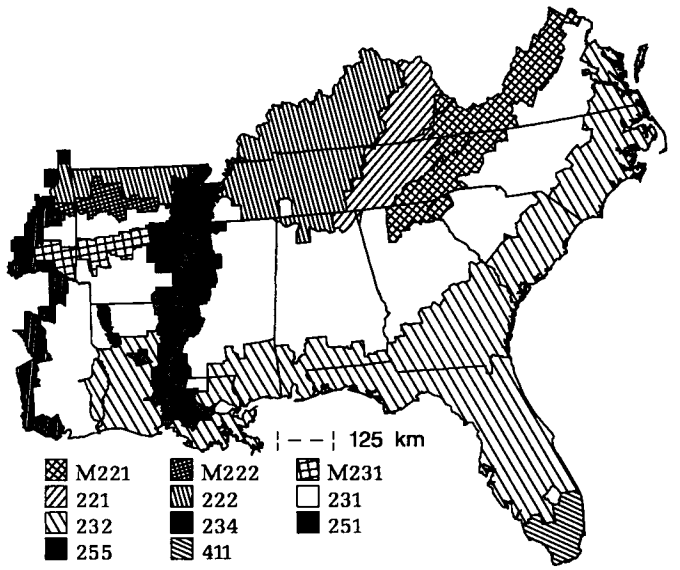
METHODS

The National Framework of Ecological Potential referenced areas of land with similar ecological potential chiefly from regional climate data, physiography, and other georeferenced data sources (ECOMAP 1993; Bailey 1995, 1996). Ecological subregion class boundaries were estimated at 1:7,500,000-m (Bailey 1995) and later at 1:1,000,000-m (Keys et al. 1995) resolution. Resolution was the capability to distinguish between separate but adjoining classes; boundary location accuracy was not specified.

Forest resource data came from surveys conducted by the U.S. Forest Service Forest Inventory and Analysis program (FIA) from 1988 through 1995. These included surveys for Kentucky (Alerich 1990); the southeastern states of Florida (Brown 1996), Georgia (Thompson 1989), North Carolina (Johnson 1991), South Carolina (Conner 1993), and Virginia (Johnson 1992); and the midsouth states of Alabama (Vissage and Miller 1991), Arkansas (Hines and Vissage 1988), Louisiana (Vissage et al. 1992), Mississippi (Hartsell and London 1995), east Oklahoma (Miller et al. 1993), Tennessee (Vissage and Duncan 1990), and east Texas (Miller and Hartsell 1992).

Extant FIA survey data referenced land use, current physiography, and vegetative conditions from 0.4-ha forested plots stratified by county and sampled by state (Kelly 1991). The FIA geo-referenced plot locations from county maps and aerial photos, an approach that yielded location accuracy of ± 300 m or 1:600-m resolution (Z. Zhu, U.S. Forest Service, Sarkville, Miss., pers. com.). Thus, integration of FIA data with the framework was not straightforward due to differences in the types of information, classes used to organize them, and resolution of the boundaries.

As a practical solution to the problem of integration, I adjusted the framework and FIA data to a common county land unit. Data supplied by R.G. Bailey (U.S. Forest Service, Fort Collins, Colo., pers. com.) used geographic information software to estimate area within ECOMAP (1993) boundaries digitized from a 1:7,500,000-scale map by section, province, and county. To align subregions and counties, I assigned each county uniquely to a province by its plurality area, and to a section based on its area plurality within the county's assigned province (Figure 1). Sections within each province provided additional detail with which to interpret provinces (Figure 2).



Code	Province Name
M221	Central Appalachian Broadleaf Forest-Coniferous Forest- Meadow
M222	Ozark Broadleaf Forest-Meadow
M231	Ouachita Mixed Forest
221	Eastern Broadleaf Forest (Oceanic)
222	Eastern Broadleaf Forest (Continental)
231	Southeastern Mixed Forest
232	Outer Coastal Plain Mixed Forest
234	Lower Mississippi Riverine Forest
251	Prairie Parkland (Temperate)
255	Prairie Parkland (Subtropical)
411	Everglades

Figure 1. Ecological province by county based on county province plurality, southern United States.

Counties were not always ecologically homogeneous. In theory, precision declines with the increasing number of subregions and declining dominance of one subregion within a county. This was a disadvantage for very large and climatically diverse counties as in the western United States. For the South, I assumed subregion boundaries were of sufficient precision to permit assignment by county, integrate other county data sources, and form conclusions by province. The advantage was being able to incorporate other common county-based information about human population and land area from the U.S. Census Bureau, Economic Research Service, and other agencies.

