Special Session 4.

Burning Issues and Smoke Screens: Heat and Light in Southern Forests

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Opening Remarks

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The title of this special session, "Burning Issues and Smoke Screens: Heat and Light in Southern Forests," has both metaphorical and literal significance-as I'm sure your examination of this morning's program has revealed. And there is no more fitting context than the southern forest resource, as we sit in the middle of the Florida peninsula, to address the theme of this conference: "Changing Resource Values in Challenging Times." "Changing" is perhaps the best available single-word characterization of the South's forest resource situation, and challenging times are upon us all. This special session will focus on key changes and challenges faced by natural resource managers in the Piedmont and Coastal Plain forests of the South. It is a sequel to last year's session, titled "The Changing Face of Eastern Forests," and will be followed next year by a companion session on western forests.

Forests hold a prominent (many would say "dominant") place on the landscape and in the economic, cultural and environmental fabric of the South. It has been so since long before the advent of European influence. The South is the birthplace of professional forestry in this nation, a region rich in ecological diversity and natural beauty, the "nation's woodbasket," and increasingly a battleground for competing interests in diverse and changing resource values. Furthermore, the South's community of natural resource professionals is the most tightly interwoven network of federal and state agencies, universities, industries, and conservation groups that I have found anywhere. Could there be a better case study for examining the issues implied in the theme of this conference?

As the Chair of this special session, I have the honor of introducing the topic. I also have the prerogative to do so by rather cavalierly making a number of assertions and leaving it to the speakers to support or refute them. I will make nine such assertions.

First, the southern forest is virtually unique in the world. Nowhere else can one find the South's combination of high forest productivity, ecological diversity and prominence of largely unregulated private forest ownership over such an extensive region. It is a nationally critical resource that is predominantly developed and shaped through independent decisions and actions made by a very large number of private citizens operating in their own self interest and in response to personal values and free-market forces. The fact that it has thrived so successfully in the past is a constant source of bewilderment for our international visitors.

Second, the recovery of the southern forest, following abusive agricultural practices and exploitive forest extraction in the 19th and early 20th centuries, is the most noteworthy testament to the success of the conservation movement that one can cite. Many simply cannot accept that today's cherished and contested forestlands were farmed-out, burned-over, seriously eroded "lands that nobody wanted" just 60 or 70 years ago. We ail can be proud of this recovery. Historians will someday look back on our generation of land stewards, and our recent predecessors, and say "they're the ones that began rebuilding our soil."

Third, the forests of the South are brand new; they have never existed anywhere before, and they aren't "done" yet. The combination of past land abuse, wave after wave of exotic pest intrusions, altered natural disturbance patterns, direct human pressures on land use and forest resources, and other indirect influences of human activity have left us with vastly altered forest systems. Loss of the American chestnut is but one illustration of this point. Little about these forests can be called "natural"; we have much to learn about how they function, how they are yet responding to past and ongoing influences, and what they will (or could) ultimately become. We do, however, know that they're on a one-way track. Future forests will not be the same as today's, and the pathway to past forest conditions has long-since been blocked.

Fourth, social forces driving change in our management of natural resources will intensify at all scales, accelerating the pace of change in our forests and the values we demand of them. As we face continued population growth, urbanization, demographic shifts to the South, nationwide evolution of policies governing public forest management, development of third-world nations and emergence of globalized economic networks, the intensity and complexity of natural resource issues and conflicts will surely increase and place even greater demands on southern forests and those who manage them. Can we adapt and respond quickly enough to avert a meltdown?

Fifth, the emerging global concern over sustainability-meeting the needs of today's society without impairing the ability of future generations to meet *their* needs-will become the central issue driving public debate over natural resource management in the U.S. Today's polarizing arguments over wilderness, roadless areas, below-cost timber sales, ecosystem management, recreational opportunity, fiber supply and endangered species recovery will meld into the fabric of this broader, potentially unifying context. The South will become the stage on which the sustainability issue will play out most visibly in our nation. And it will happen over the next decade. We are still ahead of a crisis, but will have to invest quickly to stay there. We will need to strengthen collaborative approaches to large-scale management. We will also need better tools for adaptive management-tools based on credible science that aid in predicting ecosystem responses to natural and human influences, monitoring conditions and trends, and choosing management actions that are truly sustainable.

Sixth, ensuring sustainability vis-a-vis southern forests will, almost by definition, require a dynamic blend of intensive management for commodity and certain experiential values with more extensive efforts to establish and maintain ecosystem integrity and functional capacity for a wide range of both commodity and amenity values. Both approaches are essential, operating in concert, to meet the sustainability criterion. Those who argue the case for reliance on off-shore fiber supplies have not fully thought through the implications for global sustainability and the potential risk to *all* of our forests from exotic species introductions.

Seventh, the never-to-return nature of southern forest dynamics poses some interesting conceptual challenges for the notion of ecosystem restoration. From a structural standpoint, if we are missing some of the pieces needed to restore forests to a desired structure based on some historical reference point, then how do we define the desired outcome-and can we call it "restoration" if the desired structure has never existed? We're forced either into an engineering design problem, or an effort to restore preexisting *functional* attributes. But do we know enough about ecosystem function, here in the South or anywhere else, to be effective in this latter pursuit? At least one of our speakers will address this point.

Eighth, fire is historically the most powerful and influential force affecting southern forests, and fire use will play a key role in any successful strategy toward southern forest sustainability. I've heard it said in various ways that prescribed fire is the most important forest management tool we have in the South, and smoke is the most critical barrier to its use. There are serious and far-reaching consequences of this dilemma.

Finally, internecine policy conflicts (read: conflicts among jurisdictional interests of independent federal agencies) pose the most pressing challenge before us. The fire/smoke issue is perhaps the most visible and important, but just one of many examples. I've often wondered, could failure to burn based on Clean Air Act regulations be considered a "take" under the Endangered Species Act? I believe that the collective attendance at this very conference has both the power and the obligation to work through such nonsense as this.

This special session is designed to explore many of the issues surrounding the above assertions. It is organized in two panels. The first pane1 will examine the current condition of the southern forest, its place in the social milieu of the South and how it all came to be this way. The second pane1 will focus on some special issues affecting the sustainability of this unique and valued resource-including restoration ecology, and the role and use of fire.

We hope you will find the presentations interesting and provocative, engage in a lively discussion and ultimately rise to meet the challenges posed here.

How Far Could a Squirrel Travel in the Treetops? A Prehistory of the Southern Forest

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Introduction

Conservation activities aimed at protecting old-growth forests; at maintaining populations of desired species groups, such as oaks (*Quercus* sp.), wild turkeys (*Meleagris gallopavo*), other game species or Neotropical migratory birds; and at increasing populations of endangered species, such as red-cockaded woodpeckers *(Picoides borealis)*, Bachman's warblers *(Vermivora bachmanii)*, Louisiana black bears (*Ursus americanus luteolus*) and Tennessee coneflowers (*Echinacea tennesseensis*), require a target environment. This target, often viewed as the environment at some specified past time, becomes the desired future condition. If the target can be considered a stable ecosystem that is self-perpetuating under control of natural processes, the envisioned environment is a defendable "natural" target for land-use planning. If the target is not easily regarded as "natural," but must involve cultural intervention for its appearance or persistence, the planning process must derive a target environment by some other method, one more clearly reflective of the values of the planners themselves.

Our purpose in this paper is to suggest time periods as potential candidates for the "original" or "natural" condition of the southern forest and to evaluate the forest conditions at those times in light of knowledge of past geological and cultural conditions.

The "Original" Southern Forest in 1607

A most useful starting point for characterizing the prehistory of the southern forest is the establishment of permanent English colonies in 1607. We begin there. A frequent vision of the forest, shared by authors too numerous to mention (e.g., Alverson et al. 1994) depicts relatively complete coverage of closed-canopy forest from the Atlantic Coast to the Great Plains. In this view, a squirrel, presumably a gray squirrel (*Sciurus carolinensis*), would have been able to move almost in a straight line from treetop to treetop across the Carolinas and Tennessee to the Mississippi River.

This view of the southern forest assumes that natural processes, beginning with glacial retreat and continuing to the arrival of European/African colonists, maintained an extensive, relatively unbroken forest canopy over the South. Several distinct implications for forest conservation and management are apparent. First, a preponderance of climax forest cover would be the historically stable, long-existing condition. Second, wildlife species adapted to later successional conditions, such as pine (*Dendroica pinus*) and cerulean warblers (*D. cerulea*), were very numerous and at carrying capacity in stable and extensive habitats. Third, early successional species, such as prairie (*D. pensylvanica*) and Bachman's warblers, were less abundant, occupied habitats ephemeral in time and space, and were selected for dispersal ability and high reproductive rates. This forest is an obvious candidate for the desired future condition (i.e., target) in the conservation planning of the southern landscape.

In reality, the 1607 forest was probably very extensive, as popular writers suggest. However, this view conceals a myth (Denevan 1992b). The myth, that long-continuing natural forces were responsible for that extensive forest, is exposed by the history of the southern forest (Williams 1989, Denevan 1992b). The southern forest was perhaps at its greatest extent in 1607, a result of changing human activity, not continuous forest development. We briefly document forest conditions at the time humans entered the South 12,000 to 15,000 Years Before Present (YBP); in 1492, at the time of contact between southern Europeans and Native Americans; and return later to 1607.

The "Original" Southern Forest in Late Glacial Times

During glacial times, the southern forest ecosystem included boreal species in communities resembling to those recognized as the Canadian spruce-fir (*Picea-Abies*) forests of today (Delcourt and Delcourt 1991). Boreal birds occurred in central Tennessee (Parmalee and Klippel 1982). Proboscideans, principally mastodons (*Mammut americanum*) and mammoths (*Mammuthus columbi*), dominated the fauna. These grazing animals depended primarily on grasses and sedges, and they likely affected the vegetation of their environment as do modem-day elephants (*Loxodonta africana*) (Fox et al. 1992). Humans hunted these large herbivores extensively throughout the Americas and, in conjunction with increasingly warm climates, probably contributed to their extinction 10,000 YBP (Fox et al. 1992). Early humans probably used fire as a part of their hunting repertoire (Buckner and Turrill in press).

By 7,000 YBP, climate amelioration permitted the currently predominant species to occupy the southern forest (Delcourt and Delcourt 1991). The pattern of post-glacial colonization by trees was species-specific, indicating that forest types as we currently recognize them (Buckner 1995, Hamel 1992) were and continue to be transient in time as well as in space on the landscape. The transience of forest communities in geologic time is the first factor creating uncertainty in setting the 1607 forest as a desired future condition.

A second factor that has received intense attention in the literature is the use of fire by people to control and modify vegetation. Records are scanty and interpretations disparate, so our conclusions will not be agreeable to all. Many writers (e.g., Day 1953) conclude that fire was used by Native Americans as a primary management tool for vegetation manipulation (cf. Van Lear and Waldrop 1989). Others (e.g., Russell 1983) conclude that the effects of Native American-caused fires were more limited in extent and confined nearer to their actual villages. A recent summary of palynological and charcoal evidence for a single site in the Southern Appalachians (Delcourt and Delcourt 1997) indicates a continuous human use of fire for the past 5,000 years. The effect of fire in the southern forest was to increase the extent of longleaf (*Pinus palustris*) and other yellow pines, increase the amount of oak in the forest, reduce the amount of hardwood midstory and understory, increase the spacing of the trees, increase forage grasses used by game animals, and maintain cleared areas for hunting and farming.

The importance of fire to the ecology of longleaf pine is well established. Because both the late successional pine warbler and early successional prairie warbler depend on pine forest habitats, both likely benefitted from persistent use of fire in the southern ecosystem (cf. Hamel 1992). Another plant that is fostered by moderate burning regimes is cane (*Arundinaria gigantea*) (Platt and Brantley 1997). Primarily a species of river floodplains of the South, cane played a prominent role in the ecology of Bachman's warbler (Hamel 1986, Remsen 1986), as well as in the economy of Native American people (Hamel and Chiltoskey 1975). Noss et al. (1995) list canebrakes as one of the endangered ecosystems of the United States. This plant is another key to understanding the prehistory of the southern forest.

The "Original" Southern Forest in 1492

Canebrakes were a common feature of the river floodplains of the South in 1607 (Platt and Brantley 1997), while pine forests were the predominant forest cover on the uplands across the South. Both plants benefit from disturbance, especially fire. Numerous early explorers noted the low population density in the southern forest in 1607 (cf. Clark 1984, Williams 1989, and especially Silver 1990). Until recently, however, the importance of events that occurred between 1492 and 1607 was not widely recognized. These events, however, shaped the forest conditions that support the myth of an unbroken forest extending from the Chesapeake Bay to the Great Plains in 1607.

The final ingredient that shaped the prehistory of the southern forest was the isolation of the Americas from Europe, Africa and Asia. That isolation created a "virgin soil" condition, not of extensive undisturbed forest, but of human populations isolated from disease pathogens (Whitmore 1991). Contact in 1492 between the Old and New Worlds injected diseases endemic in the Old World (e.g., smallpox, measles, typhus and malaria) as epidemics into the New World. The result was horrific loss of human life.

Population estimates of the Americas in 1492 vary greatly, reflecting different demographic perspectives and methods of calculation. North American estimates range from a relatively low 3.7 to 4.4 million (Denevan 1992a) to a much higher 18 million (Dobyns 1983). Fierce debates rage among demographers about the actual numbers; little debate occurs concerning events between 1492 and 1607. An anthropological consensus is that the population of the Americas was reduced by roughly 90 percent in the 1500s (Whitmore 1991, Love11 1992). Implications of this depopulation for the 1607 forest are extensive.

Human population collapse following epidemic disease outbreaks led to abandonment of Native American agricultural fields no longer needed to produce food crops and reduction of fires set to maintain those fields. Huge, open agricultural areas, measured in thousands of acres, were noted by earliest Spanish explorers, particularly the members of DeSoto's expedition in 1540 (Dobyns 1983, Cowan 1985, Doolittle 1992). Even then, depopulated villages were described. Subsequent to initial Spanish exploration, these abandoned fields, occupying vast areas in the bottomlands of the rivers of the South, reverted to forest. Probably they were colonized first by the cane that the people maintained for use as a construction material (Platt and Brantley 1997). Subsequently, these cane patches were colonized by other woody species, which in time shaded out the canebrakes. The range of Native American peoples who maintained canebrakes as sources of construction materials is a close approximation of the distribution of Bachman's warbler.

Woody encroachment onto Native American old fields may reflect the initiation of some of the old-growth bottomland forests of today. Enormous sweetgum (*Liquidambar styraciflua*) trees dominate the canopy of the spectacular forests of Congaree Swamp, Richland County, South Carolina, and the Sweetgum Natural Area on the Delta National Forest, Sharkey County, Mississippi. However, smaller individuals of the species are scarce or absent (Jones

1997, P. B. Hamel personal observation: 1981). Dense stands of sweetgum, a shade-intolerant species (Fowells 1965), develop only in **full** sun on old fields and roadsides. Without some extensive disturbance, these enormous trees will in time be replaced by more shade-tolerant species. Jones' (1997) finding that 95 percent of champion trees in Congaree Swamp have died in the past 15 years suggests that this successional process is happening now. Human population collapse following epidemic disease outbreaks, abandonment of Native American agricultural fields and reduction of fires set to maintain those fields set the stage for colonization of extensive areas by forests.

Cerulean warbler populations were high throughout the Ohio and middle Mississippi River valleys in the extensive floodplain forests encountered by early settlers (e.g., Wilson 18 IO- 18 11, Widmann 1907). Had the forests there developed continuously, the species' dependence upon vast unbroken expanses of forest would be unquestionable. The existence of large Native American populations with extensive agricultural fields in those very river bottoms well into the 16th century offers a ray of hope for the future of this currently embattled species. If cerulean warblers were the most common warblers in Mississippi Alluvial Valley forests in central Illinois in the 19th century, they were occupying lands on which the Native Americans in the 13th century constructed a metropolis, Cahokia, more populous than London at the same period (Kennedy 1994).

Conclusion

We conclude that no specific past time can be said to represent the true "original" condition of the southern forest, that human activity has shaped that forest for millennia and that the desired future condition of the southern forest has more to do with societal values than with some ideal past condition. We did not arrive at this conclusion easily. Our examination of the historical record of human inhabitation and forest development does provide an indication of the resilience of southern biota and offers hope to conservation planners and policy makers that desired future conditions can in fact be specified and achieved.

Probably, a squirrel could no more have traveled through unbroken forest from Norfolk, Virginia to Greenville, Mississippi in 1492 than it can in 1998.

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The South's Forestland-On the Hot Seat to Provide More

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Forests of the southern United States range from tropical/subtropical forests on the southern extremities of the region, oak Savannah forests on the western fringe, to central hardwood forests and high elevation boreal forests in the north. Upland and bottomland hardwood, southern pine and mixed pine-hardwood forests are found on the more moderate sites between these extremes. The South's forests have been and continue to be molded by a myriad of natural agents and human activities that affect forest values and functions, as well as the relative mix of forest benefits. The pressure on the region's forests to provide more of everything is strong and escalating each year. Major contributors to this pressure include a growing and increasingly non-rural population and increased demand on the region's forests to supply more of the wood products consumed by our nation. Conflict over what our forests should be and how they are managed highlight the need for a sound understanding of the current status of our forests. Here we provide an overview of the current status of southern forests, document changes that have taken place during the latter half of the 20th century and offer some assessment of effects on forest wildlife communities.

Data for this assessment are taken from regional forest inventory data collected by the USDA Forest Service's Forest Inventory and Analysis (FIA) units (USDA Forest Service 1992). Previous assessments of our nation's forest resources provide basic trend information for the South for 1952 and several subsequent years (USDA Forest Service 1958, USDA Forest Service 1982, Powell et al. 1993). The most recent compilation of national statistics was for 1992; these data were updated for the South using results from forest inventories completed since that time. Most of the current forest inventory data used in this assessment are available on the Forest Inventory and Analysis homepage on the Internet: www.srsfia.usfs.msstate.edu. Information on wildlife species and habitat are taken from Wildlife of Southern Forests: Habitat and Management (Dickson in preparation).

Forest Extent and Distribution

Forests cover 214 million acres (86.6 million ha) in the 13 states comprising the southern United States (Figure 1). Forests classified as timberland account for the majority (94 percent). Timberland is considered productive for traditional forest products (i.e., logs for lumber) and not withdrawn from harvesting by statute or formal regulation. Reserved forests are withdrawn from timber harvesting and account for 3 million acres (1.4 million ha) in the South; other forests account for the remaining 9 million acres (3.8 million ha). Other forests were formerly termed unproductive forestland to denote the predominance of trees of small stature that would never achieve sufficient size to produce traditional forest products. However, these forests are often highly productive and valued for many uses, especially as habitat for wildlife species. Other forestland is concentrated in Texas, Oklahoma and Florida. In Texas and Oklahoma, oak savannah forests are predominant. In Florida, hatrack cypress and mangrove forests in the southern half of the state account for most of the other forestland.

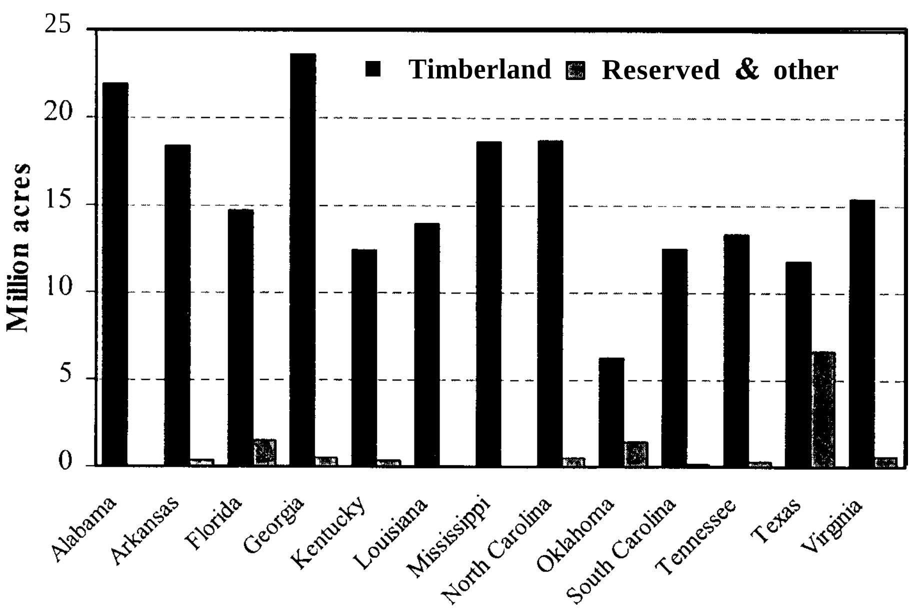


Figure 1. Forest area in the South by state, 1996.

Forest proportion-forest area as a percentage of land area-varies widely between states. In Oklahoma and Texas, less than 20 percent of the land is forested; in contrast, more than 60 percent of Alabama, Georgia, Mississippi, North Carolina, South Carolina and Virginia is forested. Forestland proportion by county also varies substantially (Figure 2). Other than western Oklahoma and Texas, which are not shown in the map, areas with the least forest are found in southern Florida, the entire Mississippi River basin, along the western fringe of the mapped region, and numerous other localities where concentrations of agricultural land or urban land uses predominate. Forests are most dominant in parts of the Appalachian Mountain range, southeastern Georgia and northern Florida, much of Alabama and eastern Mississippi, and an area extending from southeastern Texas and southwestern Louisiana to southwestern Arkansas.

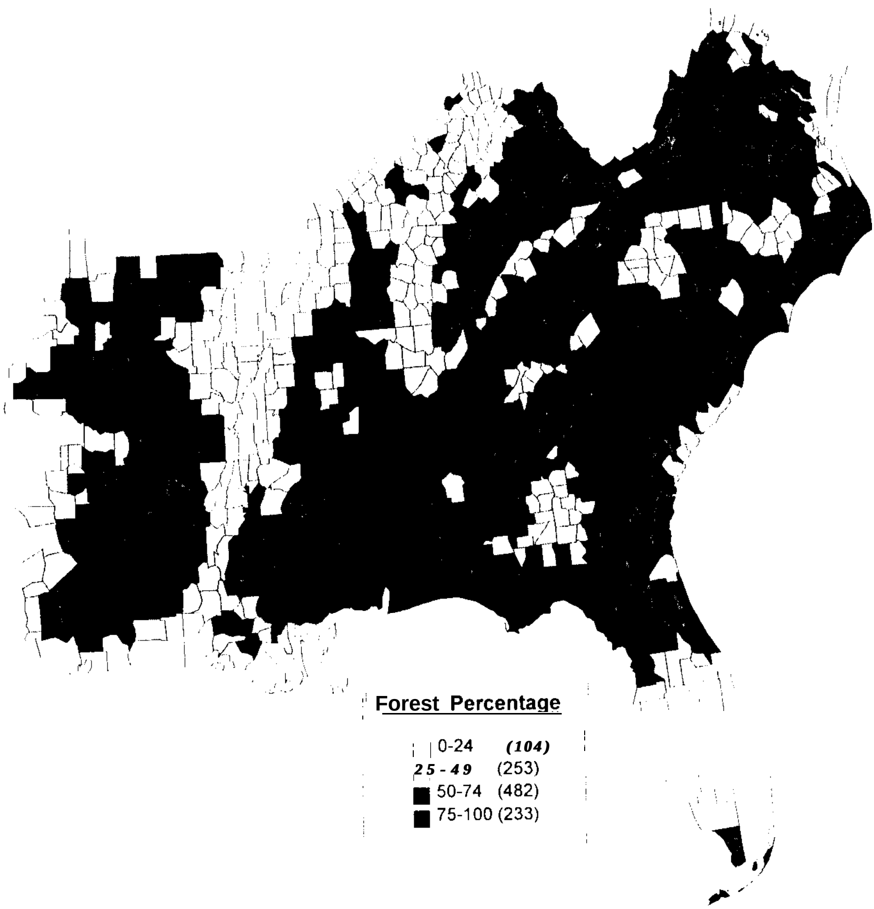


Figure 2. Forest percentage in the South by county, 1996.

Over the latter half of the 20th century, total area occupied by forests in the South has remained relatively stable according to Forest Inventory and Analysis data (Figure 3). Forest area has increased slightly during the 1990s as the movement of agricultural land to forest has more than offset the conversion of forest to other land uses. Forest area in 1996 is less then 5 percent lower than that measured for the region in 1952, with most of that loss occurring in the late 1960s and 1970s. Reductions in area of reserved and other forestland were recorded during the period; however, all of the reduction was in the other forest category, as the acreage of reserved forest increased during the period.

Ownership

At **138** million acres (55.8 million ha), nonindustrial private forest (NJPF) owners control more than two-thirds of the timberland in the South (Table 1). Forest industry has the next largest share with nearly 41 million acres (16.5 million ha), or 20 percent, followed by national forest with 11 million acres (4.6 million ha) and other public agencies with nearly 10 million acres (3.9 million ha). These ownership totals do not include reserved and other forestlands.

Table 1. Area of timberland (in million acres) in the southern United States by ownership class, 1952- 1996.

Ownership class	1952	1962	1977	1987	1992	1996
National forest	10.8	11.1	11.5	11.8	11.6	11.5
Other public	6.6	6.7	6.9	8.2	8.9	9.7
Forest industry	31.8	33.6	36.9	38.0	39.0	40.8
Nonindustrial private	155.3	157.3	144.3	139.4	139.8	137.9
All owners	204.5	208.7	199.6	197.3	199.3	199.9

The NIPF owner group includes an extremely diverse mix of owners with widely varying backgrounds and land-management objectives (Birch 1996). Farmers and ranchers, all other private individuals, and corporations other than forest industries are included. This diversity results in an infinitely variable forest, a positive outcome for wildlife as well as forestry. However, dealing with ownership diversity presents challenges in the development of landowner assistance and other natural resource programs. The NIPF owner group accounts for more than half of the timberland in every southern state except Florida, where they have 49 percent. States with the highest proportion of NIPF control include Kentucky (90 percent), Tennessee (80 percent), Virginia (77 percent) and North Carolina (76 percent). Since 1952, NIPF timberland acreage in the South has declined 11 percent, from 155 to 138 million acres (62.7-55.8 million ha). Most of this drop occurred by 1977, with slight reductions occurring in the latest decades.

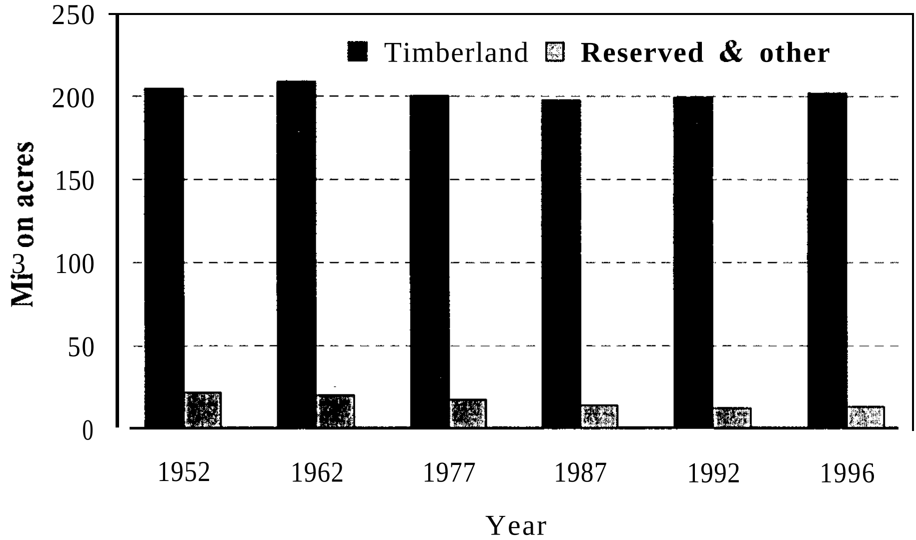


Figure 3. Forest area in the South, 1952-1996.

Forest industry ownership is generally highest in the deeper South. In Louisiana, Texas (eastern), Florida, Georgia, Alabama and Arkansas, forest industry controls 25 percent or more of the timberland. Since 1952, acreage in forest industry holdings has increased by 28 percent; increases have been recorded throughout the period. While it is too soon to discern any long-term trend, evidence from some very recent inventories in the South shows forest industry ownership on the decline. This trend is apparent in Florida, Georgia (inventory underway), South Carolina, North Carolina and Virginia.

Public ownership (national forest and other public combined) of timberland is highest in Florida (19 percent) and Arkansas (17 percent). The trend for public ownership has also been upward, increasing by 21 percent since 1952. Most of the increase has been for other public agencies with only modest change in national forest ownership of timberland.

Forest Composition

The South is often perceived and characterized by visitors as well as inhabitants as a land of southern pines. However, this perception is not substantiated by inventory data. There are more hardwood trees than softwoods for almost all tree sizes for each state (Table 2). A ratio of 1.O and higher in the table indicates more softwood trees than hardwood trees for any state and tree size.

Florida and Georgia are the only states where softwood trees outnumber hardwoods and that is only for pole size trees; Texas and South Carolina have ratios for some tree sizes that are very close to 1 .O.

Table 2. Ratio of softwood to hardwood stems, by state and diameter class.

	D.b.h. class (in inches)			
State	1 .o to 4.9	5.0 to 10.9	11.O to 16.9	17.0+
Alabama	0.25	0.78	0.73	0.47
Arkansas	0.24	0.60	0.58	0.35
Florida	0.61	1.72"	1.14"	0.53
Georgia	0.31	1.01"	0.88	0.49
Kentucky	0.10	0.14	0.08	0.03
Louisiana	0.32	0.79	0.86	0.59
Mississippi	0.26	0.72	0.61	0.39
North Carolina	0.19	0.73	0.54	0.31
Oklahoma	0.22	0.61	0.39	0.16
South Carolina	0.37	0.99	0.83	0.55
Tennessee	0.14	0.27	0.17	0.07
Texas	0.33	0.87	0.96	0.77
Virginia	0.18	0.5 1	0.26	0.12
South	0.26	0.71	0.56	0.34

"Softwoods are more abundant than hardwoods.

Data on forest cover types assigned to stands throughout the South also indicate a preponderance of hardwood-52 percent of the timberland is classed as a hardwood type (Table 3). Upland hardwood forests occupy 75 million acres (30.3 million ha), or about 37 percent of the timberland. These stands are comprised of species such as oaks (*Quercus* spp.), hickories (*Carya* spp.), yellow-poplar (*Liriodendron tulipifera*), sweetgum (*Liquidambar styraciflua*), American beech (*Fagus grandifolia*) and red maple (*Acer rubrum*). Upland hardwood stands make up more than 50 percent of the timberland in Kentucky, Tennessee, Virginia and Oklahoma. Bottomland hardwood forests account for 15 percent of the timberland, or 30 million acres (12.3 million ha). The most common bottomland hardwood forest type is oak-gum-cypress; these forests are often comprised of numerous oak species, tupelo and blackgum (*Nyssa* spp.), red maple and cypress (*Taxodium* spp.). Bottomland hardwood forests are concentrated in Louisiana, Florida, Mississippi and South Carolina.

Southwide, one-third of all timberland is classified as a pine forest type (50 percent or more of the tree stocking is pine). While the proportion of timberland in pine cover types varies widely across the region, Florida is the

Table 3. Percentage of timberland in southern states by forest management class.

State	Pine plantation	Natural pine	Oak-pine	Upland hardwood	Bottomland hardwood
Alabama	18	18	19	33	10
Arkansas	12	17	16	38	16
Florida	33	19	9	14	25
Georgia	23	26	12	25	15
Kentucky	1	5	7	82	5
Louisiana	18	21	12	15	34
Mississippi	16	15	17	32	20
North Carolina	11	22	14	38	14
Oklahoma	10	13	14	53	IO
South Carolina	21	23	15	20	20
Tennessee	3	8	12	72	5
Texas	15	21	21	27	15
Virginia	10	12	13	62	4
South	15	18	14	37	15

only southern state where pine types make up more than 50 percent of the timberland. If oak-pine stands (pine stocking between 25 and 50 percent) are included, the percentage of timberland with significant pine stocking exceeds one-half of all timberland in six states -Alabama, Florida, Georgia, Louisiana, South Carolina and Texas. Loblolly pine (*Pinus taeda*), shortleaf pine (*P. echinata*), slash pine (*P. elliottii*) and longleaf pine (*P. palustris*) are the primary pine species in the region.

At 3 1 million acres (12.5 million ha), pine plantations make up 15 percent of timberland in the South, just short of the natural pine total. An additional 3.8 million acres (1.5 million ha) were planted, but hardwoods dominate the stocking; these stands are included in the oak-pine or hardwood types. Loblolly pine is the species most widely planted throughout the region, whereas slash pine is often planted in the southernmost portion. Planting of longleaf pine is increasingly common as efforts to reestablish the species on former longleaf sites are escalating. Pine plantations make up more than one-fourth of the timberland in many areas including the southern coastal area of South Carolina, southeastern Georgia, northern Florida, southern Alabama and Mississippi, southwestern Louisiana, and southeastern Texas (Figure 4).

An examination of changes in stand cover type categories since 1952 reveals major shifts within the pine resource (Figure 5). Area in natural pine stands has dropped to less than half the 72 million acres (29 million ha) that existed in 1952. Concurrently, pine plantation area has increased from 2 to 3 1

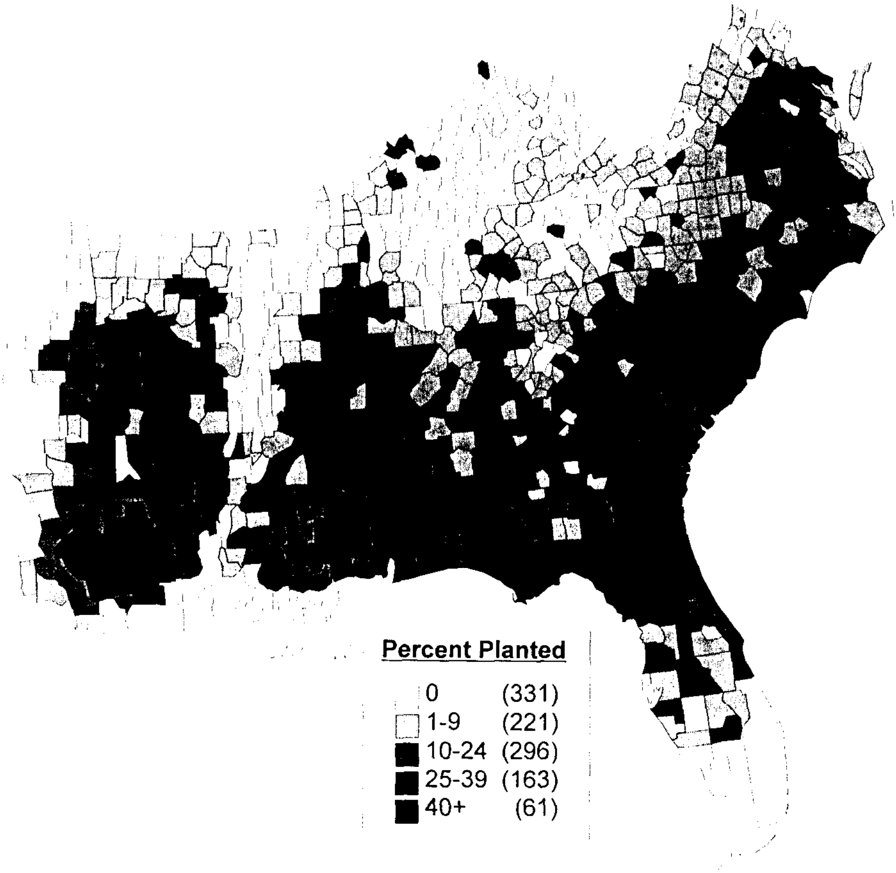


Figure 4. Percentage of timberland originating from tree planting in the South by county, 1996.

million acres (0.8-12.5 million ha). Upland hardwood stands have risen slowly during the period; bottomland hardwood area dropped until around 1970 and has been relatively stable since that time. Oak-pine stands have made up a fairly constant area of around 30 million acres (12.1 million ha) for most of the period.

The balance between pine and hardwood cover types has been relatively constant in the South during the past four to five decades. Increases in pine plantation area have come primarily at the expense of natural pine. While hardwood stands have been and continue to be converted to pine plantations, this activity is apparently not happening at a rate greater than pine stands are moving to hardwood types after disturbance or cutting.

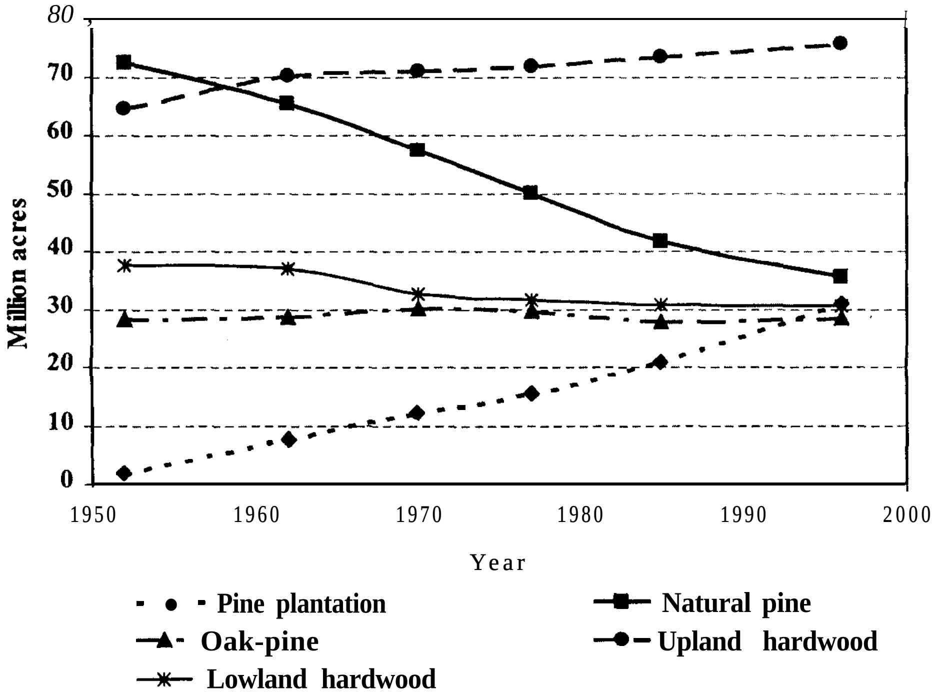


Figure 5. Timberland area in the South by forest management class, 1952-I 996.

Stand Size and Age Structure

The mix of tree sizes in a region combined with successional stage and forest types can have a significant bearing on wildlife habitat suitability. Stand size class is one variable available for use in evaluating the mix of stands dominated by trees that range in size from seedlings to sawtimber. Sapling-seedling stands primarily have trees less than 5.0 inches in diameter at breast height (d.b.h.); poletimber stands have trees between 5 and 9 inches d.b.h. for softwoods and between 5 and 11 inches for hardwoods; sawtimber stands have trees primarily larger than the poletimber upper limit listed above.

Current stand size distributions for the South show that the sawtimber stand size class is the most abundant for both pine and hardwood forests (Figure 6). Bottomland hardwood forests have the highest percentage of sawtimber stands; sawtimber stands outnumber poletimber and sapling-seedling stands by 3 to 1. Stand size distributions are more balanced for pine/pine-hardwood and upland hardwood forests but sawtimber stands still prevail. Sapling-seedling stands are most prevalent in pine/pine-hardwood forests. Stand size distributions often reflect levels of harvest activity in each of the different forest types.

Much higher levels of harvesting occur in pine stands than in hardwood; harvests that remove a major part of the stand usually returns an area back to a sapling-seedling stand size. Inventory data from 1952 to 1996 show that sawtimber stands have increased in prevalence during the period. Poletimber stands were the dominant stand size category in the South in 1952.

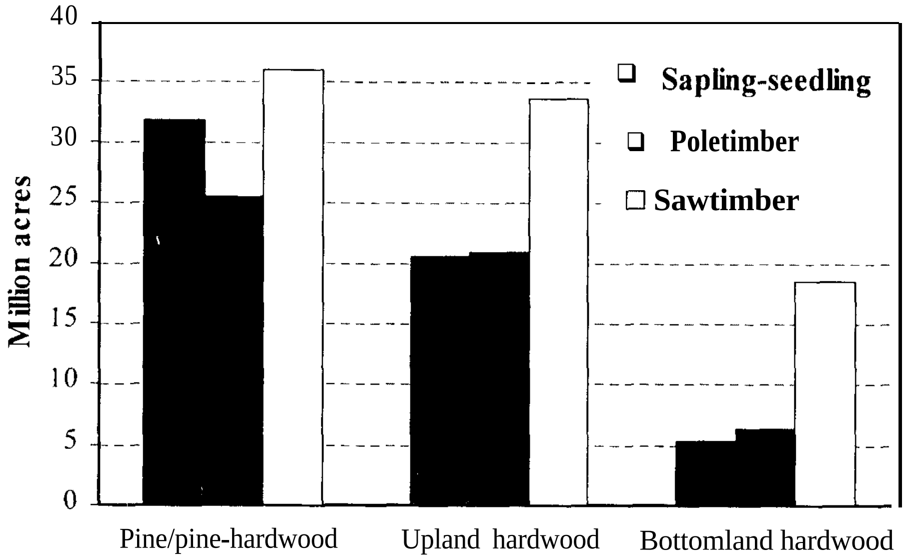


Figure 6. Timberland area in the South by forest-type group and stand-size class, 1996.

Changes in the number of trees existing on timberland between 1977 and 1996 by d.b.h. class also show a pronounced shift toward higher proportions of large diameter trees (Table 4). During the past two decades, numbers of both softwood and hardwood species have increased for the largest diameter classes and declined for the smaller diameter classes. Number of softwood stems have increased in the 16-inch and larger diameter classes, with increases of 30 percent or more for the 22-inch and larger classes. Number of hardwood stems have increased in the 12-inch and larger classes, with increases of 30 percent or more for the 20-inch and larger classes.