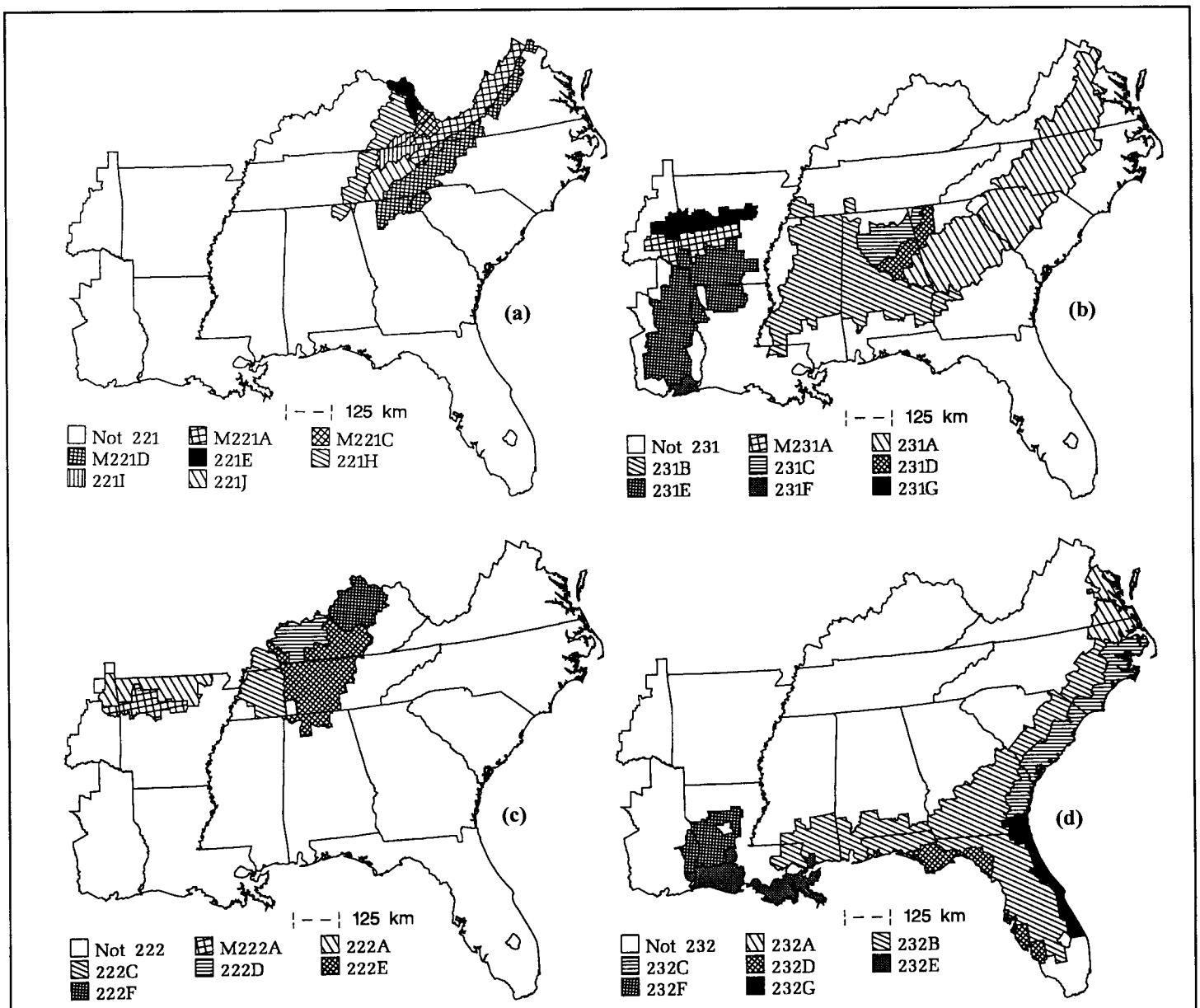
Forest area, federal research natural areas (RNAs), and area of reserved and other public land by county came from government agency records and additional FIA samples that determined forest and nonforest land largely from 1:58,000 nominal scale aerial photos. FIA personnel verified a portion of photo-interpreted samples and county assignment by on-the-ground inspection and available maps. Ownership information came from county records or direct owner contact.

FIA assigned ground plots to land-use classes (sensu Anderson et al. 1976). "Forest land" was land with ≥10% tree crown cover, including land temporarily with <10% tree crown cover but not developed for other uses, ≥ 0.4 ha in area, and ≥ 37 m in width. FIA further classified forest land as reserved forest land, timberland, and other forest land. "Reserved" was forest land reserved from timber production, that is, federal and state wilderness areas and selected state and county parks. "RNA" was applied to areas of federal forests restricted from selected activities. "Timberland" was forest land capable of producing industrial wood at a rate ≥ 1.4 $m^3ha^{-1}year^{-1}$. FIA obtained the area of National Forest System (NFS) land by county. "Other forest land" (i.e., woodland in earlier reports using FIA data) was forest land on sites that were too xeric or hydric to support industrial wood production at ≥ 1.4m^3ha^{-1} $year^{-1}$.

Forest resource estimates came from more than 1,000,000 photo-interpreted points on aerial photographs, 90,000 points on the ground, and 44,000 plots in areas classified as timberland. U.S. Forest Service and other public agencies supplied area estimates for reserved forest land and RNAs by county. For continuous data, I calculated mean values by plot for normally distributed or log-transformed data and judged associations not significant if the 95% confidence interval around the grand mean overlapped with means for individual provinces. For categorical data, associations were not significant if the probability of the chi-square value was 5% or more.

Traditional forest resource value indicators included forest type and wood-oriented descriptors: natural versus planted, sawtimber diameter class, average basal area, slope class, and potential site productivity. Kelly (1991), Hansen et al. (1992), May (1990), and most FIA resource bulletins contain further details. FIA procedures for estimating land use and traditional forest resource attributes used in this study were essentially the same by state (Hansen et al. 1992). Estimates of human population and metropolitan status were from the U.S Census (Butler and Beale 1993).