Stand age data provide us with a more detailed look at the successional stages for forest stands than is possible using stand size class data. As compatible data on stand age were not available across the region and for consecutive inventory periods, this assessment was conducted for Florida, North Carolina, South Carolina and Virginia where data for three inventories permitted the assessment of age structure changes across three decades from the 1970s to the

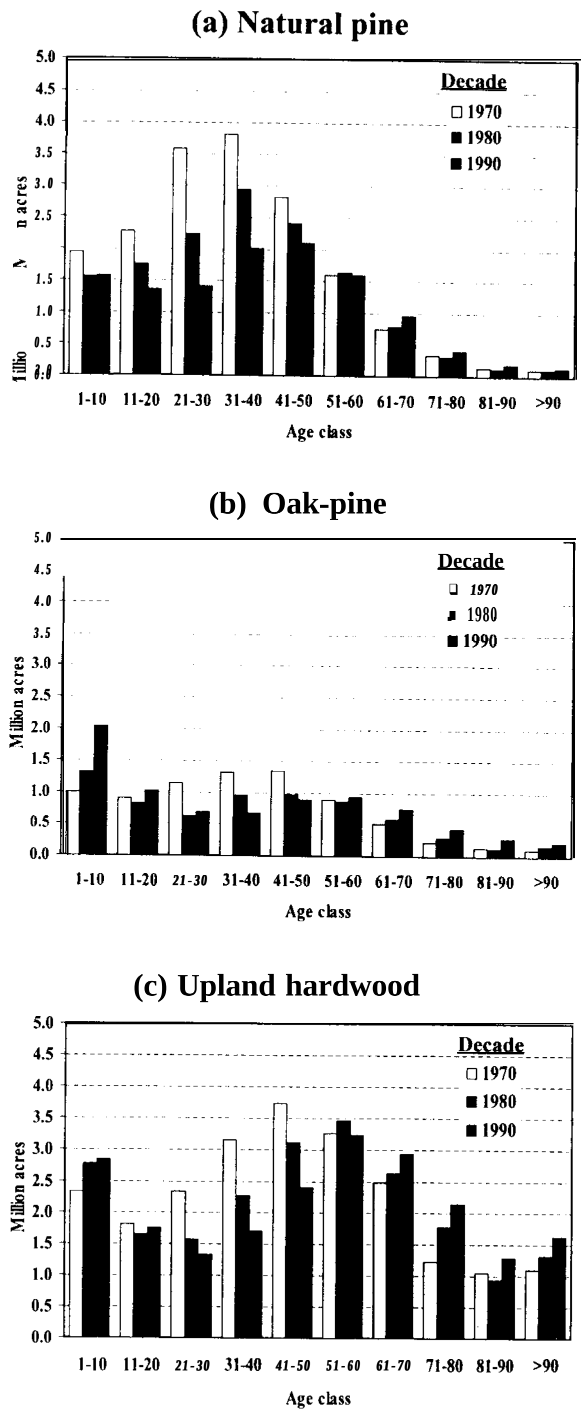
1990s (Figure 7). Mixed age stands were not recognized for this analysis; in these stands, age class was assigned based upon the average age of dominant and co-dominant trees in the stand.

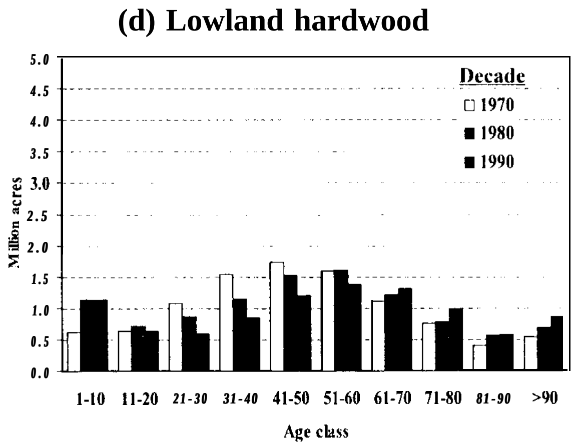
Table 4. Number of trees (in billions) on timberland in the South by diameter class and species group, 1996, and percentage change, 1977- 1996.

	Softwoods		Hardwoods	
Diameter class (in inches)	1996	Percentage change 1977- 1996	1996	Percentage change 1977-1996
2	13.272	-23	64.529	-12
4	7.660	-22	16.438	-24
6	4.630	-11	6.638	-16
8	2.794	-4	3.675	-8
10	1.477	-9	2.268	-2
12	0.858	-6	1.419	3
14	0.488	-1	0.923	10
16	0.266	6	0.560	14
18	0.133	14	0.331	23
20	0.066	22	0.189	31
22-28	0.057	31	0.222	30
30+	0.004	33	0.030	33
Total	31.708	-18	97.221	-13

For natural pine stands, the current age structure and change since the 1970s clearly depicts the reduced extent of this type in these four states. A progression of these stands toward older age classes and a more balanced age structure is also clear. Area of natural pine stands greater than 50 years old has increased, even in the face of strong harvesting pressure and a 32-percent reduction in total area in natural pine. Two factors contribute to this buildup in older stands: 1) many of the stands between 21 and 50 years old have clearly progressed through the age classes; and 2) older stands are not being harvested at a rate proportionate to their abundance, suggesting that these stands might be held off the timber supply market due to owner preferences and objectives that are not compatible with harvesting, especially clear-cutting.

Age profiles for oak-pine stands in these four states reveal the same trend toward more older stands; the buildup in stands older than 50 years is more pronounced for oak-pine stands. One obvious difference for oak-pine stands is the strong buildup in the youngest stands. Harvested stands tend to restock with a mixture of pine and hardwood species. Many of these stands naturally change to a pine or hardwood type as the trees grow and compete for space.


(a) Natural pine
Decade
1970
1980
1990
Age class
1-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-90
>90
(b) Oak-pine
Decade
1970
1980
1990
Million acres
Age class
(c) Upland hardwood
Decade
1970
1980
1990
Million acres
Age class



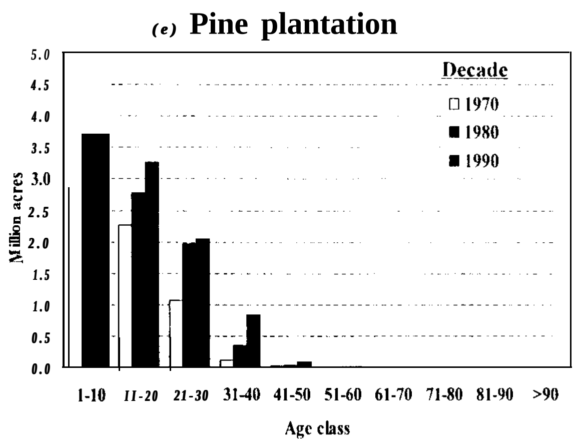


Figure 7. Change in age structure of timberland in Florida, North Carolina, South Carolina and Virginia by decade and forest management and stand-age class.

Regardless of whether they remain classified as oak-pine, the trends evident here are more older stands and more early successional habitat with a mix of softwood and hardwood species.

Age structure changes for upland and bottomland hardwood forests since the 1970s follow the same pattern described above for mixed pine-hardwood stands. Both hardwood stand types show strong increases in acreage for age classes greater than 60 years old. Increases in the early successional stages are also evident; these increases probably result from increased timber harvest during the period.

With a strong concentration of stands in the youngest age classes, pine plantations have a strikingly different age structure than do the other stand types. Growth in each age class for each time period is evident. Strong replenishment rates (planting after harvest and establishment on agricultural land) have created an age structure heavily weighted toward young stands. This structure is also maintained by harvesting (liquidation) of planted stands at a much younger age than natural stands-harvesting by age 20 is not uncommon. Planted stands will supply increasing volumes of timber in the next decade-a trend that is already well underway. In regions where pine plantations are concentrated, such as southeastern Georgia and northeastern Florida (see Figure 4), these stands are already supplying half or more of the softwood harvest.

The Changing Forested Landscape-Implications for Wildlife

Currently, southern forests are vastly different than those that existed when European settlers arrived centuries ago (Dickson in preparation). Almost all current forests have been repeatedly altered by humans. Many forested areas have always been in tree cover, but have sustained cycles of harvesting, restocking and growth. The history of yet other southern forests is one of clearing, cultivation, abandonment and reversion back to forest. Only rare pockets of unaltered old-growth stands remain.

It is clear that wildlife species have been impacted by changes in the quantity and quality of forested habitat. Some species such as the ivory-billed woodpecker *(Campephilus p. principalus)* are now extinct as a result of habitat loss and/or exploitation. Other species such as the red-cockaded woodpecker *(Picoides borealis)* have lost much of their preferred habitat and now benefit from widespread recovery efforts as a result of their classification as endangered. However, most species have probably experienced population cycles in unison with the cycles occurring within the forests of the region. White-tailed deer *(Odocoileus virginianus),* wild turkey (*Meleagris gallopavo*) and beaver (*Castor canadensis)* are species that in recent decades have experienced low populations followed by pronounced rebounds related to forest change and restoration and management activities. A downward trend in populations of many Neotropical migratory bird species is currently underway (Finch and Stangel 1993), due in part to habitat loss, change and fragmentation in the southern United States, as well as in tropical wintering grounds.

Southern forests will continue to go through cycles of change. Combined with the impact of legislation and management programs, broad-scale changes underway in the region's forests will alter the suitability of the southem landscape as habitat for various wildlife communities. On the other hand, some attributes of southern forests are not changing rapidly and this stability is an important factor to consider. Some of the most prominent changes underway in southern forests, as well as stable attributes are summarized below.

- Forestland remains the predominant land use throughout much of the South.
- The forestland base in the South has been generally stable for several decades, and no severe reductions are anticipated in upcoming decades.
- The diversity in ownership of forestland in the region will continue to promote heterogeneous forest conditions.
- From a regional perspective, the South's forests are extremely diverse, with a mix of tree species and forest cover types.
- The overall mix of pine, hardwood and pine-hardwood stands has not changed greatly in five decades. Specific forest types, such as longleaf pine, have declined in extent, with resultant impacts on wildlife species dependent upon them.
- The pine component of the region's forests is moving steadily toward more planted stands and fewer natural pine stands.
- Both natural pine and hardwood stands are maturing-there are more stands in older age classes and more trees in larger diameter classes. While these stands are far from being old growth, this trend is a positive one for species needing late successional habitat.
- Area of young, early successional stands is also increasing, especially for pine plantations, pine-hardwood and hardwood stands.

Southern forests will continue to be stretched to meet the demands of our society. The region's population will continue to grow and become more interested in how our forests are managed. More people will demand that all forest values are given equal attention. These demographic and social changes combined with continued increases in demand on our forests to supply more wood will result in intensified conflict about forests and their management. These conflicts can be handled through partnerships with all parties, embracing ecosystem management principles and employing a diversity of management scenarios across the landscape.

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Voices From Southern Forests

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Introduction

The faces and voices of the South have been changing dramatically over the last several decades, just like the rest of the nation. Population growth, immigration, urbanization, expanding minority proportions, a thriving **economy,** rising environmental sentiments and shifts in property ownership, among many other changes, have put forest and wildlife management in a much different context than at any time in the region's history. This paper examines the changing social, economic, attitudinal and other voices of Southerners and speculates about the meaning these changing voices might have on the future of forest and wildlife management in the South.

More Voices

Since 1970, the population of the South has grown from just more than 56 million to almost 87 million, growth of nearly 3 1 million, a 54-percent gain. The southeastern coastal subregion, South Carolina, Georgia and Florida, grew the fastest at 87.3 percent. The South's population growth was second in the nation only to the West and was the only region with net growth from domestic in-migration, gaining around 380,000 through in-migration between the 1980s and the middle 1990s.

In some southern states, the rate of population growth in just 28 years has been nothing short of phenomenal. Among the South's 13 states, those having the highest rates of growth since 1970 were Florida (more than doubling, with 118.8 percent growth), Texas (73.9 percent), Georgia (63.1 percent), South Carolina (46.9 percent), North Carolina (46.3 percent) and Virginia (46.0 percent). Northern Virginia; the Atlantic and Gulf Coast counties; Florida; North Georgia; the Piedmont Crescent of North Carolina, South Carolina and Georgia; Northwest Arkansas/Northeast Oklahoma and Southeast Texas are subregions having the most counties with high population growth since 1970—all above 55 percent in just 28 years (Figure 1). Nine counties grew between 300 and 399 percent in those 28 years (seven were in Georgia or Florida), eight grew between 400 and 499 percent (five in Texas), five grew between 500 and 799 percent (in Florida, Georgia and Texas) and one, Flagler County, Florida, grew 880 percent! Remarkably, 198 of the South's counties saw population losses over these same 28 years. Of counties losing population, 62 are in Texas, 23 in Arkansas, 21 in Oklahoma, 20 in Mississippi, 14 in Louisiana and 11 in Alabama.

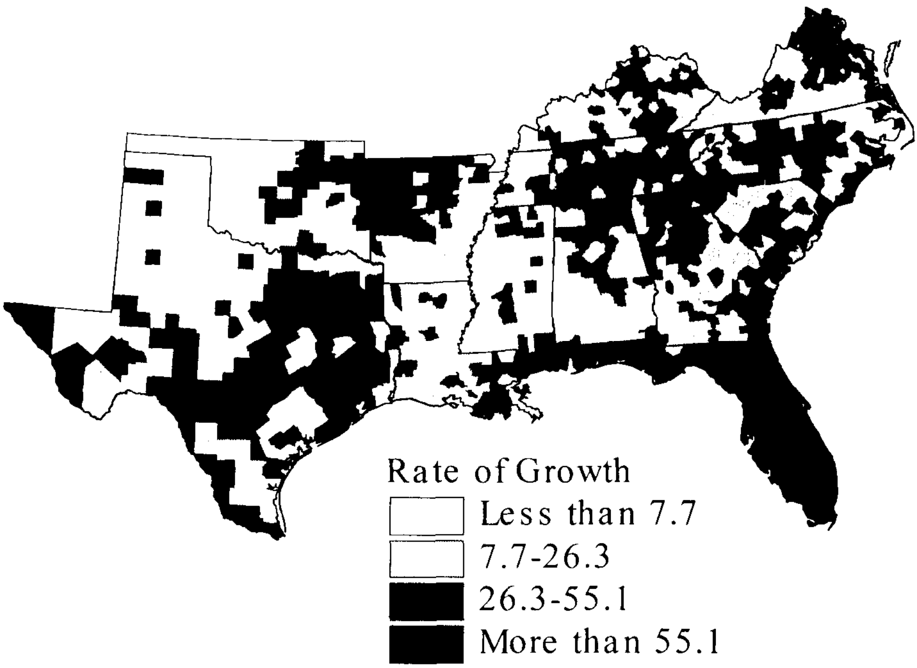

Figure 1. Percentage growth of population among counties of the South, 1970-1998.

More Voices, Especially Urban Ones

While population in both metro and nonmetro counties grew as a whole, it is obvious that metropolitan counties accounted for most of the South's gain between 1970 and 1998.

- The slowest growing half of nonmetro counties grew 15.2 percent in total population.
- The fastest growing half of nonmetro counties grew 30.9 percent.
- The slowest growing half of metro counties grew 63.2 percent, twice as fast as the fastest growing half of nonmetro counties.
- The fastest growing half of metro counties grew 68.0 percent.

Of the 10 fastest growing Metropolitan Statistical Areas (MSAs), eight are in Florida and two in Texas. Punta Gorda, Florida, tops the list with 420.9-percent growth between 1970 and 1998. The next six fastest growing MSAs are also in Florida. Only one MSA, Pine Bluff, Arkansas, lost population, -1.2 percent.

Population growth is concentrated for the most part in ever expanding urban areas, while a number of other counties trend toward becoming more rural through loss of population. Of the 164 counties in the South with more than loo-percent growth in population since 1970, 119, almost 73 percent of them, are classified as metropolitan counties. Of the nonmetro counties showing the greatest gains in population, most are either adjacent to counties included in MSAs or in high natural amenity subregions, such as the Southern Appalachians, the Ozarks or along the Atlantic coast (Economic Research Service 1997).

Of total population growth in the South since 1970, just more than 26 million, 85 percent of the total, was in 180 counties classified as metropolitan. Further, 35 percent of total regional growth occurred in only 92 metropolitan counties in just three states, the Atlantic coastal states of South Carolina, Georgia and Florida. Currently, the largest Metropolitan Statistical Areas in the South are Dallas/Ft. Worth (4.7 million), Houston/Galveston/Brazoria (4.4 million), Atlanta (3.6 million), Miami/Ft. Lauderdale (3.6 million), Tampa/St. Petersburg/Clearwater (2.3 million), Norfolk/Virginia Beach (1.6 million) and Orlando (1.6 million).

Minority Voices

More voices, more urban voices and increasingly, more minority voices are rising from the forested South. In the past 20 years, there has been increasing interest in minority voices, particularly those of African Americans. Studies of blacks' perceptions of nature have contributed to a better understanding of how this minority population views forests and other aspects of nature (Johnson et al. 1997b). Much of the available research has looked at minority interests in outdoor recreation and, to a more limited extent, at human/wildlife interactions (Dolin 1990). While a great deal of the focus has been on urban populations outside the region, the results nonetheless are useful in better understanding minority voices in the South (Johnson et al. 1997a). In a sense, examining the findings of these studies gives "voice" to the apathy or disinterest perceived to exist among blacks concerning nature and wildlife. In this paper, we include comparative results from the recent National Survey on Recreation and the Environment (NSRE), with a focus on attitudes toward wildlife management issues.

Dolin (1990) discusses five theoretical postulates that have been offered to help explain blacks' presumed lower interest in nature, wildlife or wildlife causes: socioeconomic status, personal priorities, mythology, lack of access and identification with slavery. The socioeconomic status postulate says that blacks have less interest because of lower socioeconomic status, giving them less time or discretionary income for wildlife pursuits. Similarly, the personal priorities hypothesis says that outdoor activities and wildlife involvement are not high in priority because other, more pressing material concerns are more important in blacks' everyday lives. As for mythology, Dolin postulated that blacks view nature more holistically than whites, thus not perceiving themselves as separate from nature. As a result, blacks identify less with the idea of specially designated parks, have less familiarity with parks and nature preserves in general, and have less desire to have contact with nature and wildlife. However, Marks (1991) reported results from a study that appeared to refute the mythology hypothesis. He found that blacks in a South Carolina county were less likely than either whites or Lumbee Native Americans to believe that animal and human worlds exist as a single, holistic space, that humans are not distinct from other animals, or that non-human animals feel pain as humans do.

The "lack-of-access-to-wildlife" hypothesis suggests that blacks have lower interest in nature and wildlife because they were denied access during the segregationist era, a phenomenon believed to persist today through local customs. Marks (1991) mentions that even hunting activities have been segregated in that blacks hunt mostly rabbits, squirrels and racoons, while whites pursue deer and quail. Finally, the slavery identification hypothesis holds that blacks lack an identity with the natural environment, including wildlife, because of their history with slavery where their relationship with the land was compulsory, rather than voluntary.

All these theories are compelling. Taken alone, however, none of them provides a satisfactory explanation. Rather, as Floyd and Gramann (1993) surmised, a number of influences probably work together to determine environmental attitudes, recreation behaviors and certainly wildlife involvement. Also, any one theory can be more or less salient for specific segments of the southern African American population. For example, socioeconomic status or personal priorities may be less important to more affluent African Americans, and slavery or mythology may be less meaningful to rural blacks who live close to the land. As Marks (1991) observed, black hunters in his study may have felt less sympathy and more distinction between themselves and wild animals because as the most marginalized members of the community, they needed ways to assert a superior status to some other life form.

To gain further insight into African American wildlife views, we analyzed four wildlife associated questions from the NSRE and compared responses between black and white Southerners (Table 1). In this comparison, whites were more likely than blacks to say an opportunity to view wildlife was important and that wildlife encounters made their recreational trips more enjoyable. However, there were no differences for contributions to wildlife organizations or preferences for wildlife interpretive signs. These findings suggest that while most southern African Americans are sensitive to wildlife management issues, some may prefer less direct contact with wildlife.

Table 1. Percentage of population 16 years old or older in the South by race and wildlife attitude, 1994-1995.

	Race		
Wildlife attitude	Black[a]	White[b]	chi square
The opportunity to view wildlife and/or fish in a natural setting is important to my selcctionof outdoor rccreation areas	76.2	85.5	0.042
If asked, I would contribute time, money or both to an organization that works to improve the qualityof wetlands, streams and lakes, even if the resultsof this activity may not be observed for 5 to 10 years	71.7	77.5	0.278
I prefer to look for wildlife where there are interpretive signs or other information sources to answer questions I may have	77.4	72.8	0.409
When I encounter wildlife during an outdoorrecreation trip, it always makes me more satisfiedwith the trip	75.7	96.2	0.001

[a]N = 70

[b]N = 454

In further analysis of the NSRE, southern blacks and whites of comparable socioeconomic status were compared for involvement in various wildlife recreation activities. When compared, whites were more likely to participate in nonconsumptive wildlife activities and fishing, generally indicating a greater desire than blacks for wildlife recreation. Hunting was the one exception.

Looking further at minority voices, we focused on low-income residents of economically depressed inner-city areas who usually are disadvantaged in terms of access to natural resources and outdoor recreation due to lack of opportunities, fear of crime or other local conditions (Kaljee et al. 1995). In 1990, approximately one in seven census tracts in the nation's hundred largest cities were classified as an area of extreme poverty where minorities, especially blacks and Hispanics, were more likely to reside. Blacks in these depressed urban communities typically made up three-fifths of the population, although, increasingly Hispanic Americans are moving into these poor neighborhoods.

To get a better idea of inner-city attitudes about wildlife, wildlife questions from the NSRE were compared between inner-city, metropolitan and rural respondents. Metropolitan residents are those living in cities, but not in the depressed inner-city areas. Comparing responses to the same four wildlife management questions shows that inner-city respondents are less likely than either metropolitan or rural dwellers to contribute to wildlife organizations or to be more satisfied when encountering wildlife during an outdoor recreation trip. However, inner-city dwellers were more likely than metro respondents to say the opportunity to view wildlife or fish and wildlife interpretive signs were important. Overall, rural respondents appeared more supportive of wildlife issues, compared with either of the urban groups.