Other resource value indicators were population density, proportion in metropolitan areas, forest fragment size, proximity to nonforest features, and evidence of har-



(a) *M221 Central Appalachian Broadleaf Forest-Meadow:* M221A Northern Ridge and Valley, M221C Northern Cumberland Mountains, M221D Blue Ridge Mountains. *221 Eastern Broadleaf Forest (Oceanic):* 221E Southern Unglaciated Allegheny Plateau, 221H Northern Cumberland Plateau, 221I Southern Cumberland Mountains, 221J Central Ridge and Valley.

(b) *M231 Ouachita Mixed Forest:* M231A Ouachita Mountains. *231 Southeastern Mixed Forest:* 231A Southern Appalachian Piedmont, 231B Coastal Plains, Middle, 231C Southern Cumberland Plateau, 231D Southern Ridge and Valley, 231E Mid Coastal Plains, Western, 231F Eastern Gulf Prairies and Marshes, 231G Arkansas Valley.

(c) *M222 Ozark Broadleaf Forest-Meadow:* M222A Boston Mountains. *222 Eastern Broadleaf Forest (Continental):* 222A Ozark Highlands, 222C Upper Gulf Coastal Plain, 222D Interior Low Plateau, Shawnee Hills, 222E Interior Low Plateau, Highland Rim, 222F Interior Low Plateau, Bluegrass.

(d) *232 Outer Coastal Plain Mixed Forest:* 232A Middle Atlantic Coastal Plain, 232B Coastal Plain and Flatwoods, Lower, 232C Atlantic Coastal Flatwoods, 232D Florida Coastal Lowlands (Western), 232F Coastal Plains and Flatwoods, Western Gulf, 232G Florida Coastal Lowlands (Eastern).

Figure 2. Ecological sections by county based on county section plurality within selected provinces, southern United States. See McNab and Avers (1994) for detailed descriptions by province and section. (A file with codes by province, section, state, and county for the coterminous United States is available from the author).

vesting, livestock grazing, hunting, and other human uses. Metropolitan counties in the South (densely populated areas) have high woodland real estate value (Rudis 1991), which may have eclipsed timber production value (DeForest et al. 1991) of comparable forests elsewhere. Extensive and large forests are critical habitat for some bird species (Hamel 1992), important habitat for viable populations of large carnivores with broad home ranges (Lowman 1975), and are preferred by recreation users with interests in primitive-recreation (e.g., hunters, backcountry campers [Rudis 1987]). Forest recreation users, particularly those oriented toward primitive experiences, dislike encountering litter, trash, and other human intrusions (Rudis 1987). Forests in densely populated areas or near urban and built-up land probably have greater importance as recreation resources than as timber resources. Forests near agricultural land probably have more importance as windbreaks, shade for livestock, or temporarily abandoned (fallow) agricultural land than as land for timber production.

For brevity and consistency, I examined only midsouth states' attributes associated with other forest values, because FIA attributes tied to other resource values differed among Kentucky, the midsouth, and the southeastern states (U.S. Forest Inventory, Economics, and Recreation Research 1992). In the midsouth states, FIA field crews recorded, for each 0.4-ha forested plot, forest fragment size; distance from roads, agricultural, and urban areas; timber production activities since the last survey; the presence of fire evidence, livestock use, fences, and signs; and evidence of human intrusions (hunting activity, beverage containers, and other miscellaneous litter). Forest fragment size was the contiguous area of forests ≥ 0.4 ha unbroken by nonforest cover ≥ 37 m wide. FIA measured fragment size in classes (midpoints used in calculations) as 0.4–4 (2), 5–20 (12), 21–40 (30), 41–202 (121), 203–1,012 (607), 1,0132,023 (1, 518), and >2,023 (arbitrarily set to 3,323) ha.

I defined a province's forests as less vulnerable to urban influences if average forest fragment size, distance from urban and built-up land, and forest area per person were large, and proportion of land in metropolitan counties, forests with beverage containers, and forests with other miscellaneous litter were small. Such a province had the most potential for primitive-oriented recreational pursuits. I also assumed a province's forests were less vulnerable to agricultural influences if few forests were near agricultural land or fences, and if few forests had livestock use evidence.

Table 1. Land area by land cover and forest land use class, southern United States provinces, 1988–1995.

Code	Province	All Land Area	Nonforest Land	Forest Land				
				All Forests			Unreserved	
				Proportion	Area	Reserved	Timberland	Other[a]
		1,000 ha		*% of land*	*1,000 ha*			
231	Southeastern Mixed Forest	48,989	16,900	66	32,089	153	31,923	14
232	Outer Coastal Plain Mixed Forest	41,740	17,584	58	24,156	363	23,676	117
222	Eastern Broadleaf Forest (Continental)	16,872	9,628	43	7,244	70	7,064	110
234	Lower Mississippi Riverine Forest	9,780	6,666	32	3,114	0	3,114	0
M221	Central Appalachian Broadleaf Forest--Coniferous Forest-Meadow	9,102	7,099	69	6,296	376	5,897	23
221	Eastern Broadleaf Forest (Oceanic)	6,466	4,791	71	4,616	153	4,460	2
255	Prairie Parkland (Subtropical)	4,002	2,491	38	1,511	4	1,348	159
411	Everglades	2,127	1,612	24	515	109	77	328
M231	Ouachita Mixed Forest	2,297	621	73	1,677	19	1,651	6
M222	Ozark Broadleaf Forest-Meadow	1,626	516	68	1,110	34	1,061	15
251	Prairie Parkland (Temperate)	503	375	25	128	0	113	15
	All land	143,504	61,048	57	82,455	1,281	80,385	790
	Percent of all land	*100*	*43*		*57*	*1*	*56*	*1*

[a]Forests yielding <1.4 m^3 ha^{-1} $year^{-1}$, a.k.a. "woodland" in earlier U.S. Forest Service reports.