Economic Voices

One of the principal indicators of the strength of an economy, nationally or intraregionally, is its population's income. As incomes rise or fall, so do consumption of goods and services, savings, government tax receipts, and people's lifestyles. As incomes rise, so too does the influence of consumers' voices. Per capita income in the South in 1980 was $11,453; by 1990, it was $12,898—a rise of a little more than 12 percent in 10 years (English and Gentle in preparation). This was a moderate growth rate, below that of the North at almost 18 percent and the Pacific Coast at almost 14 percent. The national per capita income growth rate between 1980 and 1990 was 14.5 percent. Growth in per capita income in all regions, however, has accelerated as the United States' economy has heated up. While the gains were modest relative to other regions, the South had the most to gain by having the lowest per capita income in 1980.

The southern growth that did occur resulted in the nation's largest decline in percentage of people living in poverty. Increasingly, the share of total wage earner income going to women and minorities is rising, changing the distribution of consumer "voting" power.

Along with income, sustainability of a region's economy is dependent on its productive diversity. Measured as a ratio of the number of viable economic sectors relative to the maximum number of sectors possible, the South experienced a growth in economic diversity of almost 18 percent between 1982 and 1992 (English and Gentle in preparation). This rate of diversification was slightly higher than the national average between 1982 and 1992, which was just more than 17 percent.

More specific to the forests of the South are economic trends associated with forest industry. McLaren and Lyddan (1997) surmised that the "Sunbelt" region has emerged in the 1990s as the focal point of the world's forest products industry. Estimates show the region accounting for an estimated 25 percent of world paper production, 33 percent of pulp output and 35 percent of solid-wood products manufacturing. Output of both southern pine plywood and pine lumber grew about 80 percent in the 1980s and 1990s. These dimensions of wood industry growth reflect growing product demand, advances in manufacturing technology and declines in federal timber harvests in the Pacific Northwest. The South also accounts for an estimated 40 percent of the productive timberland in the U.S., 45 percent of total housing starts, 45 percent of U.S. paper production, 65 percent of paperboard production, 73 percent of pulpwood consumption, 70 percent of wood pulp output, 45 percent of lumber production and 65 percent of panel output. An estimated 46 of the 50 largest wood-consuming pulp mills **in** the U.S. are **located** in the region.

Forest-based industries in the South employ nearly 650,000 people, reflecting an annual increase of I .38 percent per year since 1982 (Aruna et al. 1997). Forest industry employment in the South accounts for about 40 percent of the total U.S. forest-based employment, with wages increasing from $8.5 billion in 1982 to $15.3 billion in 1990 (excluding inflation). Forests in the South are significant to its economy, and Forest Service projections show continued increases over the next two decades (Haynes et al. 1995).

Environmental Voices

As the "philosopher" Yogi Berra is reported to have said, "Things ain't what they used to be, and they never were." This may be an apt description of our understanding of the attitudes of Southerners toward their environment. Generalizing about the South and Southerners has long been a favorite national pastime. Among the generalizations sometimes heard is that Southerners are slow to change; that they are among the last to adopt the changing lifestyles of the nation. Thus, goes the thinking that Southerners have yet to jump aboard the environmental bandwagon, including concerns for endangered species and environmental protection. What's more, being conservative, Southerners would never tolerate government meddling in the activities of private landowners.

Research of the past decade suggests, however, that if such characterizations of Southerners ever were true, they are rapidly becoming less true. So, in addition to the growing number of voices, in addition to urban, minority and economic voices, southern environmental voices are rising and increasingly being heard.

Over and over, research has shown that environmental attitudes vary little across geographic regions (e.g., Christianson and Arcury 1992). Thus, looking broadly at Americans' environmental attitudes is usually a good reflection of those found in a particular region or state. In the South, as elsewhere, environmental concern among our citizenry developed rapidly in the 1960s and seemed to peak by Earth Day, 1970 (Dunlap 1991). This was followed by an apparent decline in concern during the early 1970s, but this decline began a turnaround in the latter half of that decade leading to a rebound in public attention toward the environment in the 1980s. By the early 1990s, environmental concern as evidenced by opinion surveys had attained an all-time high. In 1994, only 2 percent of the American public indicated they were unsympathetic to the environmental movement (Times Mirror 1994). Ninety percent indicated they believe there is a reasonable balance needed between economic progress and environmental protection.

Thus, the first environmental voice being discovered in the South that we discuss is that of the general public. Opinion polling over the past two decades strongly supports the contention that "environmentalism has become not only a top-of-mind issue for the vast majority of Americans, but increasingly it is becoming a way of life for people both as voters and as consumers" (Times Mirror Magazines Conservation Council 1992). Opinion surveys of residents of Alabama and the Mid-South conducted in 1992 also provided evidence that the environmental values and opinions of Southerners closely mirror those of the broader general American public (Bliss et al. 1994). Three-quarters of respondents to these southern surveys agreed with the statement, "Private property rights should be limited if necessary to protect the environment," while fewer than one quarter agreed that, "Forest owners have the right to do as they please with their forests, regardless of what it does to the environment" (Bliss et al. 1994). Moreover, southern forestland owners share the public's concerns about clearcutting and herbicides, support regulation of harvesting practices on private land where necessary to protect environmental values, and seek a balance between protecting the environment and protecting the rights of private property owners. As well, differences of opinion between owners of large and small tracts, and between urban and rural owners, are not as great as commonly assumed (Bliss et al. 1997).

In another poll conducted for the Southern Appalachian Assessment (Cordell et al. 1996), the following were among the attitudes of that region's residents:

- "There should be more harvesting of timber in national forests" (less than 18 percent agreed).
- "Land that provides critical habitat should not be developed" (almost 73 percent agreed).
- "The Endangered Species Act has gone too far, and it should be restricted" (less than 34 percent agreed).
- "Industries which pollute streams and air should pay for cleanup" (almost 84 percent agreed).
- "More public land should be set aside as wilderness" (almost 69 percent agree).

The second newly discovered environmental voice is that of grassroots environmental and other non-governmental organizations (NGOs) which have sprung up in communities throughout the South. In Alabama, for example, ongoing research has identified some 150 grassroots groups interested in sustainable development (Bailey et al. 1997). These groups range from single-issue NIMBY ("Not in My Back Yard") groups fighting hazardous waste incinerators, to private property rights organizations, "waterwatch" groups and groups opposing timber harvesting on national forests.

As striking as the diversity of these groups is the main-stream character of their members. The typical grassroots activist in Alabama is less likely to be a radical, wild-eyed, long-haired youth than a fiscally conservative, middle-aged, working mother of three with deep concerns and opinions about environmental issues (Bailey et al. 1993). Increasingly, grassroots organizations are connected with national, even international networks and communicate via newsletters, faxes, e-mail and chat rooms in cyberspace. Many have their own web pages and are thereby linked to potentially thousands of web surfers. Through such electronic media, local issues become state issues and state issues can gain global attention.

A third newly discovered environmental voice is that of communities. Along with increasing environmental awareness has come growing concern about the social and economic aspects of a forest-based economy. The economic and social life of much of the South is intricately enmeshed with the forest, which provides raw materials for the region's economy, as well as the defining features of the landscape.

A growing body of research illustrates the consequences, both positive and negative, of different levels of forest dependency (Bliss et al. 1998a, 1998b, Sisock 1998). For example, the pulp and paper industry in Alabama is the major employer and economic lifeblood of many communities. State tax policies designed to recruit and sustain the industry in the state, however, have left impoverished local public school systems (Joshi 1997). The voices of those who call for more positive social outcomes from forest-based industry and development are only beginning to be heard, but they will almost surely grow in influence.

Owner Voices

Added to the environmental voices are many other voices arising from the growing number and changing composition of owners of private rural land. Of these owners, steadily increasing proportions live elsewhere but on the land (absentees), and they own it for an increasingly wide range of reasons. In a recent survey of owners (Teasley et al. in preparation), the estimated regionwide percentage who own 10 or more acres and who are absentee owners was 56.2 percent. The makeup of private land in tracts of 10 or more acres, as reported by all owners, is 48 percent woodland, 21 percent pasture land, 21 percent crop or hay land, 2 percent water, and 8 percent other uses. The reasons owners give for owning rural land include having personal recreation opportunities (43 percent), raising livestock for sale (42 percent), investing to eventually sell (39 percent), growing landscaping shrubbery for sale (31 percent), providing recreation opportunities for others (31 percent), enjoying my own personal green space (27 percent), living in a rural setting (25 percent), renting dwellings for profit (25 percent) and using as a tax shelter (20 percent). Eight percent indicated owning to provide habitat for wildlife and 3 percent indicated growing timber for sale as a reason. Forty-three percent of southern landowners are retired, 26 percent are self employed and 18 percent work for a private business. Their average age is 61, and only 12 percent are under age 45. Forty-two percent are 65 years or older, and 44 percent have an annual income of $50,000 or more.

As mainstream Americans, landowners are little different than others in the environmental attitudes they hold. In a survey of southern landowners (Teasley et al. in preparation), nearly 77 percent agreed to strongly agreed with this statement, "The balance of nature is very delicate, so we must try to limit economic growth that exploits nature." This environmental voice was heard equally strongly from resident as well as absentee owners. And, when asked what they intended to emphasize on their land, 38 percent indicated improvement of the natural conditions, while about 27 percent indicated uses that will earn income. About 32 percent were undecided about what to emphasize. A significantly higher percentage of absentee owners put emphasis on income earning, while a higher percentage of resident owners emphasized improving natural conditions.

As recreation demand in the Nation continues its growth, pressures rise for access to both private and government lands. Private owners have responded to those seeking access in a number of ways, but the end result has been a gradual and steady decline in the amount of private land accessible to all but persons known by and close to the owners. In the South, 41 percent of owners post an average of 238 acres. Among the most prominent of reasons for posting are, "to know who is on the property" (40 percent), "to keep out persons not having permission" (40 percent) and "to keep hunters out" (32 percent). About 80 percent of southern owners expect to post the same acreage in the future, but 15 percent indicate they plan to post more.

Mostly, persons allowed on private land include members of the owner's household, immediate family members not currently living in the household, and friends, acquaintances or familiar others. A relatively low percentage of owners lease to outside individuals, clubs or other groups for hunting or other recreation (just more than 7 percent). The average lease covers 4 18 acres and between 10 and 15 persons. The majority of owners who lease do so at a fee lower than they believe the market would bear as a way to encourage someone they trust to help care for the land (66 percent). Even fewer owners permit persons having no personal relationship with them and not leasing, i.e., the general public, to use their land (6 percent).

Increasingly, southern landowners are absentee owners; significant because resident and absentee owners differ. Higher percentages of absentee than resident owners are members of business, trade or timber associations, whereas, higher percentages of resident owners are members of farm or breed associations. Resident owners have owned their tracts an average three years longer than absentee owners, and higher percentages have added acreage to their original tract. Further, the percentage of land in forest or woodland cover on resident-owned tracts is substantially less than that on absentee tracts (41 percent versus 53 percent). On the other hand, the percentage of resident land in pasture is substantially greater (27 percent versus 16 percent). Resident owners put greater emphasis on grazing livestock, whereas absentee owners emphasize harvesting timber, leasing for growing crops or for recreation, and share cropping.

Resident owners tend to be somewhat younger, and there is a higher percentage who are male when compared with absentee owners. Absentee owners tend to have higher annual incomes than resident owners, with substantially higher percentages earning in excess of $80,000. The changing voice of the private rural landowner, as more of them are urban-dwelling absentee owners, can have dramatic influences on forest and wildlife management in the South.

Population on the Land

Figure 2 identifies the half of counties in the South that have the greatest percentage of their total area in undisturbed land use, including forest, water, range, and other undeveloped and uncultivated land. This is considered an indicator of wildlife habitat availability. Superimposed upon these more "habitat-abundant" counties is projected population expressed in population per square mile as expected by the year 2020. The darker the shading, the greater the population density growth expected. There are a number of darker-shaded counties raising the possibilities of substantial population impact on wildlife habitat in some areas of the South by the year 2020.

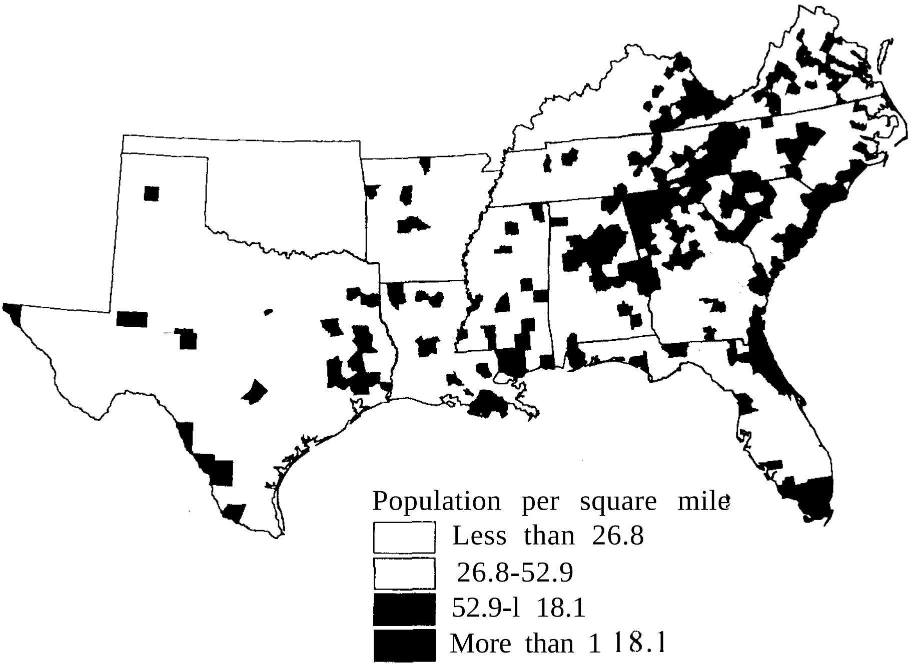

Figure 2. Projected population per square mile for the half of counties in the South having the greatest proportion of area in undisturbed land uses by 2020.

Implications for Forest and Wildlife Management

More people, different people, changing attitudes and more affluence are changing the voices heard from and speaking about the South's forests. Few would argue with Yogi in his summation, "Things ain't like they used to be, and they never were." In this paper, we have observed a number of key trends that are sure to be important in determining the nature of forest and wildlife management now and in the future. Briefly summarized, they are:

- *Population growth* in the South is and will continue to be THE most significant factor influencing what we as natural resource managers do, might think about doing or can do as we seek to carry out our missions. Spreading development, more demands on the land, pressures for domestic water, etc., will reduce the area we have to work with, increase the number of voices calling on us to serve their causes, diminish the quality of and stresses on the natural environment, and of necessity push us toward alternative approaches to resource management. These changes will be especially acute in areas that are anywhere near the South's spreading urban complexes whose inhabitants will increasingly live a life detached from the land.
- *Minority populations* and their proportion of total population are growing rapidly. Many live in inner cities, while many others are gaining economic status. For many, there is little expressed affinity for the natural environment. Minority voices may speak for a somewhat different set of priorities from our forests and other natural forms of habitat than the predominantly white, rural Southerner of the past.
- *The economy* of the South is growing and diversifying steadily. Demands for raw materials, land for development, land to live on, and shifts toward more of a service and retailing economy are changing economic priorities, even in the face of a booming forest industry. Forests and habitat for wildlife are not likely to be high in priority on the agenda of such an economy.
- *Owners of private land* increasingly mirror generally empathetic public attitudes toward the environment, are trending toward more absentee owners and are steadily decreasing general public access to their land. While absentee owners are oriented more to income earning, all owners voice interest in improving natural conditions on their land, including wildlife habitat. Increasingly, landowners are likely to be a factor acting to moderate somewhat some of the harsh impacts of population growth and urbanization on the South's forests and wildlife. In addition to the influence of landowner voices, another moderating influence is likely to be the significant number of southern counties that are losing population. These counties are becoming more rural-like in population levels.

- Among factors of change and the voices arising from those changes, second only to population growth and urbanization is the rising influence of the ***environmental voices*** of Southerners. While most Southerners may not readily act out their environmental leanings through the choices they make in the supermarket or by changing their consumptive lifestyles, they almost certainly will voice their environmental concerns in the voting booth, at city council meetings, on the phone to their legislative representatives and over the internet.

Overall, it seems to us that the fate of the South's natural resources, especially its forests and its wildlife, may not be all bad. Moderated by the trending in some counties and subregions toward a more rural-like character, by concern for the natural components of private land by its owners and by rising environmental leanings, it seems to us that pressures from urbanization, enormous population growth and booming economic demands may take shape in ways that will make responsible forest and wildlife management doable, at least through the next decade.

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People, Space and Time: Factors That will Govern Forest Sustainability

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Introduction

People and their social organizations are the most substantial agents of change in forested ecosystems throughout the world. Even in the developed countries in the temperate latitudes, ongoing growth and the transformation of economies continue to reshape forested landscapes. Resulting changes in both the extent and the structure of forests hold consequences for ecological function and environmental health. Accordingly, it is important to understand how people have and may further change the condition of forested landscapes in order to gauge the prospect for forest sustainability.

Specifically, a better understanding of how people make choices regarding land and resources in pursuit of various benefits is needed. Lands shift into and out of crop production in response to crop prices. Timber is harvested from forests based on the value of various forest products. People set aside their land for recreation in the pursuit of peace and quiet as congestion increases. The cumulative human impact on landscapes is a consequence of all individual choices intended to pursue individuals' goals in response to the genera1 scarcity of goods and services produced by lands in the region. This is especially true in the U.S. South where nearly all land is held by private owners. People are at the center of sustainability for other reasons as well. It is ultimately the provision of goods and services, including environmental services such as clean water and air, that motivate social concerns for sustainable development, and it is only through social systems—e.g., resource markets or political institutions-that any substantial changes in forested systems could be achieved. Understanding how these systems interact with individual behavior to shape landscapes is crucial knowledge for defining strategies for sustainable development.

In addition to improving our knowledge of how human and natural systems interact (a long-term research endeavor), in the short run we also need to develop approaches for monitoring and forecasting human impacts on forested ecosystems. Criteria and indicators for social and biological components of forested ecosystems are at the core of current sustainability initiatives. At present, these indicators measure vectors of change and their consequences in isolation, and little work has been done to develop synthetic indicators that can monitor the underlying processes of change at appropriate scales. This paper examines the definition and use of indicators of change in forest conditions and how they might be adapted to monitor processes of change. In particular, we examine the two principle vectors of change in forested ecosystems, land use and timber management, and how these changes might be adequately monitored. We find generally that broad-scale indicators of sustainability may, at best, be devoid of information; at worst they may mislead. The paper discusses challenges for measuring forest conditions, especially in a way that connects human actions with ecological consequences.

Vectors of Change

While human populations have many direct and indirect effects on the structure and function of forested ecosystems, land use and timber harvesting and management summarize a majority of significant impacts. These vectors of change have been applied to nearly every acre of the South (with the possible exception of some small inaccessible swamp areas). Furthermore, land use and timber management are vectors that continue to be in flux, and they will shape the future landscape of the South. Tracking these two powerful forces of change should provide useful aggregate information on the sustainability of forested ecosystems in the South and elsewhere.

Land Use

Forests can be viewed as a residual land use in the South. Do nothing with land in this region, and it will become wooded. Much of today's forests originated in this manner, reverting to forest either after a timber harvest or after an agricultural practice was abandoned. Alternatively, forestation can be viewed as an active investment, and over the past couple of decades, forests originating from tree planting have expanded considerably. These two definitions of stand origin provide endpoints on the broad spectrum of actual forest uses.

Tracking overall timberland area in the South provides one measure or indicator of the persistence of forests in the South. Timberland area peaked in the South in the mid-1960s at about 209 million acres. Between the '60s and '70s, the amount of timberland declined to about 200 million acres, as land was converted mainly to agricultural uses and then leveled off (Powell et al. 1993). This stability, however, masks some countervailing changes. Over the last 15 years, timberland area has declined somewhat in the southeastern portion of the South (the states from Virginia to Florida) but has increased in the southcentral region (the remaining states).

To the extent that most forestland is a residual land use, it is important to understand what has happened with other land uses in the region as well. That is, in most cases it is not the value of forests that determines whether land becomes forested. Rather, it is the relative value of nonforest uses of land. Agriculture is the other dominant use of land in the South (measured here after excluding Texas and Oklahoma, because they can distort proportions) where cropland accounted for about 58 million acres in 1992 (Census of Agriculture). This is a decline of nearly 10 percent since 1982, due mainly to policies that have aimed to reduce the pool of cropland in the United States, especially on marginal lands. Policies in the agricultural sectors will likely continue to have direct impact on the area that becomes or remains forested in the South.

In the South (again exclusive of Texas and Oklahoma), roughly 56 percent of land is timberland and 18 percent is cropland. The remaining 26 percent is split into roughly thirds between grassland pasture, urban and other miscellaneous land uses. Urban land use is especially relevant to concerns regarding ecosystem sustainability. These areas represent the most substantial human footprints on lands. In these areas, dominated by impervious surface and high densities of human populations, ecosystem structure is greatly simplified and ecosystem function clearly disrupted. Roughly 25 million acres of land were in urban use in 1992. Percentage gain in urban area has been substantial, but over the last thirty years, the resulting percentage reduction in rural land use has been relatively small because of its large share of the landscape.

On the surface, the amount of timberland in the South indicates stability in forested ecosystems, with some countervailing declines in cropland and expansion in urban areas. The result is "no-net-loss" of forested area. But does the area of timberland completely illuminate changes in forest condition in this or any other region? Clearly not. The area of forestland may be stable while the age and species distribution of forests change dramatically. The ownership profile of forests may also shift over time portending changes in management intent, and forest productivity may increase or decrease in response to various forces.