RESULTS

FIA data for surveys conducted between 1988 and 1995 showed nonforest land dominating in 5 out of 11 provinces. Forest land occupied from 24% to 73% of land area (Table 1). Ninety-seven% of forest land use was timberland, with the remainder in forests with limited potential for, or reserved from, timber production. The greatest proportion of forest was in the Ouachita province (M231), and the least was in the Lower Mississippi province (234) and the forest "fringe" provinces—that is, those with conditions too wet (Everglades[411]) and too dry (temperate and subtropical Prairie Parkland [251, 255]) to support commercial wood growth. The Outer Coastal Plain (232) and Southeastern (231) provinces together accounted for most (63%) of the South's land area, 57% of its forest area, and 69% of its timberland. These two provinces had 53% of the South's public forests, but only 40% of its reserved forest area (Table 1).

One could argue that reserved and other public forests afford a degree of protection from nonforest use, with reserved forests and RNAs the most protected. Public forests represented 12% of the land and 11% of the timberland area (Table 2). By province, the proportion of public forest area was larger than average in the mountain (M221, M222, M231) and Everglades (411) provinces, and smaller than average in the subtropical Prairie Parkland (255), Eastern Broadleaf (221), and Southeastern (231) provinces. Reserved forests by province were 0% to 5% of the land area, and in the South as a

Table 2.—Forest area by ownership, land use, and public land designation class, southern United States provinces, 1988-1995

Code	Province	Total Forest Land	All Public Forests		Public Forests					Private Forests	
					Federal and State Reserved	Unreserved				Unreserved	
						Timberland		Other			
			Proportion	Area		National Forest	Other	Public	Other*	Timberland	Other[a]
		1,000 ha	*Percent of land*		*1,000 ha*						
231	Southeastern Mixed Forest	32,089	*8*	2,454	153	0.8	1,180	1,119	2	29,623	12
232	Outer Coastal Plain Mixed Forest	24,156	*12*	2,969	363	1.4	986	1,502	117	21,187	0
222	Eastern Broadleaf Forest (Continental)	7,244	*9*	621	70	0.1	143	396	12	6,525	98
234	Lower Mississippi Riverine Forest	3,114	*13*	398	0	0.2	103	294	0	2,717	0
M221	Central Appalachian Broadleaf Forest--Coniferous Forest-Meadow	6,296	*30*	1,866	376	2.3	1,307	158	22	4,430	0
221	Eastern Broadleaf Forest (Oceanic)	4,616	*16*	731	153	0.1	375	200	2	3,884	0
255	Prairie Parkland (Subtropical)	1,511	*4*	65	4	0.0	0	59	3	1,290	156
411	Everglades	515	*86*	441	109	0.0	0	4	328	73	0
M231	Ouachita Mixed Forest	1,677	*20*	334	19	0.8	255	56	2	1,338	5
M222	Ozark Broadleaf Forest-Meadow	1,110	*33*	367	34	0.8	308	21	2	731	12
251	Prairie Parkland (Temperate)	128	*18*	24	0	0.0	0	21	2	91	13
	All forest land	82,456	*12*	10,269	1,281	6.4	4,657	3,831	494	71,890	296
	Percent of forest land			*12*	*2*	*b*	*6*	*5*	*1*	*87*	*0*

[a] Unreserved forests yielding <1.4 m^3/ha/year

[b] 0.01 percent.

RNA= U.S. Forest Service Research Natural Areas.

whole they averaged 1%. Reserved forests were too small by themselves and, except for the Southern Appalachians, too widely scattered to support viable animal populations with large home ranges, such as black bears (Rudis and Tansey 1995). RNAs were also forests with limited human development, but their total area was small.

Most provinces with steep slopes had a greater than average proportion of forest area in public land (Table 3). The province's forests with the steepest slopes, the Central Appalachian (M221), contained a third of both reserved and RNA forests of the South. The greater proportion of public forest land on steep slopes ensured protection from nonforest use, downstream flooding, and reduced water quality. The fact that private forest land on steep slopes protected downstream water quality probably meant that they were less vulnerable to conversion to nonforest use or intensive timber production.

Less protected were forests on private land on level terrain. Private ownership controlled the majority of forests in all but the Everglades province (411) (Table 3). Nonindustrial private forests were the majority in all but the Ouachita province (M231). Forests of the Lower Mississippi (234) had the greatest potential for wood production, had the highest average basal area, and the greatest proportion of sawtimber stands, but the province had the smallest proportion of area in forest cover. The "mixed" forest provinces, that is, the Ouachita (M231), Outer Coastal Plain (232), and Southeastern (231) provinces, had one-fifth of their timberland in plantations and substantial ownership by forest industries.

Forest type groups varied distinctly by province and reflected differences in ecological potential and current conditions (Table 4). Southern conifers did not comprise a major component in any of the provinces, but when oak-pine forests were included they formed a majority in the mixed (231, 232, M231) provinces. Among southern conifers, loblolly and

Table 3. Timberland area by ownership class, proportion in planted and sawtimber diameter class, and average basal area, slope, and site productivity class, southern United States provinces, 1988–1995

Code	Province	All Timberland	Ownership Class			Planted Stands	Sawtimber Diameter[a] Class	Average		
			Public	Forest Industry	Other Private			Basal Area	Slope	Site Productivity[b]
		1,000 ha	*Percent*					$m^2\ ha^{-1}$	*Percent*	$m^3\ ha^{-1}\ yr^{-1}$
231	Southeastern Mixed Forest	31,923	7	20	73	19	41	16.8	8	6.9
232	Outer Coastal Plain Mixed Forest	23,676	11	28	62	28	38	15.4	2	5.7
222	Eastern Broadleaf Forest (Continental)	7,064	8	4	88	2	45	18.6	16	4.8
234	Lower Mississippi Riverine Forest	3,114	13	19	68	6	71	21.3	3	8.0
M221	Central Appalachian Broadleaf Forest--Coniferous Forest-Meadow	5,897	25	3	72	3	61	20.2	35	5.5
221	Eastern Broadleaf Forest (Oceanic)	4,460	13	5	82	3	57	20.9	29	5.6
255	Prairie Parkland (Subtropical)	1,348	4	5	91	4	43	15.8	5	5.1
411	Everglades	77	5	—	95	—	45	14.0	0	3.4
M231	Ouachita Mixed Forest	1,651	19	48	34	29	30	17.4	13	5.2
M222	Ozark Broadleaf Forest-Meadow	1,061	31	3	65	4	34	18.4	17	3.8
251	Prairie Parkland (Temperate)	113	19	—	81	—	41	17.2	12	3.3
	All timberland	80,385	11	19	70	17	43	17.2	10	6.1
	±2 standard errors (overall average)	*na*	*na*	*na*	*na*	*na*	*na*	*±0.2*	*±0*	±0.1
	Chi-square ($P(X^2)<0.001$)		*1,186*	*2,169*	*1,765*	*2,743*	*1,333*	na	na	na

[a] Sawtimber stands were ≥16.7% stocked with live trees, half or more stocked with live trees ≥12.7 cm, and half or more stocked with live trees ≥22.9 cm (softwoods) and ≥27.9 cm (hardwoods).

[b] Average potential growth of industrial wood in fully stocked natural stands.

na not applicable.

— none sampled.

slash pines surpassed shortleaf and longleaf pines in all but the Ozark (M222) and temperate Prairie Parkland (251) provinces. The Outer Coastal Plain (231) contained the last vestiges of an historically extensive longleaf pine type. The shortleaf community type occurred chiefly in the Ouachita province (M231) and portions of the Southeastern province (231). Among hardwood types, oak-hickory was the dominant forest type in provinces to the west and north; lowland hardwoods dominated in the Everglades (411) and Lower Mississippi (234) provinces. The province with the most diverse forests, that is, forests having the most number and proportion of different forest type groups, was the Southeastern (231). The least diverse were fringe provinces (411, 251, 255).

Forest area per capita differed greatly by province, with the Ozark (M222) having the lowest and the Everglades (411) the highest population density (Table 5). More recent data incorporated from the 1995 U.S. Census suggested that population density recently increased in the Ozark (M222) province. There were essentially no forests in metropolitan counties of the temperate Prairie Parkland province (251), and the Everglades province (411) had all of its timberland in metropolitan counties.

Timber resource production activities and associated disturbances differed by province, with many of the timber-associated disturbances occurring in the mixed provinces (231, 232, and M231) (Table 6). These were the provinces with 19% or more of timberland in forest plantations, mostly classed as pine types, and substantial area in forest industry land. Recent fire evidence was greatest (14% to 25%) in the mixed-forest provinces and the

Table 4. Timberland area and proportion by forest type group, southern United States provinces, 1988–1995

Code	Province	All Timberland	Forest Type Group[a]									
			Northern Conifers	Southern Conifers					Oak-Pine	Oak-Hickory	Other Hardwoods	
				Longleaf	Slash	Loblolly	Shortleaf	Other			Lowland	Upland
		1,000 ha	*Percent of row*									
231	Southeastern Mixed Forest	78,882	—	1	1	28	4	3	18	34	11	—
232	Outer Coastal Plain Mixed Forest	23,676	—	4	18	21	0	3	14	16	24	—
222	Eastern Broadleaf Forest (Continental)	7,064	0	—	—	2	1	3	9	76	7	3
234	Lower Mississippi Riverine Forest	3,114	—	0	0	12	1	—	6	18	64	—
M221	Central Appalachian Broadleaf Forest-Coniferous Forest-Meadow	5,897	4	—	—	2	1	7	13	70	1	3
221	Eastern Broadleaf Forest (Oceanic)	4,460	1	—	—	2	2	7	11	74	1	3
255	Prairie Parkland (Subtropical)	1,348	—	—	—	8	6	1	11	50	24	—
411	Everglades	77	—	—	15	—	—	—	4	5	76	—
M231	Ouachita Mixed Forest	1,651	—	—	—	21	19	0	25	31	5	—
M222	Ozark Broadleaf Forest-Meadow	1,061	—	—	—	1	9	1	15	71	2	—
251	Prairie Parkland (Temperate)	113	—	—	—	—	3	—	—	91	7	—
	All timberland	80,385	0	2	6	19	3	3	15	37	15	1
	Area (1,000 ha)		265	1,198	4,563	15,083	2,149	2,474	11,851	30,096	12,220	466

[a] Excludes 19,000 ha nontyped (nonstocked).