The crux of the problem of developing a good indicator of forest sustainability is to measure something that proxies for the relative scarcity of the actual conditions of interest. The amount of timberland, however, may be flawed as an indicator of forest extent when we are concerned with measuring specific services rendered from forest, for example, the relative scarcity of certain ecological or wildlife values. The capacity to grow trees in an area not used for something else (the definition of timberland) may not be a good measure of the extent and especially the condition of forested ecosystems. A better indicator would be one that weights forested areas by factors that account for the effects of disturbance regimes or landscape structure on the production of specific ecosystem services. In the case of wildlife, for example, we need to augment measures of forested area to account for the effects that human presence may have on its habitat values. To explore this idea further, we examine the spatial distribution of human populations in the South and construct a measure of timberland that adjusts for potential effects of human presence on ecological function.

Influence of Human Populations

One way to account for human influence on the condition of a forest is to consider the population density in the vicinity of the forest. Forestland may occur in areas that range from practically no human presence to nearly urban conditions, and we posit that most ecological or habitat values of forest areas are inversely related to human population density. For example, Pye et al. (1997) find a strong relationship between population density and the average size of forest patches within southeastern counties. Average patch size decreases as population density increases. Patch size serves as an indicator of two types of ecological values. First, smaller patches mean more edge habitat and less interior forest habitat in the same area of forest. Second, average patch size is directly related to forest fragmentation. Reduced connectivity indicates barriers to species dispersal and in some cases to species persistence. Population density may therefore provide a proxy for fragmentation within forested areas.

Population has grown substantially in the South over the past 40 years. The U.S. Census indicates that population increased 84 percent, from 452.5 million in 1950 to 782.0 million in 1990. This population growth has not, however, been evenly distributed (Figure 1). Rather, it has been focused in certain areas, most notably Florida, other coastal areas, and the "Piedmont Crescent" from Raleigh, North Carolina to Birmingham, Alabama. In parts of these areas population has doubled or even tripled over this 40-year span. In contrast, other portions of the South, most notably a large area stretching from the Mississippi Delta to southeastern Georgia, experienced population declines over the same period, fueled largely by labor-saving technological change in agriculture.

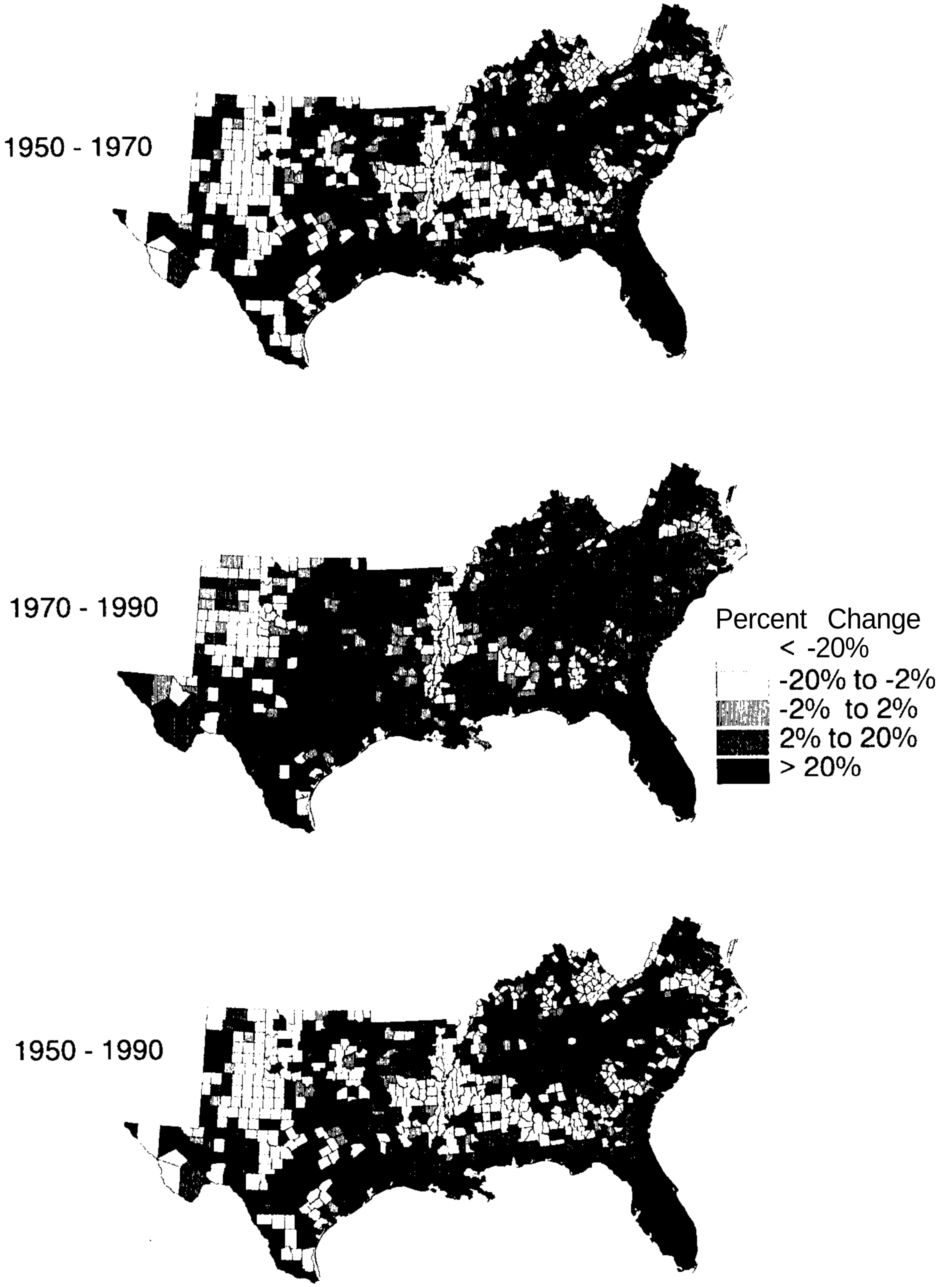

Figure 1. Percentage change in human population density for counties in the South, 1950- 1990, measured for three periods.

Changes in population density do not have a proportional impact on the area of timberland within a county. To illustrate, Figure 2 charts the share of timberland in North Carolina counties as a function of population density. As expected, the function shows a negative relationship between population and timberland area. However, it indicates also that a majority of a county will still be considered timberland up to a population density of about 550 people per square mile. At even 1,000 people per square mile (the upper end of the range of population densities in North Carolina), the share of timberland is still about 32 percent. This suggests that a portion of timberland in the South is located in an essentially urban environment. In these urbanized counties, it is clear that while land may meet the physical criteria for timberland, the forest may have neither commercial timber nor ecological attributes of great value (though they may have considerable aesthetic and other environmental values).

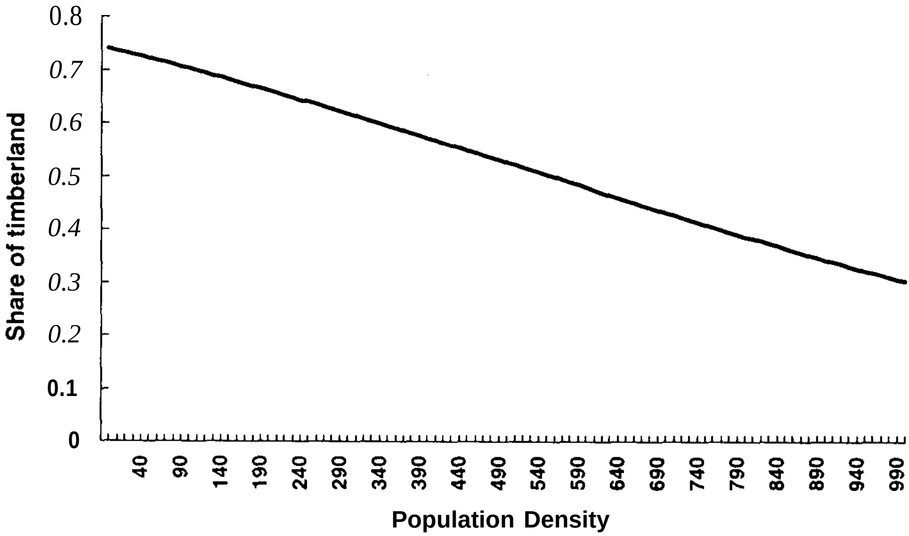

Figure 2. The share of a county classified as timberland as a function of population density. Relationship is defined using a logistic regression and controlling for the share of land in agricultural use. For the displayed relationship, the share of cropland is held constant at 15 percent.

To fully develop these effects of human population density on forest areas requires some weighting for human presence. Ideally, this would be based on research regarding the effect of population density on specific ecological functions. Here we demonstrate the potential effects of human presence on forests by constructing an ad hoc index that weights North Carolina forest by an inverse function of a county's population density based generally on the relationship between population density and average patch size. The function is scaled by assuming that forests in rural areas with population densities of 9 people per square mile (the minimum population density in the state) are not impacted by human presence. These areas receive a weight of 1 .O. At the upper end of the scale (1,000 people per square mile) we assume that forestland is so fragmented that it loses all of its ecological or habitat value. These areas receive a weight of zero. We estimate the weights for intermediate densities using an exponential function motivated by the log-log relationship between patch size and population density:

$$weight = e^{-0.005 * population\ density}$$

Figure 3 summarizes the implications of this adjustment scheme by comparing measured timberland with weighted timberland for the three most recent forest inventories of North Carolina (1974, 1983 and 1992). Weighting timberland area by population density reduces effective timberland area by an average of about 35 percent across these surveys. More importantly, the weighted measure indicates a different pattern of change when compared with raw timberland. Raw timberland declined between 1974 and 1983 at about -0.6 percent per year, but then increased slightly between 1983 and 1992 (+0.2 percent per year). In contrast, population weighted timberland declined by -.8 percent per year for 1974 to 1983 and -0.3 percent per year for 1983 to 1992. As a result, the ratio of effective timberland to measured timberland declined over time.

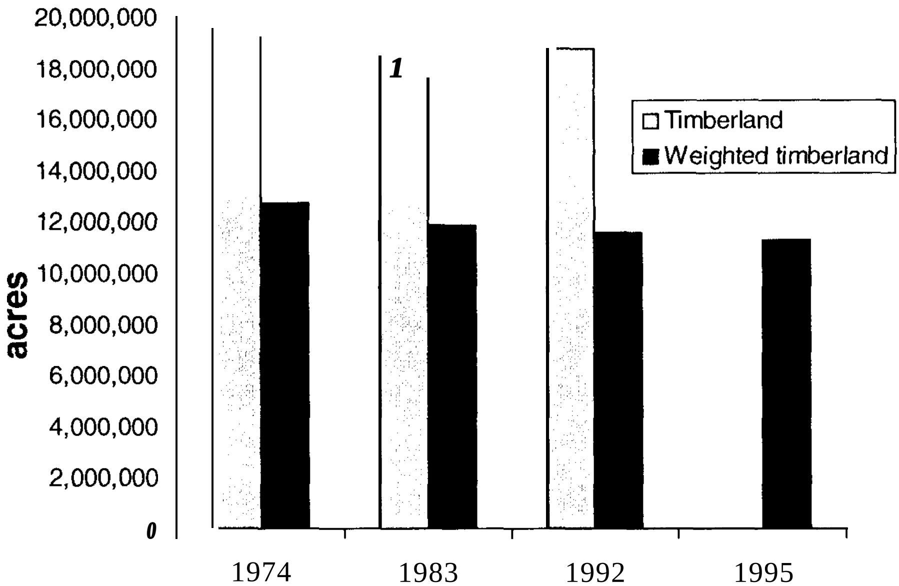

Figure 3. Raw timberland and population-weighted timberland area in North Carolina for three forest inventories (1974, 1983, 1992) and projected for 1995.

To examine the potential effects of the most recent population growth in North Carolina, we weighted timberland area from the 1992 survey with population densities estimated by the Bureau of Census for 1995. The result indicates a further erosion of effective timberland. Furthermore, the forecasted loss of effective timberland is at substantially higher rate (-0.9 percent per year) than estimated for the 1983 to 1992 period (-0.3 percent per year). This provides some indication that most recent development in North Carolina may be having substantial effect on the extent of forests in the state before even accounting for the likely loss of raw timberland (though these losses might be mitigated by transitions from agricultural to forest uses).

Clearly, this is an arbitrary weighting scheme, but our intent here is to illustrate some concepts (we did however, apply some sensitivity analysis to the relationship between the endpoints and found the pattern of results quite robust to these changes). These results do suggest that an accounting for the effects of human presence on the ecological services provided by forest could lead to different findings regarding sustainability. In particular, the extent of forests may serve as a misleading indicator for the relative scarcity of the services provided by forests (recall especially that the ratio of effective to measured timberland decreased over time), and no-net-loss in timberland may mask substantial declines in the services rendered from the forests of the South. In addition, these results raise important concerns regarding the implications of the recent acceleration of population growth in North Carolina.

Timber Harvesting

Besides the expanding population of the southern landscape, timber harvesting and management is the other major vector of change influencing the condition of forestlands in the South. We generally examine what the influence of further expansion in timber harvests might be and focus especially on how an adequate indicator of consequent changes could be constructed.

The South has been called the wood-basket of the United States and with good reason. In 1992, the region produced 50 percent of the softwood and 42 percent of the hardwood timber produced in the country (Powell et al. 1993). These figures reflect the result of steady, strong growth in timber harvest from the South over the last 30 years (Figure 4). Over this period, timber production grew at a relatively steady average annual rate of 2 percent per year for softwoods and 2.2 percent per year for hardwoods. Product mix has been dominated by sawlogs (to produce lumber) and pulpwood (to produce paper products), each of which represent 40 percent of total output. The remaining 20 percent is made up of veneer logs, fuelwood and furnish for composite wood products.

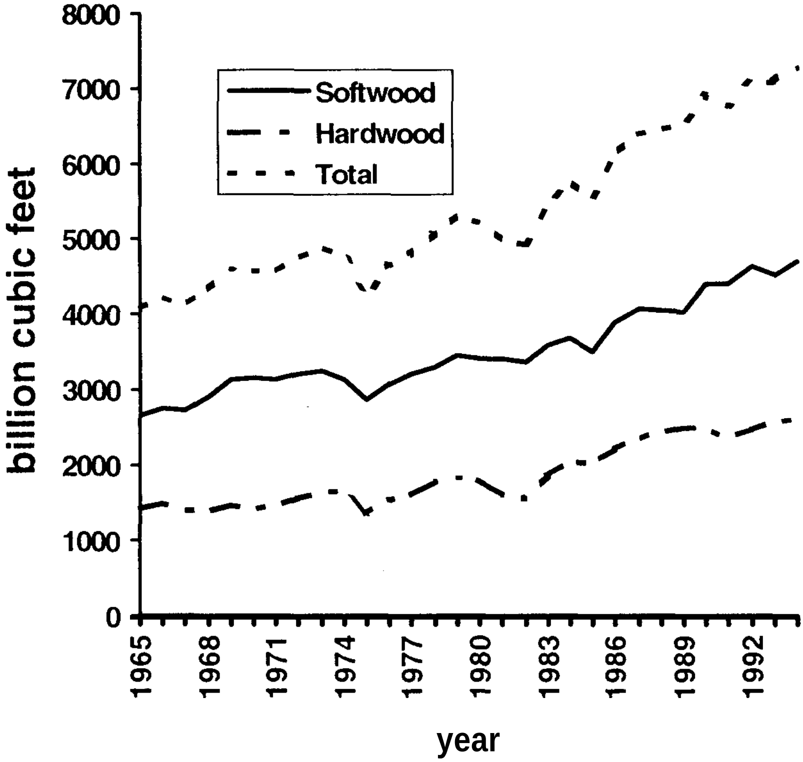

Figure 4. Total hardwood and softwood timber production from the South, 1965-1994

The recent history of timber harvesting in the South is and future harvesting will be heavily influenced by activities in other parts of the country. For example, harvest reductions on federal lands in the West have had a discernable impact on the markets supplied by southern lumber (Murray and Wear in press). Trade policy with Canada on softwood lumber has also likely had an effect. Therefore, any forecast of timber production in the South needs to be set in the context of the other regions of North America. To do this, we rely on forecasts of total timber production in the South generated by the national RPA timber market model (Haynes 1995). Then to fully develop local consequences of these changes, we simulate the spatial distribution of harvests using a detailed southem timber market model called SERTS (Abt et al. 1993). SERTS provides detailed forecasts of timber harvests by subregion of the South.

National timber market forecasts indicate that any future increase in U.S. production would come from the South. Softwood harvest is expected to increase 24 percent over the next 30 years (a rate of +0.7 percent per year) and hardwood production is expected to increase even more, by about 39 percent (+1.1 percent per year) over the same time period (Haynes 1995). This rate of increase could lead to substantial changes in forest structure if spread evenly across the entire landscape. However, it appears that change will be concentrated in certain areas so that these impacts will be heavily focused on a portion of the southern landscape.

An analysis based on forecasts generated by the SERTS model indicates that the location of softwood production could shift in two important ways. First, production would increase substantially in the southeastern coastal plain where timber harvesting and management are already the most intensive. Second, timber production would expand to the north with large increases, especially in Tennessee and Arkansas, but also in Virginia. These increases in production offset losses in two other large regions. One is the western coastal plain from southern Texas to middle Mississippi. The other is the Piedmont Crescent region from Raleigh to Birmingham.

Increased production from the southeastern coastal plain and northern South reflect two different responses to increased demand for forest products. The first is increased investment and intensified management forecast for the coastal plain. This expansion at the intensive margin of forestry is likely justified because of the very strong demand for pulpwood in an area with extensive pulping capacity. The pulp and paper industry cannot easily shift capacity elsewhere because of high capital costs and environmental regulations so that investors can justify more intensive forest management. In this region, we expect that forest type diversity might decline (though age class diversity would likely increase) as plantation area expands. Of course, this depends on the extent to which plantation pine replaces natural pine or other forest types and the ecological differences between these groups.

The other type of market response exhibited in this forecast is an expansion at the extensive margin which involves extending the distance over which timber is procured. Increased production from northern reaches of the South, especially Tennessee and Arkansas would feed softwood lumber markets which have much more mobile capital than the pulp and paper sector. The biological consequences of this type of expansion might be different. We would anticipate that increased harvesting might lead to some increased tree planting, but not to the same extent as in the coastal plain-i.e., the returns to investment would not be as great. Natural regeneration would likely be the preferred approach. As a result, we could expect a much more land-extensive forestry with more area disturbed per unit of harvest in this area.

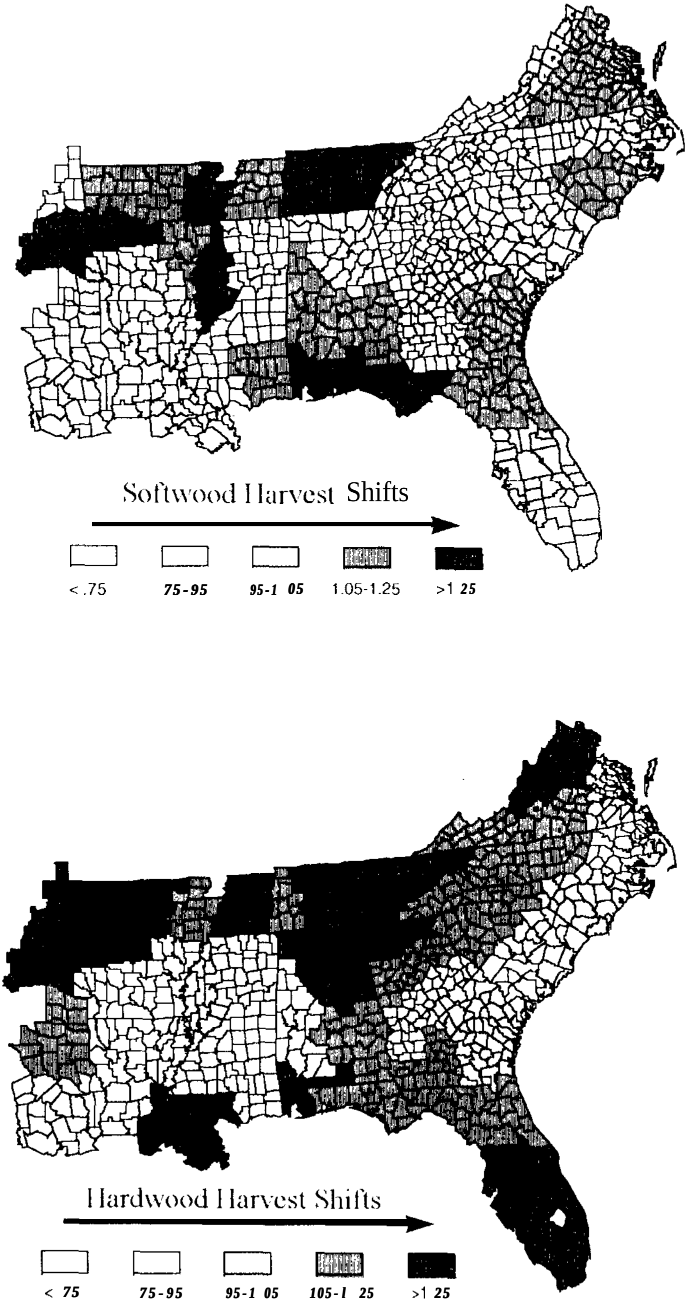

Figure 5. Changes in regional share of timber harvests by the year 2020 for softwoods and hardwoods in the South, forecast by the SERTS model.