Forest types are based on plurality dominance (May 1990) and largely follow Society of American Foresters cover types (Eyre 1980). Northern and southern conifers are ≥50% conifer; all others are <50% conifer. Scientific nomenclature (Little 1979) for predominant genus or species:

Northern conifers (*Picea-Abies* and *Pinus strobus-Tsuga canadensis*). Southern conifers: plurality in longleaf (*Pinus palustris*), slash (*P.elliottii*), loblolly (*P. taeda*), other (*Juniperus virginiana, P. clausa, P. virginiana*). Oak-pine (*Quercus*-southern conifers). Oak-hickory (*Quercus-Carya*).

Other lowland hardwoods (*Ulmus-Fraxinus-Populus deltoides, Quercus-Liquidambar-Nyssa-Taxodium*).

Other upland hardwoods (*Acer-Fagus-Betula* and *Populus-Betula*).

— None sampled.

temperate Prairie Parkland province (251) (Table 6). An earlier assessment suggested that most forests containing fire evidence were not associated with wildfire, but with activities associated with prescribed fire, like site preparation, pine plantation management activities, other timber harvests, and livestock grazing (Rudis and Skinner 1991). Harvest activities occurred in all provinces—chiefly "other" harvest practices like commercial thinning and diameter-limit, seed tree, shelterwood, and uneven-aged cutting.

Popular notion holds that clearcutting is a widespread aspect of timber management in the South. For midsouth states, no more than 13% of timberland was clearcut in any province (Table 6). In Table 6, harvest activities are noted only for the period between surveys approximately a decade earlier. On an annual basis, the proportion clearcut amounted roughly to 1% per year. In that same time interval, almost twice as much timberland was harvested using other cutting practices.

Other attributes suggested vulnerability to nonforest use and potential for combined resource production. All indicators differed significantly by province (Table 6). The provinces' forests differed in vulnerability to agricultural influences, that is, in the proportion of forests near agricultural land and fences and with evidence of livestock use. Average rank by province placed the Ouachita (M231) as least vulnerable, and the Eastern Broadleaf (222) and subtropical Prairie Parkland (255) as most vulnerable to agricultural influences. Combined livestock and forestry production programs had the most potential for adoption in provinces with substantial livestock grazing, for example, the subtropical Prairie Parkland province (255).

Indicators of human impact, such as beverage containers and other litter, forest fragmentation, hunting activity and evidence, proximity to roads, and urban or built-up land, showed significant differences by province (Table 7). Forests near roads, urban areas, and beverage containers and other litter also suggested increased access, which favors urban-oriented recreational activities such as picnicking. Urban

Table 5. Land area per person, forest land use, and portion in metropolitan counties, southern United States provinces, 1988–1995

Code	Province	Land Area			Forest Area[a]			Portion in Metropolitan Areas[b]			
		1990[a]	Change 1990–1995		All Forests	Forest Land Use		Land	Forest	Timber-land	Reserved Forest
						Timber	Reserved				
		ha per person		*Percent*	*ha per person*			*Percent of resources*			
231	Southeastern Mixed Forest	2.3	-0.2	-7	1.5	1.5	0.007	31	27	27	60
232	Outer Coastal Plain Mixed Forest	2.1	-0.1	-7	1.2	1.2	0.019	34	28	28	32
222	Eastern Broadleaf Forest (Continental)	2.8	-0.2	-7	1.2	1.2	0.012	24	19	19	19
234	Lower Mississippi Riverine Forest	4.5	-0.1	-3	1.4	1.4	0.000	18	22	22	0
M221	Central Appalachian Broadleaf Forest--Coniferous Forest-Meadow	2.8	-0.2	-6	2.0	1.8	0.117	27	25	26	13
221	Eastern Broadleaf Forest (Oceanic)	2.9	-0.2	-6	2.1	2.0	0.068	20	17	16	61
255	Prairie Parkland (Subtropical)	1.2	-0.1	-8	0.5	0.4	0.001	20	15	16	0
411	Everglades	0.5	0.0	-8	0.1	0.0	0.025	88	71	100	67
M231	Ouachita Mixed Forest	3.8	-0.2	-4	2.8	2.7	0.032	17	13	14	15
M222	Ozark Broadleaf Forest-Meadow	7.8	-0.7	-10	5.3	5.1	0.163	20	16	16	0
251	Prairie Parkland (Temperate)	3.8	-0.1	-3	1.0	0.9	0.000	0	0	0	0
	All land	2.3	-0.2	-7	1.3	1.3	0.020	29	25	25	34

a 1990 Census, corrected as of April 1995.

b Sensu Butler and Beale (1993).

influences were greatest when forest fragments were small, and when forests were near urban or built-up land and had beverage containers and miscellaneous discarded material of human origin.

Average ranking of the urban influence criteria yielded the Ozark province (M222) as least vulnerable, and the subtropical Prairie Parkland province (255) as most vulnerable. These two provinces also had the most and least timberland per person, respectively. In fact, human population density was directly associated with forest fragmentation (Figure 3). A province with intermediate vulnerability was the Lower Mississippi (234); human population there was relatively low and average fragment size was intermediate compared with other provinces.

Restrictive hunting signs were most important for the Lower Mississippi (234), subtropical Prairie Parkland (255), and Southeastern (231) provinces. Evidence of a tree stand or shells indicated hunting activity was comparatively more important in the Lower Mississippi (234) than in others. Having both indices ranked at the top suggested that income-generating opportunities from hunting lease sales was greatest in the Lower Mississippi province (234).

DISCUSSION AND SUMMARY

Results of this assessment highlight the reduced importance of longleaf pine and shortleaf pine; a shortage of protected areas; the relative importance of forest disturbances such as fire, livestock grazing, recreation opportunities; and the impacts associated with human activities in the South's forests. Differences among provinces in land area by wood resource productivity, protection, disturbance, threat, and human impact suggest that there is a need to tailor forest resource analysis, management, and resource incentive programs according to subregions with similar ecological potential. An ecologically oriented program would be able to suggest incentives for increased wood production in sparsely forested provinces with commercial spe-

Table 6. Timberland area by resource production activities, associated disturbances, and province, midsouth states, 1988–1995

Code	Province	Proportion of Southern U.S.		Midsouth Timberland Area	Timber				Other			
					Planted Stands	Management	Commercial Harvest		Within 1/4 mile of		Evidence of	
		All land	Timberland				Clearcut	Other[a]	Agriculture	Fences	Livestock	Fire[b]
		— Percent —		*1,000 ha*	*Percent (of midsouth states' timberland)*							
231	Southeastern Mixed Forest	*61*	*63*	20,068	19	13	11	24	47	30	8	14
232	Outer Coastal Plain Mixed Forest	*26*	*29*	6,809	27	23	12	21	37	25	8	25
222	Eastern Broadleaf Forest (Continental)	*57*	*63*	4,431	3	2	2	16	73	43	17	7
234	Lower Mississippi Riverine Forest	*100*	*100*	3,103	6	7	4	21	44	15	6	1
M221	Central Appalachian Broadleaf Forest--Coniferous Forest-Meadow	*6*	*5*	297	2	1	0	8	54	32	12	9
221	Eastern Broadleaf Forest (Oceanic)	*54*	*49*	2,187	4	4	4	15	49	27	9	9
255	Prairie Parkland (Subtropical)	*100*	*100*	1,348	4	4	3	10	73	64	31	8
M231	Ouachita Mixed Forest	*100*	*100*	1,651	29	20	13	20	31	23	15	18
M222	Ozark Broadleaf Forest-Meadow	*100*	*100*	1,061	4	6	2	14	54	35	18	9
251	Prairie Parkland (Temperate)	*100*	*100*	113	0	2	0	5	67	44	20	17
	All timberland	*50*	*51*	41,068	16	12	9	21	48	30	10	14
	Chi-square ($P(X^2)<0.001$)				*988*	*722*	*355*	*147*	*896*	*683*	*526*	*523*

[a] Partial (diameter-limit, uneven-aged) cutting, commercial thinning, salvage harvest, seed tree, and shelterwood cutting.

[b] Includes wildfire and unknown causal agents. Rudis and Skinner (1991) estimated that three-fourths of fire evidence was associated with human activities.

cies appropriate to a province's ecological potential. One example is establishment of sweetgum (*Liquidambar* L.), willow (*Salix* L.), poplar (*Populus* L.), and oak plantations in the Lower Mississippi (234), a province with few pines, apparently high demand for hunting, and the highest potential wood productivity in the South.

There was an imbalance among provinces in the area devoted to protection and to plantations. By historical accounts (e.g., Williams 1989), local political concerns and land costs have played a more important role in the purchase of land than ecological considerations. Results of this study suggest that protection priority should be given to forests of the subtropical Prairie Parkland province (255), because they are most vulnerable to both urban and agricultural influences. Ninety-one percent of the timberland in that province was in the nonindustrial private owner class, the largest proportion of all provinces (Table 3), and almost a third of the timberland was associated with livestock grazing (Table 6). To augment timberland area, private owners may be receptive to investment incentives in income-generating opportunities like hunting lease sales (Marsinko et al. 1992), active agroforest operations (Child and Byington 1980), and other uses that complement timber production. Public purchase of land and conservation easements that relinquish future development rights are options whereby public expenditure can help to mitigate further forest losses.

The unbalanced occurrence of plantations in mixed provinces probably had something to do with the provinces' potential for pine production. The fact that forest industries owned a substantial portion of land in the mixed provinces (Table 3) also played a role. Forest industries, like public agencies, took control of selected areas of the South early in this century (Williams 1989). Forest industry land purchases in other provinces may be the most reliable way to balance the proportion of plantations by province.

Table 7. Land area and timberland area by human influence and province, midsouth states, 1988–1995