Forecasts from the SERTS model indicate a much different pattern of change in the hardwood market. The model generally shows that harvest shares would shift between the two major hardwood producing areas of the South from the area centered on the Mississippi Delta (mainly Louisiana, Mississippi and Arkansas) to the Southern Appalachians and the neighboring Piedmont (northern Georgia, South Carolina, Tennessee and Virginia). However, these changes in harvest share mask the finding that all states in the South are forecast to increase the absolute quantity of hardwood harvests on their lands.

The general implication of this forecast is that timber management would become viable over a wide area of previously unmanaged hardwood forest types. Hardwood inventories have accumulated steadily over the past 40 years, but this forecast indicates that the accumulated volume will be heavily utilized in the near future. Associated forecasts of inventory indicate a slight decline in the hardwood component by the year 2020.

The spatial distribution of hardwood harvests raises a major concern. Much of the growth in hardwood harvests will be concentrated in the Piedmont region and in Tennessee where heavy population growth has been concentrated and is expected to continue. Coupling strong demand for timber with strong development pressures could lead to substantial change in forested ecosystems within this region. Furthermore, it is likely that the anticipation of development in rural areas could dissuade landowners from managing for long-term objectives, whether they be habitat conditions or timber productivity. This so-called "impermanence effect" could have an important impact on the residual forests of this region.

Discussion

In many ways, forest sustainability is about managing change in forested ecosystems. Research is needed to understand how wildlife and other benefits rendered from forests are influenced by forest extent, structure and condition. Likewise, research is needed to understand better how people make choices regarding the use of their land and their resources. In sum, we lack some key insights into the implications as well as the vectors of change in forested ecosystems.

While research pursues more and better knowledge of these process we also need to develop better tools for monitoring change in forested ecosystems in meaningful ways. Current international efforts (e.g., the Santiago Declaration) focus exclusively on monitoring forests and economies through several criteria and indicators (the Santiago Declaration calls for measuring more than 60 variables). However, many criteria and indicators may not be measured at appropriate scales to provide meaningful insights into change in forested ecosystems. Furthermore, they could even mask substantial changes.

We have demonstrated the potential hazard of using an intuitively appealing and plausible measure of forest extent: raw timberland. This measure may provide useful insights into, for example, potential carbon sequestration in forests, but it may not provide useful insights into the provision of specific habitats, etc. Aggregation across broad regions may also mask important changes. For example, no-net-loss in the South's timberland masks gains in the southcentral and losses in the southeastern subregions. Using raw timberland to indicate trends in forested habitat may also be misleading. Weighting timberland by a measure of human disturbance regimes indicates that a gain in raw timberland in North Carolina masks a loss in "effective timberland."

National assessments of timber production indicate that the South will continue to be the source of expanding national output (e.g., Haynes 1995). Increased harvesting is expected to be offset by intensified management and forest investment. A dissagregate spatial analysis of southern production indicates that expanding timber harvests may have disproportionate impact on the forested landscapes in specific parts of the South. Increasing harvest in the South would result in expanded investment and production in the southeastern coastal plain but would also require expanded production in the northern portion of the South. Here we anticipate that population growth and development coupled with increased timber harvesting will have a compounding effect on forests. It is unclear how forest owners and the structure of forested landscapes will respond, but these forecasts raise concern about forest sustainability in this region.

Spatially explicit measures of forest change provide qualitatively different insights into the potential sustainability of forests in the South. While stability might be projected for the region as a whole, specific areas may be subject to accelerated changes. For example, the measures examined here suggest that our concern regarding changes in forest structure should not be focused as much on the traditional high-production regions of the South. In these areas, we anticipate that ongoing investment will stabilize forest conditions. Rather, population growth coupled with expansion at the extensive margin of forestry suggests that change in forest structure and condition could be most substantial in a region stretching from Virginia through North Carolina, and northern Georgia to Tennessee.

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Intensive Management—
Can the South Really Live Without It?

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Introduction

Over the past five years, the public and private sectors have debated the future of forest management and its implications for the next century. In the public sector, resource managers have debated the meaning and significance of "ecosystem management," a term coined in 1992 by then-Forest Service Chief F. Dale Robertson; he suggested that this approach to forest management would "blend the needs of people and environmental values in such a way that the National Forests and Grasslands represent diverse, healthy, productive, and sustainable ecosystems." Resource managers in the private sector have also debated among themselves and with their counterparts in the public sector about ecosystem management. The forest products industry's dominant view is that ecosystem management is a process with different meanings and applications, which are based on ownership and objectives (Owen 1995).

Within the private sector, debate also has focused on the traditional application of multiple-use forestry, using the principles of sustainable forest management. This is defined in the Sustainable Forestry Initiative (SFI) of the American Forest and Paper Association (AF&PA 1995) as "... [meeting] the needs of the present without compromising the ability of future generations to meet their own needs by practicing a land stewardship ethic which integrates the reforestation managing, growing, nurturing, and harvesting of trees for useful products with the conservation of soil, air and water quality, wildlife and fish habitat, and aesthetics." Thus, sustainability as defined by industry is about more than assuring a sustainable timber supply; it is also about sustaining the full spectrum of forest values.

Among the most prominent questions in these debates has been the role that intensive management plays as an element of a broader, nationwide forest management philosophy. The clearest advantages of plantations are immediate occupancy of a deforested site, rapid growth and high yield. For example, plantations of genetically improved loblolly pine (*Pinus taeda*) can produce 26 percent greater yields at 20 years than loblolly pines grown from unimproved wild seed (AF&PA 1997). Extensive use of plantations can therefore contribute significantly to the South's fiber supply over time.

Intensively managed plantations may provide most of the world's demand for wood pulp or construction material (Sedjo and Botkin 1997). The increasing importance of plantations in the South is likely related to technological improvements that have increased productivity and yields on intensively managed plantations, as well as to the increasing number of regulations and costs with harvesting second- and old-growth forests in other regions and nations. For example, a major forest industry in the West Gulf region recently sold or exchanged nearly a third of its land, because the demand of current and future mills can be met through a high-yield forestry program on just a portion of its land base.

However, intensive management has its detractors. There are major concerns about adverse environmental effects that result from harvesting, site preparation, use of herbicides, reforestation with a single species resulting in a "monoculture" using genetically improved seedlings and reliance on short rotation lengths. Concerns also exist about the effects of clearcutting a stand within the context of a larger area-a "forest fragmentation" effect.

Some suggest that the South can live without intensive management. In this paper, we will attempt to show that, in the context of southern forestry, intensive management is of great economic importance and can be applied in ways that have a sound ecological basis.

The Role of Intensive Management in Southern Forestry

Definition

Intensive management refers to the use of clearcutting as a primary reproduction cutting method, followed by site preparation and establishment of coniferous or hardwood plantations. Included in this definition is the use of planting as a tool to reestablish forest stands on open areas that had historically been forested, such as abandoned agricultural fields or pastures.

This is not to infer that other reproduction cutting methods cannot be considered intensive forest management. The preharvest inventories, preparation of marking tallies, marking, and establishment of natural regeneration under the uneven-aged, single-tree selection method (cf. Baker et al. 1996) certainly require intensive attention by highly trained foresters. Nonetheless, we will restrict our definition of "intensive" to the establishment of plantations.

The intensiveness associated with clearcutting and planting has two elements. The first refers to the ecological changes that result. Clearcutting produces the greatest possible change in forest conditions that can occur during secondary succession. Removing the biomass of all trees of commercial size and value, and the mortality or suppression of much of the remaining woody biomass through site preparation (burning, mechanical cutting or removal, and/or use of herbicides), creates ecological conditions that are starkly different from those that existed prior to harvest. Continuous canopy cover is lost, the forest floor is broken up, biogeochemical cycling is completely changed, and solar radiation and other microclimatic effects reach all the way to the forest floor. Plantation establishment, whether on a recently harvested site or an abandoned agricultural field, represents additional change in ecological conditions, because the intention is usually to establish a single dominant woody species—and, moreover, to do so rapidly.

The second element of intensiveness is the considerable capital investment required for site preparation and planting. A typical prescription in the West Gulf Coastal Plain using site preparation with herbicides, broadcast burning and planting is on the order of $150 per acre; intensive site preparation using the shear-rake-windrow-burn and plant technique can cost about $200 per acre (Dubois et al. 1995). Natural stands can be established at much lower cost, although they have less immediate growth potential.

Scope

Source of data. Forest Inventory and Analysis (FIA) data provide the best means to evaluate the scope of intensive management in the South. FIA data are available in the Eastwide Forest Inventory database on the World Wide Web. The current extent to which intensive forestry is being conducted was determined by tallying the extent of artificially established forest area (whether in pine type, hardwood type or mixed pine-hardwood type) as a percentage of commercial forest area for 13 southern states (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, eastern Oklahoma, South Carolina, Tennessee, eastern Texas and Virginia). For the trend over time, eight states had two forest surveys in digital form (Arkansas, Florida, Mississippi, North Carolina, Oklahoma, South Carolina, Texas and Virginia). In these States, artificially established forest area was tallied as a percentage of commercial forest area for two inventory periods-the 1980s and the 1990s.

Current extent of intensive management in the South. According to 1990s FIA data, the 13 states in the South contain a total of 365557,000 acres. Of this, 199,87 1,000 acres (58.7 percent) are in timberland (Table 1). Slightly more than 21.2 million acres of timberland (10.6 percent of timberland area) is in public ownership, 11.5 million acres (5.7 percent) of which is in national forests. Forest industry owns slightly more than 40 million acres (20.4 percent) of timberland in the South. However, most of the timberland in the South—more than 137 million acres, or 69 percent-is owned by non-industrial private forest (NIPF) landowners.

Table 1. Total land area and timberland area in total and by major ownership categories, for the 13 southern states, based on most rcccnt Forest Inventory and Analysis data for each state.

		Timberland area”				
State	Total land area[a, b]	Total”, [b]	National forest[a, b]	Other ublic[a, b]	Forest industry”. [b]	NIPF[a, b]
Alabama	32,496	21,932	605	557	5,499	15,270
Arkansas	33,328	18,392	2,274	935	4,529	10,655
Florida	42,085	14,651	1,029	1,802	4,601	7,217
Gcorgia	37,702	23,631	752	894	5,870	16,116
Kentucky	25,227	12,347	699	376	204	1 1,068
Louisiana	26,265	13,783	568	743	4,422	8,049
Mississippi	30,025	18,587	1,107	844	3,314	13,322
North Carolina	33,708	18,711	1,082	920	2,420	14,287
Oklahoma	10,104	4,896	223	414	I.047	3,212
South Carolina	20,485	12,455	560	554	2,394	8,947
Tennessee	26,447	13,265	556	953	1,144	10,612
Texas	2 1,594	I I.774	577	213	3,770	7,214
Virginia	26,09 I	15,448	1,468	515	1,555	11,910
All states	365,597	199,871	1 1,500	9,719	40.772	137.880

“Values are in thousand acres.

[b]Numbcrs in rows and columns may not add to totals duc to rounding.

Southwide, 1990s FIA data show that plantations (pine type, hardwood type or mixed pine-hardwood type) occupy 34.7 million acres, or 17.4 percent of the timberland area in the South (Table 2). By state, the area in plantations varies from slightly more than 154,000 acres in Kentucky to slightly more than 5.5 million acres in Georgia. The amount of timberland in plantations varies from 1.3 percent in Tennessee to 33.8 percent in Florida. Four states-Alabama, Florida, Georgia and Mississippi-account for nearly 19 million acres, or almost 55 percent, of total plantation area in the South.

Table 2. Timberland area of plantation origin (pine type, hardwood type or mixed pine-hardwood type), and percentage of timberland area in plantations (in parentheses), by ownership class and total, for the 13 states in the South.

	Timberland area”				
State	All[a, b]	National forest[a, b]	Other ublic[a, b]	Forest industry”,[b]	NIPF[a, b]
Alabama	4,411.2	35.7	39.8	2,264.6	2,071.1
	(20.1)	(5.9)	(7.1)	(41.2)	(13.6)
Arkansas	2,418.6	208.3	28.2	1,495.4	686.7
	(13.2)	(9.2)	(3.0)	(33.0)	(6.4)
Florida	4,945.1	319.7	267.7	2,628.1	1,729.6
	(33.8)	(31.1)	(14.9)	(57.1)	(24.0)
Georgia	5,502.5	77.4	52.5	3,154.7	2,2 17.9
	(23.3)	(10.3)	(5.9)	(53.7)	(13.8)
Kentucky	154.6	8.5	11.9	2.6	131.6
	(1.3)	(1.2)	(3.2)	(1.3)	(1.2)
Louisiana	2,645.8	121.8	29.6	1,756.4	738.0
	(19.2)	(21.4)	(4.0)	(39.7)	(9.2)
Mississippi	4,110.8	223.6	79.3	1,618.2	2,189.7
	(22.1)	(20.2)	(9.4)	(48.8)	(16.4)
North Carolina	2,289.7	28.8	71.5	1,224.8	964.6
	(12.2)	(2.7)	(7.8)	(50.6)	(6.8)
Oklahoma	610.2	50.3	0.0	515.5	44.4
	(12.5)	(22.6)	(0.0)	(49.2)	(1.4)
South Carolina	2,828.1	69.7	169.7	1,260.0	1,328.7
	(22.7)	(12.4)	(30.6)	(52.6)	(14.9)
Tennessee	518.5	3.6	33.3	265.7	215.9
	(3.9)	(0.6)	(3.5)	(23.2)	(2.0)
Texas	2,413.9	118.5	5.3	1,761.1	529.0
	(20.5)	(20.5)	(2.5)	(46.7)	(7.3)
Virginia	1,856.5	21.6	33.0	765.1	1,036.8
	(12.0)	(1.5)	(6.4)	(49.2)	(8.7)
All states	34,705.3	1,287.3	82 1.7	18,712.3	13,884.0
	(17.4)	(11.2)	(8 . 5)	(45.9)	(10.1)

“Table values are in thousand acres (percentage) for each combination of ownership category by state.

[b]Numbers in rows and columns may not add to totals due to rounding.

Public versus private ownership of plantations. Most plantations are on private lands. Southwide, 89 percent of the timberland base is under private ownership; private land accounts for 94 percent of the timberland of artificial origin.

Within the public sector, 11.2 percent of timberland area in the national forests Southwide is in plantations (Table 2). In five states (Florida, Louisiana, Mississippi, Oklahoma and Texas), plantations account for more than 20 percent of the national forest timberland base. Conversely, plantations account for less than 5 percent of the national forest timberland base in Kentucky, North Carolina, Tennessee and Virginia-where national forests are primarily hardwood forests.

In the other public sector (other federal, state, county and municipal lands), only 8.5 percent of the timberland base in the South supports plantations (Table 2). Two states stand out as exceptions-South Carolina, with 30 percent of the forest land in this sector in plantations, and Florida, with nearly 15 percent.

More forest industry land is in plantations than any other ownership. Nearly 46 percent of the timberland held by forest industry in the South is of artificial origin (Table 2). In four states, the proportion exceeds 50 percent (Florida, Georgia, North Carolina and South Carolina); in only three states (Arkansas, Kentucky and Tennessee) is the proportion less than a third.

In the NIPF sector, only 10.1 percent of the timberland base is in plantations, though that represents slightly more than 13.88 million acres of NIPF ownership (Table 2). Alabama, Georgia and Mississippi each contain more than 2 million acres of plantations in the NIPF sector; proportionally, Florida leads the southern states with 24 percent of NIPF timberland in plantations. Three states (Kentucky, Tennessee and Oklahoma) have less than 5 percent of NIPF forestland in plantations.

Changes over time for states with two inventories. Between the 1980 and 1990 FIA reports, the eight states with digital data analysis capability showed a 3.9-percent increase in the percentage of timberland in plantations (Table 3). This represents an increase from 16.5 million acres in the 1980s to nearly 21.5 million acres in the 1990s. The percentage change increased in all eight states, ranging from 1.4 percent in Oklahoma to 5.7 percent in Mississippi.

The largest increase was in the forest industry sector, where plantations occupied 7.1 percent more of the timberland in the 1990s than the 1980s. Again, all states showed an increase, ranging from 4.5 percent in Oklahoma to 11.9 percent in Texas. This represents a gain of nearly 1.1 million acres for these eight states alone (which together comprised 61 percent of the timberland area in all 13 states).

Table 3. Difference in the percentage of timberland of artificial origin between 1980s and 1990s, by ownership class and state, for states in the South with two digital Forest Inventory and Analysis reports.

	Timberland area				
State	All	National forest	Other public	Forest industry	NIPF
Arkansas	2.7	2.1	-0.6	5.7	2.1
Florida	5.6	7.7	2.5	7.0	8.7
Mississippi	5.7	4.6	2.7	6.3	6.8
North Carolina	2.9	0.1	-2.9	7.3	2.9
Oklahoma	1.4	4.9	0.0	4.5	1.0
South Carolina	4.9	2.4	5.1	8.8	5.5
Texas	5.0	5.1	-4.8	11.9	2.2
Virginia	2.2	0.3	0.7	8.1	2.7
All states	3.9	2.9	0.7	7.1	4.2

The NIPF sector showed the second largest increase; its plantations occupied 4.2 percent more of the timberland area in the 1990s than in the 1980s. The increase by state ranged from 1.0 percent in Oklahoma to 8.7 percent in Florida. However, this represents the largest absolute increase in plantation area of any of the four ownership sectors-from just more than 5 million acres in the 1980s to slightly more than 8.5 million acres in the 1990s, or roughly 70 percent of the total 5-million acre increase.

The smallest changes were in the public sector: national forest plantations increased by 2.9 percent and on other public lands by 0.7 percent. On the national forests, changes varied from a 0.1 -percent increase in North Carolina to a 7.7-percent increase in Florida. Other public ownership was the only sector where decreases in the percentage of timberland in plantations were seen at the state level; changes in that sector's plantation area ranged from a decrease of 4.8 percent in Texas to an increase of 5.1 percent in South Carolina. This represents an increase of only 216,000 acres on the national forests and 110,000 acres on other public ownerships.

Summary. The scope of intensive forest management in the South can be summarized as follows:

- One out of six acres of timberland in the South is a plantation.
- The 34.7 million acres of plantations in the South represent an area slightly larger than the state of North Carolina.
- Of every 100 acres of plantations in the South, 94 are privately owned: 54 acres are on forest industry land and 40 acres on non-industrial private lands.
- Of every *100* acres of plantations in the South, only 6 are publicly owned: 4 are in national forests and 2 are on other public holdings.

In light of these data, the debate about whether intensive management has a role in southern forestry is moot. It has become an integral element of forest management, especially on private forestlands, and its importance is increasing.

Intensive Management in a Sustainable Forestry Context

Two elements are critical to sustainable forestry-management of forest stands and management of the patchwork of forest stands across a wider landscape. The importance of these two elements is reflected in the American Forest and Paper Association's (AF&PA) Sustainable Forestry Initiative (SFI). Of 13 objectives established in the SFI to implement sustainable forestry in the forest products industry, 7 are directly related to stand and landscape management concerns-5 apply to management of forest stands and 2 to forest landscapes (AF&PA 1995).

Management of Forest Stands

At the stand level, the use of intensive treatments to regenerate individual stands has strong ecological parallels in the dynamics of secondary forest succession and natural disturbance. Clearcutting imitates the severe natural disasters that occur in nature (Smith 1986, Bonnicksen 1994), such as Hurricane Hugo's devastation in South Carolina in 1989 or the wildfires in Yellowstone National Park in 1988. As such, clearcutting has a strong natural parallel-the intensive disturbance that removes all overstory and midstory vegetation from a site. But because silviculture is intended to improve on nature, foresters typically follow clearcutting by planting a chosen species-generally an intolerant, fast-growing species.

Therefore, the first indication that sustainable forest management is successful is whether prompt reforestation of forested areas occurs following harvest. Reforestation is the successful establishment of a new stand of desirable species adapted to the site, and among the most reliable ways to reforest an area is planting.

On AF&PA member-company land, for example, prompt reforestation is called for under the SFI. In 1997, member companies reported successful reforestation within two years of harvest on more than 97 percent of sites on which reproduction cutting had occurred (AF&PA 1997). Similarly, on National Forest System land, the National Forest Management Act of 1976 (NFMA) limits reproduction cutting only to those sites on which foresters can be assured of successful regeneration within a five-year period. However, there are no similar provisions or assurances for non-industrial land in the region.

Restoring abandoned agricultural land to productive forest is a second key element of forest sustainability, especially in the NIPF ownership sector. Afforestation of such land by planting provides a net addition of acreage to the timberland base. Aldo Leopold captured this ethic in his writings, noting that he acquired the Sand County property because he "wanted a place to plant pines" (Leopold 1991); he found "a curious transfusion of courage" in the view of his Sand County pine plantings on a desolate winter night (Leopold 1987). The Conservation Reserve Program and the Wetland Reserve Program of the Natural Resources Conservation Service, as well as various state agencies, promote such restoration.

Some stands in private ownership that have been highgraded in the past may have little potential for future development or for natural regeneration, especially if seed sources are not present or are of inferior phenotypic condition. In such cases, the best option for the timely establishment of a robust stand of suitable quality is by clearcutting and planting. Where there is neither a seed source nor any alternatives to rehabilitate an existing understocked stand, intensive management may be the landowner's best alternative.

The plant communities created by intensive management may be quite different from those that were harvested or than those that might result from using natural regeneration. Whether this is an advantage or disadvantage relates to the condition of the forest on a particular site and on the intentions of the landowner.

But not every plantation is the same. There are subtle differences between intensive management as practiced on public lands versus that practiced on private lands. NFMA requires that, in almost all circumstances, lands in the National Forest System must be reforested with native species within the natural range of those species. Thus, for example, if a clearcut was prescribed in a shortleaf pine (*Pinus echinata*) stand on national forestland in the Ouachita Mountains of westcentral Arkansas, only shortleaf pine can be planted, rather than loblolly or another southern pine, since shortleaf pine is the only pine native to the Ouachitas (Critchfield and Little 1966).