Code	Province	Proportion Southern Land Area	Land Area per Person[a]	Timberland		Average[b]			Evidence of Humans			
				Area	Per Person[a]	Forest Fragment Size	Distance from Roads	Distance from Urban or Built-up Land	Hunting Signs	Hunting Activity	Beverage Containers	Misc.
		Percent	*ha*	*1,000 ha*	*ha*	*ha*	*m*	*m*	*Percent*	*Percent*	*Percent*	*Percent*
231	Southeastern Mixed Forest	*61*	3.8	20,068	2.5	343	158	2,488	13	7	23	32
232	Outer Coastal Plain Mixed Forest	*26*	2.8	6,809	1.7	387	161	2,455	11	8	22	30
222	Eastern Broadleaf Forest (Continental)	*57*	3.2	4,431	1.5	176	189	2,506	7	7	18	27
234	Lower Mississippi Riverine Forest	*100*	4.5	3,103	1.4	357	229	2,531	13	14	28	37
M221	Central Appalachian Broadleaf Forest--Coniferous Forest-Meadow	*6*	1.5	297	0.8	176	189	2,065	3	5	13	18
221	Eastern Broadleaf Forest (Oceanic)	*54*	2.3	2,187	1.4	311	198	2,208	5	5	20	27
255	Prairie Parkland (Subtropical)	*100*	1.2	1,348	0.4	125	219	2,124	13	9	27	40
M231	Ouachita Mixed Forest	*100*	3.8	1,651	2.7	360	142	2,515	3	4	16	26
M222	Ozark Broadleaf Forest-Meadow	*100*	7.8	1,061	5.1	532	204	2,729	3	4	17	24
251	Prairie Parkland (Temperate)	*100*	3.8	113	0.9	202	218	2,558	4	11	21	39
	All timberland	*50*	3.2	41,068	1.8	316	171	2,463	11	8	22	31
	±2 standard errors (overall average)					*+18, -17*	*±7*	*+59, -60*	*na*	*na*	*na*	*na*
	Chi-square ($P(X^2)<0.001$)					*na*	*na*	*na*	*178*	*106*	*95*	*113*

[a] 1990 Census, corrected as of April 1995.

[b] Average calculated from logarithm-transformed median values of ordinal classes.

na = not applicable.

Roads = truck-operable or better. Hunting signs = hunting restricted, hunt club, "posted," or "no hunting." Hunting activity = evidence, typically a tree stand, shotgun shells, or rifle shells.

Misc.= presence of discarded materials other than beverage containers: machinery, tools, food containers, other items.

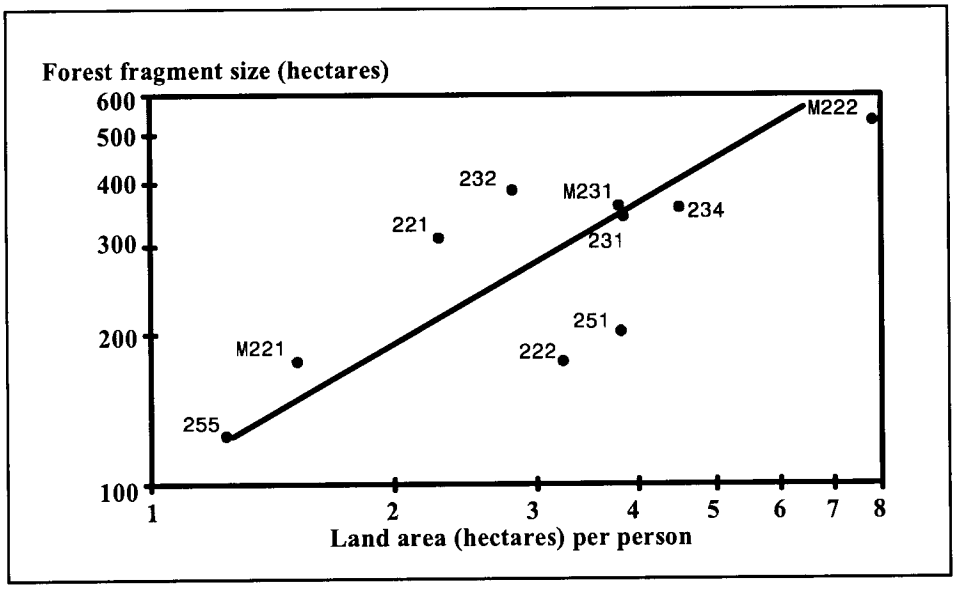


Figure 3. Forest fragment size from Forest Inventory and Analysis surveys, 1988 to 1995, versus 1990 population density per unit land area, by province, south central United States. Correlation $r = 0.79$, $P(r) < 0.01$. See Table 7 for the name of the numbered province.

Lack of southern conifer dominance in mixed provinces was due to a number of factors. Westveld (1949) suggested that there was greater wildfire frequency in the South more than 50 years ago. Rudis and Skinner (1991) noted that three-fourths of the fire evidence in midsouth states was associated with timber harvesting, management, and livestock grazing—actions frequently associated with prescribed fire management. The limited dominance of pine in all provinces could be a cause, or a result of, wildfire suppression and is certainly linked to the reduced use of prescribed fire and other hardwood control measures on nonindustrial forest land.

In this study, the area encompassing the Outer Coastal Plain province (232) and portions of the Southeast province (231) showed a plurality in species other than longleaf; but these areas are believed by some to have had far more longleaf and more wildfires in the past (Westveld 1949, Walker 1995). The Outer Coastal Plain (232), a province moderately impacted by urban influences, had a comparatively large proportion of endangered species (Flather et al. 1994). Ways to help solve the endangered biota problem include using more longleaf, establishing more public protection areas, and promoting the use of fire as a vegetation management tool.

This study illustrated the value of incorporating a global ecological framework into ecological forest resource appraisal. Realignment by county was a practical basis for aggregating the two sources of information. National forest supply scenarios and economic projections (e.g., Powell et al. 1993, Haynes et al. 1995) use resource administrative units—often by states or groups of states with similar timber potential. If such analyses grouped areas with similar ecological potential and incorporated other resource indicators, they might provide a wider array of income-generating opportunities that also reflect ecological perspectives.

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Victor Rudis is a research forester and landscape ecologist with interests in forest monitoring, including the measurement of visual quality, forest structure, and landscapes, and assessment of human impacts, dispersed recreation, forest vegetation classification, and wildlife habitat from regional forest resource surveys.

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