No such restrictions apply to private ownerships; private landowners can plant whatever they choose. For example, a major forest industry in the Ouachita Mountains plants loblolly pine rather than shortleaf on its clearcut sites. Differences also exist among ownerships in the intensity of site preparation. Site preparation and release treatments on national forestlands are often less intensive than associated with industrial forest management. The result is differences in the degree to which species that compete with planted species are suppressed. The net ecological result is subtle and largely unquantified, but apparent to the keen observer.

One might argue that with 94 percent of the plantations in the South on private land, the public land base should be managed only for late successional stages. However, this argument falls short on both legal and ecological grounds. The NFMA and its implementing regulations stipulate that the national forests provide diversity of habitat and maintenance of all native plants and animals, including those that typify early successional stages.

Intensive management using plantations is not the only tool to provide early seral habitat on federal lands; such habitat can also be provided by even-aged reproduction cutting methods that rely on natural regeneration. However, there are some ecological needs on public lands that are better or more efficiently met through intensive management. First, clearcutting and plantation establishment are used to reforest sites following natural disturbances such as wildfire or insect pest outbreaks. Second, some lands enter federal ownership after all commercial timber products have been removed from them; plantation establishment remains an effective tool for restoring the productivity of such sites. Even-aged management also helps achieve specific ecological objectives on federal lands. For example, national forests supporting red-cockaded woodpeckers (*Picoides borealis)* often use clearcutting to remove off-site plantings of slash pine and to plant longleaf pine-restoring a species to sites that originally supported it. Finally, planting is critical to ameliorate natural regeneration failures, such as might occur in a previously planted or naturally regenerated stand under abnormal microclimatic conditions.

On the other hand, private landowners in the South, especially forest products companies, use intensive management because of its productivity and economic advantages. Timber is the most important agricultural commodity in the South; in 1984, the $6.1 billion value of timber products (delivered to the mill or loading point) was double that of soybeans and cotton, and three times the value of tobacco, wheat or corn in the region (USDA Forest Service 1988). Plantation forestry is the most reliable method of ensuring an adequate flow of wood, not just for fiber production, but also for investment in mill capacity. Plantation wood tends to be uniform in diameter, length and taper, which contributes to harvest and milling efficiency. Plantations also create synergy among the public and private sectors; meeting the increasing demand for wood products through intensively managed plantations on private lands offers opportunities to reduce the extent and intensity of harvest on public forests (Sedjo and Botkin 1997).

Management of the Landscape

At the larger landscape level, the issue of scale becomes important when considering intensive management practices and sustainability. The spatial pattern and juxtaposition of plantations across a landscape may influence important ecological patterns and processes such as continuity of habitat. However, these relationships are not yet clearly accepted in the literature and have not been translated into concrete recommendations that land managers can use to apply intensive management within a landscape. Research must focus on testing such hypotheses in operational landscape conditions (Turner 1989).

A primary concern about intensive management is its effect on biological diversity. The fragmentation of habitat has been a concern for more than a decade (Harris 1984). Fragmentation can refer to spatial fragmentation, such as when a new plantation breaks up a continuous forest canopy. It also can refer to discontinuities of vegetation within an area, such as when a mixed-species stand is replaced by a stand dominated by one species (Lord and Norton 1990).

Fragmentation effects are usually attributed to three factors: forest area, isolation and edge effects. It is sometimes argued that plantations reduce the area of native forest, isolate remaining patches of native forest, and create edges which attract predators and nest parasites; species associated with native forests might then decline in abundance. Such concerns arise because of the common assumption that stand-level habitat quality in plantations and native forests differs greatly for many species. Some (e.g., Terborgh 1989: 168) have even charged that southern pine plantations are "biological deserts."

However, research suggests that if the structure of vegetation is similar between plantations and native forests, wildlife communities can be similar as well. In North Carolina, for example, thinned plantations and unmanaged tall pocosins were found to be similar structurally (Karriker 1995). Both had tall trees and were vertically and horizontally diverse. As a result, bird communities were quite similar in both habitats.

Concern about edges has its origins in research projects investigating the permanent edges created by agriculture or urbanization. However, edges created by forest management do not always appear to function as permanent edges. One factor in this phenomenon may be that intensive management often occurs in the South within highly forested landscapes; landscape-scale habitat patterns greatly influence patterns of edge-related phenomena, e.g., nest predation and cowbird abundance (Donovan et al. 1997). Predator abundance and cowbird parasitism are most severe in landscapes highly fragmented by agriculture or urbanization. Cowbirds appear to have difficulty exploiting highly forested landscapes, even if managed by clearcutting (Thompson et al. 1992). Thus, at least in extensively forested areas, intensive management can be compatible with the goal of maintaining viable populations of many forest interior and Neotropical migrant birds (e.g., Thompson et al. 1992).

Maintenance of biological diversity requires maintenance of a variety of successional stages (Sharitz et al. 1992), from early successional to late successional stages. If intensively managed landscapes retain a diversity of successional stages, they can support many species, some of which are of conservation interest. In South Carolina, for example, researchers from North Carolina state University (Richard A. Lancia personal communication: 1998) have identified 73 bird species within an intensively managed landscape chiefly composed of pine plantations of various ages. Other land types within the landscape are scattered "gum" ponds and native pine-hardwood and hardwood forests. Of the 73 bird species, 40 are Neotropical migratory birds, 11 are high-priority species (as designated by Partners in Flight) and 13 are often viewed as forest interior species.

It thus appears likely that intensive management practices on public and private lands can be modified to enhance structural diversity (Sharitz et al. 1992) at the stand and landscape level. But more research is needed to understand better which structural features are limiting and how to enhance them.

Discussion and Conclusions

It has been only six decades since H. H. Chapman (1942) initiated the forestry profession in the South by observing that second-growth loblolly pine stands in the West Gulf Coastal Plain could be profitably managed from establishment to final harvest. Since then, one out of six acres of timberland in the South now supports a planted stand. Intensive forest management has thus become one of the most important silvicultural tools in the toolbox of the forester. If the concept of forest sustainability is to have lasting importance in southern forestry, it must provide, as it did in the land ethic of Aldo Leopold, for the ecological attributes and economic values of the pine or hardwood plantation.

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Ecosystem Restoration: Fact Or Fancy?

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Introduction

Restoring degraded ecosystems is a major new focus of research and practice, particularly within federal agencies. Clarion calls within the last decade to restore, rejuvenate or rehabilitate degraded terrestrial and aquatic systems (e.g., Cairns 1988, 1995, National Research Council 1992) have been answered by redirection of agency effort and by proposed increases in federal funding for restoration programs. Nevertheless, the scientific basis for ecological restoration is thin and much discourse rests on emotion and myth. As Cairns has stated (1995: 7) "restoration was an aspiration and . . . rehabilitation was an achievable goal."

Ecological restoration is generally accepted as the reestablishment of natural ecological processes that produce certain dynamic ecosystem properties of structure, function and processes. But restore to what? The most frequently used conceptual model for the restoration process is the shift of conditions from some current (degraded) dynamic state to some past dynamic state, generally that presumed to have occurred prior to European settlement. We find an alternative conceptual model more helpful, that of the self-renewal—rehabilitation—restoration continuum (Maini 1992, Walker and Boyer 1993, Stanturf and Meadows 1996). In this model, the state of the forest ecosystem can range from "natural" to "degraded" and can be affected by reversible or irreversible changes. As the forest moves from a natural to a degraded state, the ability of a manager to prevent irreversible changes decreases, and the cost of intervention increases non-linearly. The need for restoration presumes a loss of ecosystem function, for example, by clearing of the forest and conversion to agriculture (Stanturf et al. 1995). A continuum model avoids the problem of precisely specifying an endpoint for restoration, and offers a context for landowners with management objectives other than preservation to contribute to ecosystem restoration.

Restoration of the myriad communities of bottomland hardwoods and the diverse communities of longleaf pine is the subject of intense interest in the southern United States. In this paper, we examine some common myths about restoration of these forest ecosystems from the perspective of a continuum model. The potential for restoration of bottomland hardwood ecosystems to the Lower Mississippi River Valley has barely been tapped. If current funding levels are maintained, close to 200,000 hectares could be restored over the next decade. The bulk of this will be on private land enrolled in the Wetlands Reserve Program (WRP), a federal incentive program (Shepard 1995). In contrast to forested wetlands, the major blocks of remaining longleaf pine ecosystems are on public lands, and restoration activities are planned or underway on many of these lands across the South. Private landowners, however, can be voluntary partners in conserving these ecosystems in a mixed ownership mosaic. Much research is in progress to sharpen our understanding of the economic as well as the ecological values of longleaf pine and bottomland hardwood ecosystems.

The Restoration Context

Bottomland Hardwood Restoration

The dominant goal of bottomland hardwood restoration programs, both on public and private land, has been to create wildlife habitat. In 1987, the U.S. Fish and Wildlife Service began an aggressive restoration program directed at wildlife refuges on public lands but also including private land. The Corps of Engineers continues to construct flood-control and drainage structures but must now mitigate wetland losses through restoration on other sites. Their mitigation programs are geared toward offsetting losses of fisheries and wildlife habitat. On private forestland, most landowners cite wildlife habitat as a major benefit of ownership. The federal Conservation Reserve Program (CRP) began in 1985 to subsidize establishing permanent cover on erosive and other fragile private land such as wetlands, in order to improve water quality. Wildlife habitat creation and water quality improvement are goals of the Wetlands Reserve Program (WRP). New programs such as the Wildlife Habitat Improvement Program (WHIP) and the Environmental Quality Incentives Program (EQIP) have similar emphases.

The strategies used to restore bottomland hardwood ecosystems cover a spectrum, ranging from extensive to intensive. An extensive strategy has been pursued on public land. It is to seek the lowest cost per acre and usually involves widely spaced plantings of heavy-seeded species of value to wildlife for hardmast. This is accomplished using bare-root seedlings or direct-seeding acorns. The idea is to establish those heavy-seeded species such as the oaks that are hardest to establish. These species provide hardmast, and the manager then relies on natural invasion through wind and water dispersal of light-seeded species. The light-seeded species are needed not only to provide diversity, but also to fill in the space between the oaks in order to occupy the site fully.

More intensive strategies are available that are more costly but provide benefits quicker. Using an intensive approach, a manager establishes a closed canopy forest sooner, and directly intervenes to shape the structure and composition of the future stand. This also provides the potential for income to the landowner. Intensive strategies involve planting more seedlings per acre, or employing more intensive site preparation or subsequent weed control than is allowed under WRP (Stanturf et al. in press). Even more intensive approaches involve establishing multispecies stands, including interplanting a fast-growing species such as cottonwood (*Populus deltoides*) as a nurse crop for Nuttall oak (*Quercus Nuttallii*) (Schweitzer et al. 1997, Stanturf and Shepard 1995, Twedt and Portwood 1997).

Longleaf Pine Restoration

Longleaf pine ecosystems once occupied more than 90 million acres in the lower Coastal Plain from Virginia to eastern Texas. Fire maintained open stands of mature longleaf pine (*Pinus palustris*) and biologically rich understories. The depletion of the longleaf ecosystem began with large-scale harvesting in the late 1880s and early 1900s that depleted seed sources for natural regeneration. The frequent fires that reduced competing vegetation and controlled brown-spot needle blight, a damaging foliar disease, was excluded from many stands by the middle of this century. This has allowed loblolly pine (*P. Taeda*) and other species more aggressive than longleaf pine to replace it across most of its range.

In the past, survival of planted longleaf stock was generally poor. Advances in regeneration technology have greatly increased survival (Barnett et al. 1990). The delay in stem elongation that characterizes this species (called the grass stage) keeps established seedlings at a stage where they are very susceptible to competition. Fire is the ecological tool for controlling competing vegetation and favoring longleaf pine, and must play a role in restoration. Frequent use of fire may hasten initiation of height growth and will reduce competing vegetation, thereby stimulating growth and development of the biologically diverse, fire-adapted understory so characteristic of this ecosystem.

Restoration Myths

Myth I: Reforestation Equals Restoration

All restoration goals can be simplified into one immediate goal: to re-establish the dominant tree overstory, whether closed canopy bottomland hardwoods or open stands of longleaf pine. Although some argue that this is incomplete restoration, it is a necessary and costly first step. Despite all that we know about establishing these dominant tree species, still there are frequent failures, and we need techniques for sites where our standard prescriptions do not work. Nevertheless, we know relatively little about establishing understory species (Walker and Boyer 1993) and even less about non-vegetative components or the impact of restoration on soil quality (Schoenholtz et al. 1997).

Reforestation, however, does not equal restoration. The goal of restoration is broader than simply establishing a tree canopy of a few selected species. Functional reestablishment of the natural system is the ideal, even if we must recognize the impracticality of this goal (Kusler and Kentula 1990). Fortunately, as Cairns (1986) suggested, most functional attributes are correlated to vegetation structure and composition. Which brings us back to the question, restoration to what standard?

Restoration guidelines generally recommend identifying older, relatively undisturbed stands as the criteria for successful restoration. Reference sites for bottomland hardwoods may have hydroperiods altered by the same hydrologic alterations that contributed to the degradation of the site to be restored. Hydrologic modifications and natural succession continue to influence species composition and biological diversity, primary productivity, and the ultimate success of restoration efforts. The interaction of succession and hydroperiod under natural conditions is dynamic and complex. When one or both have been altered by human intervention, however, the present condition of a reference site may not be an appropriate goal for the future condition of a restoration site (Stanturf et al. 1995).

The continuum model avoids the difficulty of setting a single point in time as the standard by which we judge success or failure. If we accept that a range of stand conditions is within the accepted tolerances, we can allow succession and future management intervention to shape stand structure and composition along a trajectory toward an acceptable endpoint (Mitsch and Wilson 1996).

Myth 2: The Same Strategy Works on All Ownerships

Restoration of public land in the lower Mississippi Valley relies on native species planted mostly in single-species plantations of oak at wide spacing, to allow natural invasion of other species. Sites that do not flood frequently or are more than 100 meters from existing seed sources may not seed in successfully (Allen 1990). We question the appropriateness of this extensive strategy for private land on two counts. First, a more intensive approach would provide a more diverse stand and landscape quicker. Second, the extensive approach is inappropriate if the landowner wants to produce timber. The stocking that results from federal cost share programs, which are administered using the extensive strategy as practiced on public land, will not be sufficient to support a commercial pulpwood thinning even at age 20 or 30 (J.C. Goelz, USDA Forest Service, personal communication: 1996).

Even on public land, the extensive approach can be challenged. Wildlife managers believe the low-cost, extensive strategy described above will meet their objectives (Haynes et al. 1993). Managers will have few opportunities, however, for manipulating these understocked stands in the future to further enhance wildlife habitat. Even when natural invasion successfully increases stocking, it takes 20 or more years to develop a closed forest (Allen 1990). During that interval, significant opportunities will be missed to provide habitat for Neotropical migratory birds (Twedt and Portwood 1997) and other wildlife (Wesley et al. 1981).

Myth 3: Ecological and Economic Values Are Incompatible

Ecological and economic goals are not mutually exclusive. Rather a "win-win" situation is possible, especially on NIPF, where landowners are usually not interested in maximizing commodity outputs. A related myth is that NIPF owners are not interested in restoration. It may be true that many landowners cannot afford expensive restoration costs without a promise of future financial returns. Under the continuum model, objectives other than preservation are allowed, and NIPF owners can play an important role in ecological restoration.

Even if a landowner omits financial return as a secondary objective and primarily desires to benefit wildlife, the easiest way to create the desired habitat may be to thin a young stand. The sale of the thinning could help to offset the cost of improving habitat, easing the financial burden of management for wildlife. This might make the difference in some ownerships whether the stand is thinned at all, especially on public land where appropriations for management are shrinking.

We believe the more intensive strategy for restoring bottomland hardwoods will have multiple ecological and economic benefits. In addition to providing future income from pulpwood harvests, natural succession and invasion by other species will be accelerated simply by having a closed canopy forest sooner. This will be more attractive to bird and mammal vectors of heavy seeds as well as light seeds. If a closed canopy stand is established sooner, other wetland functions will be restored to levels typical of a closed forest, rather than an open field of soybeans. Future options to manipulate stand structure abound. In the cottonwood and Nuttall oak interplanting, we have the option to harvest all the cottonwood at age 10 in the summer (in order to reduce coppice regrowth, thereby completely releasing the 8-year-old oak stand); harvest in the winter and encourage another 1 O-year cottonwood pulpwood rotation from coppice; or partially harvest the cottonwood at age 10, retaining a few individuals for future sawlog or den trees. For most NIPF owners, the cottonwood stand will be an interim step along a path toward a naturally self-renewing bottomland hardwood forest.

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Fire and Biodiversity: Studies of Vegetation and Arthropods

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Introduction

Fire is a critical management tool in natural and mature old-field pine uplands of the Coastal Plain in the southeastern United States (cf. Myers 1990, Hermann 1995). During the last 30 years, prescribed burns have gained almost universal acceptance within wildlife and natural resource agencies. However, for much of that time, prescribed bums were used almost exclusively to decrease fuel loads and minimize the threat of wildfire. Bums were almost always prescribed within a time frame limited to the dormant or winter season and with an intensity and/or frequency that did little more than remove leaf litter and grasses. Dormant-season fire was also applied to prune hardwoods and vines in attempts to maintain an open, grassy forest.

In recent years, ecologists have encouraged natural resource managers to modify traditional prescribed fire regimes to mimic natural processes or at least recreate their outcome. This is especially true in southern longleaf pine (*Pinus palustris*) forests (cf. Means and Grow 1985, Noss 1989). Land stewards are urged to burn more frequently than in the past and to include growing- or warm-season bums (more accurately termed dry-lightning season, see below). The push to include growing-season fires in long-term management plans is based largely on an increased understanding of some important native plant responses to specific time of burn (cf. Brewer and Platt 1994a, 1994b, Platt et al. 1988, Robbins and Myers 1992, Glitzenstein et al. 1995a, 1995b). In addition, James et al. (1997) suggest that modification of traditional fire regimes might aid in the recovery of the endangered red-cockaded woodpecker (*Picoides borealis*). Recently, a few entomologists have also discussed positive aspects of growing-season fires for insect conservation. For example, Hall and Schweitzer (1992) noted that for some species, fire should occur during time periods when adult insects are mobile rather than quiescent or sedentary.

Despite the documented benefits of growing-season bums, a number of biologists question altering the use of fire. Game bird managers have expressed concern over possible nest mortality and loss of arthropods as food. Also, foresters worry that growing-season burns will depress tree establishment and/or growth. In addition, some lepidopterists believe prescribed fires may be incompatible with management for butterflies (cf. Swengel 1996) and other arthropods of conservation interest because they might increase mortality.

These views indicate potential conflicts with periodic application of lightning-season fire for ecosystem management. Past hesitancy of land managers to alter traditional prescribed fire regimes often has been based on concern over such conflicts. At times, a need for information to guide prescribed bum activities has preceded the research required to address pertinent issues. Three recent reviews of the effects of season of bum in the Coastal Plain (Glitzenstein et al. 1995a, Robbins and Myers 1992, Streng et al. 1993) provide a basis to evaluate these concerns and to determine future research needs.

In this paper, we summarize and update the state of knowledge for some components of prescribed fire in the southeastern Coastal Plain, with a primary focus on effects of season of bum on plants and arthropods. Specifically, we: 1) briefly explain season of fire terminology; 2) present a short synopsis of how fire regimes affect trees and groundcover vegetation in Coastal Plain pine forests; 3) review relevant arthropod literature; 4) discuss preliminary data from ongoing studies on season of bum on arthropods, including consideration of resources for pollinators (especially fall migrating butterflies); and 5) consider prescribed fire management in light of biodiversity issues.

Terminology and Study Design Considerations

Before exploring management issues, we review terminology related to seasonality of fire in the Coastal Plain. The phrases **warm** and **cool season,**

summer and **winter, growing** and **dormant season,** and **lightning** and **non-lightning season** are related, but not synonymous terms; dates associated with each phrase may shift depending on the latitude of a site. For clarity, the month and locality should be specified in a description of season of burn effects. In addition, it is useful to know soil type, past fire history and groundcover condition. The term **fire regime** characterizes a series of burns and includes season, frequency and severity. It is a summary of the fires applied to a site over time and provides a general description of the role of fire in structuring a specific habitat. In upland Coastal Plain forests, an evaluation of a site's fire regime or past fire history provides more useful information for understanding the ecology of the site than does a description of any one burn.

The phrase **lightning season** is of interest because it is related to local weather patterns associated with natural ignition of fire. Komarek (1964) documented that Florida's thunderstorms are common in May through September, peaking in July and August, and that lightning-ignited fires are common from April through August, peaking in May and June. Robbins and Myers (1992) noted that in Florida, early months of the thunderstorm period corresponded to drier weather conditions and proposed that a lack of moisture explains the shift in time between peak thunderstorms and frequency of lightning-ignited fires. Because this time period is delimited by local weather, the peak fire period of May to June may shift somewhat at sites north or west of Florida.

Platt et al. (1988) and others have postulated that the growing or lightning season is the time when most natural fires occurred in northern Florida. Due to the relatively high frequency of fire in the Coastal Plain, it is difficult if not impossible to corroborate season or bum intervals based on traditional means, such as tree ring fire scars or charcoal layers in sedimentation. Nevertheless, the significance of this fire period is bolstered by studies on the ecological responses of dominant plant species to different seasons of bum (see below). To facilitate communication, phrases describing time of fire should be defined by stipulating the month(s) of the bum period (see Robbins and Myers 1992, Streng et al. 1993).

Fire and Plants

Evaluation of the effect of different times of fire on vegetation is a complex process. Habitat type and past fire history of a study site must be considered (cf. Glitzenstein et al. 1995a). For example, old-field groundcover produces a fuel base with different pyrogenicity compared with vegetation dominated by wiregrass (*Aristida stricta* or *A. beyrichiana*). A site subjected to many years of fire suppression will respond differently to fire compared with a site that has been burned frequently. Fire weather and ignition patterns may also contribute significantly to fire effects (Glitzenstein et al. 1995a, 1995b, Robbins and Myers 1992).

Frequency may be as important as season of fire in determining bum effects (Glitzenstein et al. 1995a, 1995b). However, this factor is especially difficult to study because there are few places that have been studied for sufficiently long periods of time. Two of the most well-known sites are the Santee Fire Plots in South Carolina (Waldrop et al. 1987) and the Stoddard Fire Plots in northern Florida (Hermann 1995). Unfortunately, neither site is characterized by the type of groundcover thought to have dominated much of the eastern Coastal Plain uplands (cf. Peet and Allard 1993) before settlement by Europeans. The groundcover of the Santee Plots, although thought to be characteristic of old-growth forests, may be specific for non-wiregrass dominated regions of South Carolina (Glitzenstein et al. in preparation). The Stoddard Plots are old-field vegetation. Sites in central Florida studied by Rebertus et al. (1989, 1993) have more typical, presettlement groundcover, however these plots have experienced past fire suppression (Glitzenstein et al. 1995a, 1995b). Despite shortcomings and differences, vegetation data from all three sites indicate that short bum intervals (averaging three years or less between fires) promote high diversity grass- and forb-dominated understory and that longer intervals produce a lower diversity woody species-dominated understory and midstory.

Pines and Season of Burn

Concerns are often expressed over potential negative effects of non-dormant-season bums on pines. Streng et al. (1993) present convincing evidence that growth of established pines need not be sacrificed when fires are prescribed during non-winter months. Robbins and Myers (1992) noted widely varying results related to growth and mortality. They point out that negative outcomes often can be attributed to extreme burn conditions and that this situation is not restricted to lightning or growing-season fires. High ambient air temperature associated with late growing season (generally later than the time span covered by the lightning season) may contribute to higher overstory pine mortality. Robbins and Myers (1992) stress that this comes into play only when fire intensity is high (the result of extreme weather conditions and/or excess fuel accumulation) or in young trees. Mortality may be of more concern for "off-site" pines, such as loblolly (*P. taeda*), slash (*P. elliottii*) or shortleaf (*P. echinata*), than in longleaf stands.

Based on available literature, lightning-season bums do not necessarily harm pine trees, especially longleaf pines (Glitzenstein et al. 1995a, 1995b). However, fire does affect each life stage of longleaf pine differently. Studies reviewed by Robbins and Myers (1992) indicate that growing-season fires may enhance growth of grass-stage (juvenile) longleaf pine and not necessarily depress growth of adult trees. Although established juveniles thrive with fire, seedlings less than one or two years old are usually killed by tire. This age-related (actually size-related) survivorship explains why annual burns at any season prohibit recruitment of southern pines (Hermann 1995).

Longleaf seeds require patches of bare soil to become established. Inclusion of growing-season bums in a land management plan may increase the chances for longleaf pine recruitment because they may permit creation of additional areas appropriate as seed bed. On nutrient poor, sandy soils, exposed mineral soil may persist for a year or two after a fire, but on richer soil, bums must occur the year that the seed falls. Longleaf seeds are dispersed in the fall, but cones are not easily noticed until the spring, after opportunities have passed for bums in the preceding dormant season. To take advantage of unexpected "mast years" with large numbers of cones, lightning-season fires that do not scorch crowns or cones may be useful in preparing seed beds.

However, bums that occur too late in the growing season may be problematic. Robbins and Myers (1992) note pine mortality may be high after tires in late summer to fall (generally August to October) compared with early growing-season bums. Caution is also urged when lightning-season fire is first reintroduced into a landscape. Excessive litter may build up at the base of large, old longleaf pines when fires have been absent or when exclusively low-intensity dormant-season burns are applied. A bum of even moderate intensity may cause it to ignite and smolder, resulting in mortality (J. Stevenson personal communication: 1997). This situation can be overcome by hand raking around at-risk trees with excessive fuel loads or using a series of dormant-season bums designed to remove built up litter.

Hardwoods and Season of Burn

Hardwood management often is mentioned as justification for burn programs. Waldrop et al. (1987) reported that, after 30 years, annual winter fire plots had substantially more hardwood stems compared with other treatments; plots with annual summer burns had the fewest hardwood stems. Glitzenstein et al. (1995a, 1995b) presented convincing data that "spring" (April to May) fires greatly increase oak stem mortality compared with burns at other times. However, the results of much of the research on effects of season of bum are confusing (Streng et al. 1993). Rebertus et al. (1987, 1993) suggest that higher intensity is associated with lightning-season fires and is a significant factor in increased mortality of arboreal oak stems, although other studies appear to be in conflict with this interpretation. For example, Glitzenstein et al.(1995a) conclude that, when a site is burned on a regular basis and does not require habitat restoration, fire intensity plays less of a role in oak stem mortality. Robbins and Myers (1992) point out that variation in other variables, including fuel loading, fuel moisture and fire weather, may "... obscure or accentuate seasonal differences."

It must be remembered that oaks are a natural part of upland pine forests. The goal of a fire management program should be not to eradicate hardwood species appropriate to a site, but rather to manage stem density and height to promote vegetation structure deemed suitable to the habitat. It is also important to understand that decreasing stem height does not eliminate hardwood fruit; native runner oaks and many other upland woody species produce fruit when stems are at groundcover height. Research is needed on the effect of season and frequency of bums on reproduction of these species. Robbins and Myers (1992) discovered that the literature on fire effects on fruit production in groundcover woody plants is ambiguous. However, there is no indication that growing-season fires depress acorn and berry abundance.

Herbaceous Species and Season of Burn

Responses of some forbs and grasses to lightning-season fires provide compelling evidence that season of bum should be varied in long-term management plans. Patterns of regrowth, quantity of flower production and flowering phenology are all characteristics that respond to season of bum. In the Coastal Plain, perhaps the most well-known example of plant response to the season of bum is found in wiregrass. Lewis (1964), Parrott (1967) and Glitzenstein et al. (1995a) all demonstrate that flowering of this regionally dominate species is strongly enhanced by exposure to fire in March to August. However, ongoing research indicates that ambient temperature interacts with season of bum in a complex fashion so that late dormant-season bums on unusually warm days may mimic the outcome of later fires by stimulating flowering (Walker et al. unpublished).

Flowering of some other common forbs and grasses is strongly influenced by the date of a fire. In a study at St. Marks National Wildlife Refuge in northern Florida, Platt et al. (1988) present data associating flower density and phenology differences with season of burn. In a follow-up report, Streng et al. (1993) showed that five grasses and eight forb taxa were influenced by date of fire. It appears that all of these grasses follow the flowering pattern seen in wiregrass and require, or at least benefit from, April to August burns. Fires at other times of the year resulted in less than 20-percent flowering. At the

Apalachicola National Forest, also in northern Florida, a smaller experiment using two times of fires (January and May to June) evaluated abundance of flowering stalks for plant species that are potential sources of nectar for butterflies (Hermann and Van Hook unpublished, see also below). Figure I illustrates preliminary results for three of the fall-blooming composites. Although these plants all flower during approximately the same time period, they demonstrate dramatically different responses to season of burn. Blazing stars *(Liutris* sp.), goldenrods (*Solidago* sp.) and golden asters (*Pityopsis* sp.) have enhanced flowering following May or June fires. These results are similar to those reported by Glitzenstein et al. (1995a). Conversely, growing-season burns appear to eliminate flowering in an annual senna *(Seymeria cassiodes)* (Figure 1).

Burn month can also influence timing (phenology) of flowering of some groundcover species 4 to 10 months after the bum. However, the relationship between flower phenology and reproductive success is unknown; more flowers at a point in time does not automatically mean increased seed production. However, many forb flowers are important resources for numerous insects (see below) and a shift in blooming may affect these animals. Furthermore, following fire, pollinator responses to flower abundance may influence seed set. Platt et al. (1988) demonstrated that fire could alter flowering at the community level. Bums in July and August delayed peak flowering and synchronized flowering among fall flowering species. These shifts may influence nectar availability, pollinators and pollination of groundcover plants.

Timing of prescribed burn may have significance for some plant species of special concern. For example, cutthroat grass (*Panicum ubscissum),* a threatened species in central Florida, displays a pattern similar to wiregrass and does not flower to any great extent unless it is burned during March through August (Myers and Boettcher 1987). *Schwalbea americana*, an endangered forb species, exhibits a different pattern of response to fire. Kirkman and Drew (1995) indicate that fire stimulates flowering in this species, regardless of season of bum.

In summary, an examination of published information on responses of groundcover to season of fire at both community and population levels, reveals that no one time of bum enhances all species (Glitzenstein et al. 1995a, Platt et al. 1988). In addition, short-term (less than 10 years) application of growing-season fire to intact habitat does not result in major shifts in the herbaceous community relative to dormant-season bums (Streng et al. 1993). However, the observations do suggest that a variety of times and frequencies (cf. Robbins and Myers 1992) are required for implementation of prescribed fire within the context of ecosystem management.

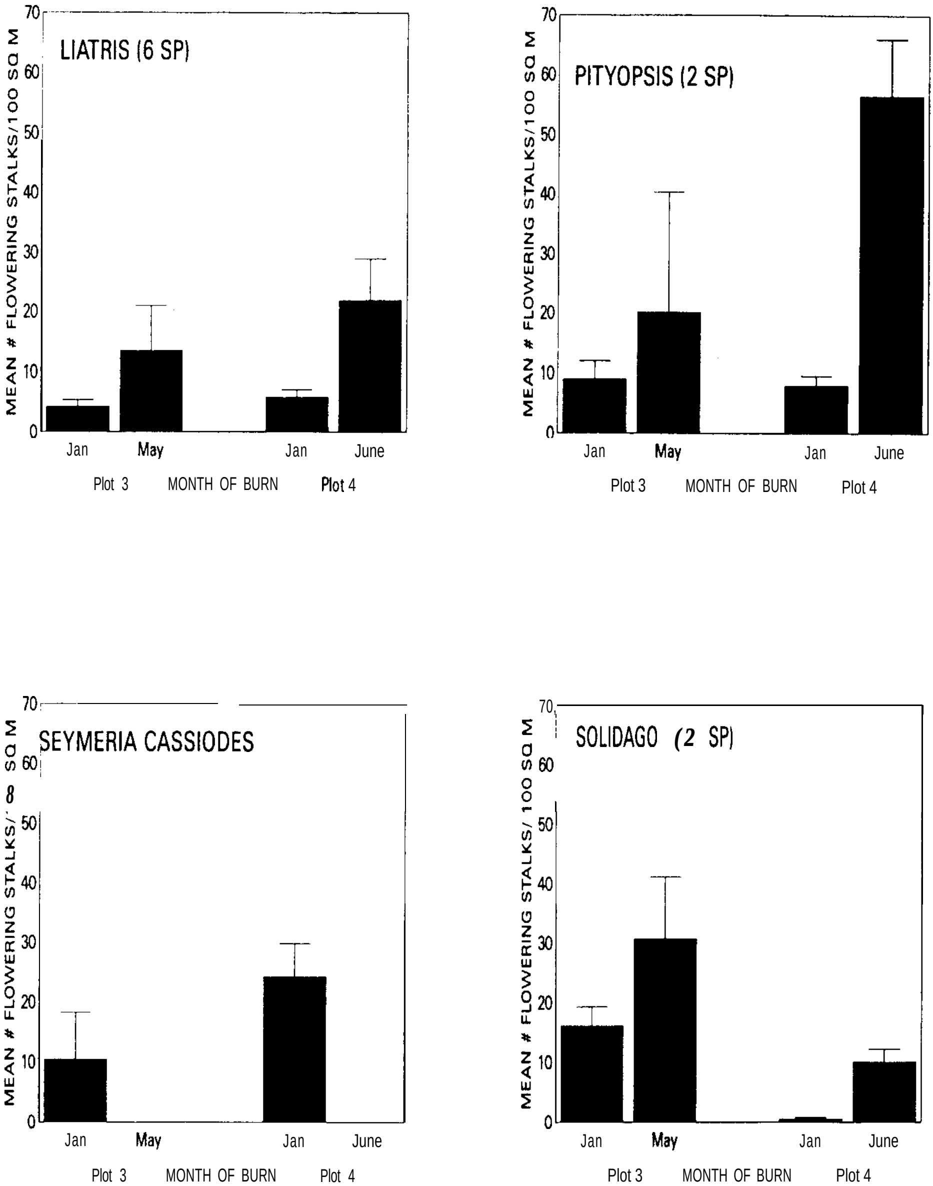

Figure 1. Examples of mean density of flowering stalks for four forb species following dormant- (January) or growing-season (late May and early June) fires on two wiregrass-dominated study plots in the Apalachicola National Forest in northern Florida (Hermann and Van Hook unpublished). Data are means +/-1 se and based on 100- by l-meter transects (n = 10 for each plot and treatment). These taxa are among many forbs in the groundcover community thought to provide nectar for fall migrating butterflies.

Fire and Arthropods

Until recently, studies of arthropods in fire-maintained habitats were usually limited to two general considerations: the ecological and economic consequences of fire as a control agent of pathogens (cf. Brennan and Hermann 1994) or as a promoter of insect pests by stressing host trees. In addition, some survey work has covered arthropods in ecosystems that naturally experienced fire at long intervals. A large volume of literature on fire and insects relates to habitats with fire intervals of 50 to 200+ years. Wikars (1997) provides a review of fire-adapted insects in boreal forests and notes that there are nearly 40 European insect species (mostly beetles) that are pyrophilous (favored by fire). These species have declined over the last century, in large part due to lack of fire.

There has been less of an effort to document arthropod fire dependency in frequently burned habitats of the Southeast (cf. Folkerts et al. 1993, Robbins and Myers 1992). In the past, this likely was due to traditional views held by some entomologists that fire "ravaged" southern pine forests, implying that, at least, butterfly collecting and studies would be unproductive on burned sites (Klots 1951: 33). More recently, lack of attention may be due, in part, to the fact that most if not the majority of the invertebrate fauna is dependent on specific habitat structure and\or vegetation composition. That is to say, many adaptations to fire may be indirect. Most Coastal Plain upland species likely require some habitat characteristics of the open-canopy, sunny, grass-dominated upland pine forest. If fire is withheld from old-field land (Hermann 1995) or old-growth longleaf pine stands (Gilliam 1995), the vegetation composition and structure begin to change within a few years. We assume that arthropod communities change as well.

There is little published information on the effect of season of burn on arthropods in Coastal Plain upland pine forests (Robbins and Myers 1992) or any habitat with frequent fires. In one short study in longleaf pine-wiregrass sites, no differences were observed in alpha-diversity of arthropod families from sites burned in February versus May (Lara Pavon 1995). Also of interest is Panzer's (1988) review of published literature from Midwest prairies; he found no indication of long-term effects on insects of different times of fire.

Hall and Schweitzer (1992) present natural history information for some insect species of special concern and use this knowledge to suggest some likely responses to fire. They surveyed four North Carolina Nature Conservancy Preserves for butterflies, moths and grasshoppers. Their general conclusion was the same that Panzer (1988) reached for prairies. They suggest that in southeastem savannas and flatwoods, many arthropods will survive and/or recolonize best after fire if the bum is in the growing season when most species have a mobile phase. Hall and Schweitzer (1992) caution against annual dormant-season fires when rare arthropods are present. They conclude that alternating fire years among areas with similar habitats and/or prescribing patchy bums will decrease the chance of local extinction of species. Hall and Schweitzer (1992) also use natural history information to suggest fine tuning of local bum plans. For example, the broad-winged sedge grasshopper (*Stethophyma celata*) is still flightless in May and early June; when this species is present, it may be appropriate to delay prescribed fire until late June when some reproduction has occurred (Hall and Schweitzer 1992).

Of special interest is the impact of season of bum on pollinators, especially butterflies and bees, and the flowers that provide pollen and nectar. Fire affects these insects directly, by imposing mortality on immobile stages, and indirectly, by altering density and/or time of availability of flower resources. Change at either level may influence the amount and/or quality of seed that results. Research on these topics is sorely needed.

Preliminary Studies on Season of Burn Effects on Arthropods and Plants

Because there is limited information on the effects of season of bum on arthropods in southern upland pine forests, we present data from two ongoing projects. In both studies (one in old-field vegetation and the other in wiregrass-dominated groundcover), arthropods were collected using portable suction devices (model 122, D-Vat Company). This collection method results in data that are best used for relative comparisons and not for tests of differences in absolute values among studies.

In one study (Brennan et al. 1995, 1997), two sites on a southern Georgia old-field bobwhite quail hunting preserve were burned, one in February and the other in early May. Figure 2 presents data on arthropod biomass and abundance. Sample periods were during June, July and August, three months important for brood rearing in bobwhite quail. The first (June) sample was collected almost seven weeks after the May fire. Insect abundances were either equal on the two burn treatments or the May bum plots supported more individuals; biomass measurements showed similar results. Percentage cover of herbaceous quail food plants were also monitored. There was no significant difference between fire treatments; no important plant group was greatly depleted by growing-season fire and some were enhanced (Figure 2). In addition, the number of bobwhite quail coveys counted by the land manager during the hunting season was either the same or slightly higher on sites burned in May versus February (Figure 2). This result was also observed in two subsequent years.

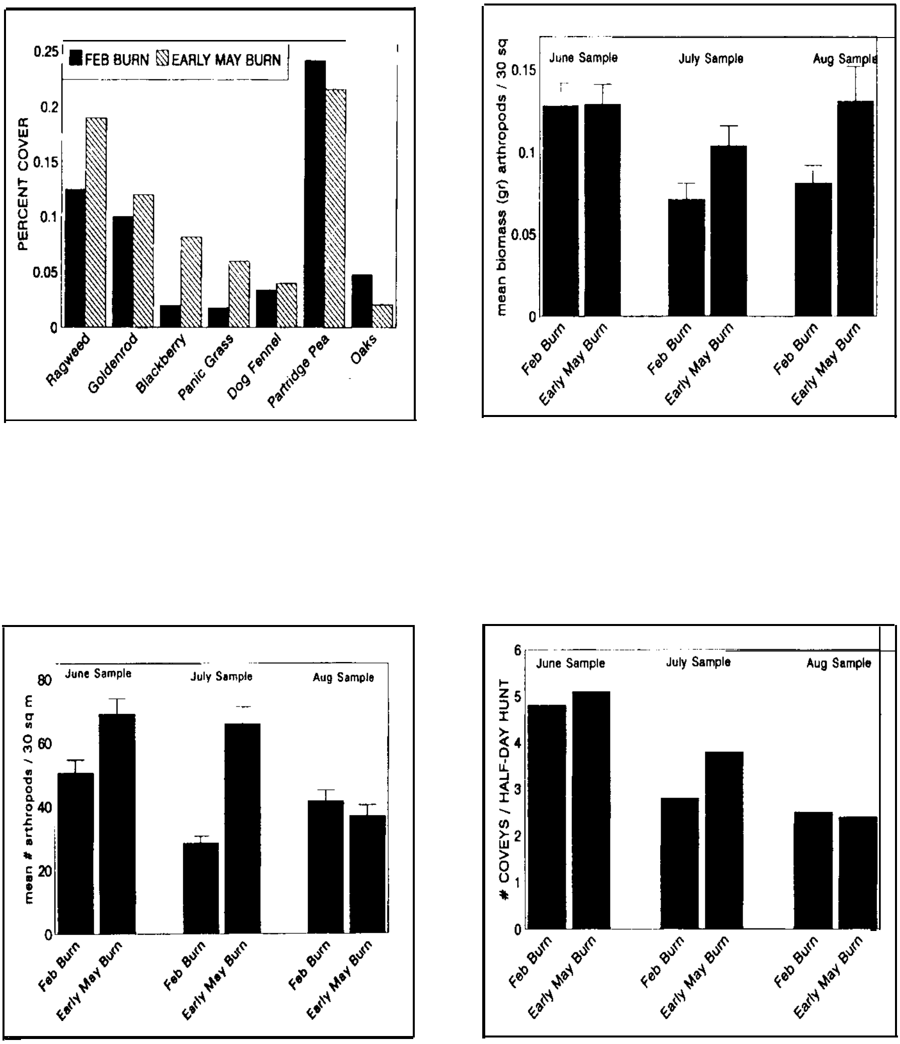

Figure 2. Data from two experimental fires on a private bobwhite quail hunting preserve in southern Georgia (based on Brennan et al. 1995, 1997). The groundcover vegetation consists of old-field species. Bums were applied in late February and early May to plots that encompassed previously established hunting courses, each a few hundred acres in size. Data on arthropods and plants are presented as means +/- 1 se and based on 1- by 30-meter transects (n = 25 for each bum type). Information on number of quail coveys was provided by the land manager of the private preserve.

In the other study (mentioned earlier), plots were located in mesic, wiregrass-dominated areas in the Apalachicola National Forest (NF) in northern Florida. USDA Forest Service staff burned experimental plots, half in January and half in late May or June. Figure 3 illustrates a subset of data (Hermann and Flowers unpublished) that correspond to the sample time period used in the study by Brennan et al. (1995, 1997). In contrast to that work, the May fires in the Apalachicola NF occurred less than two weeks before insect sampling in June. Therefore, it is not surprising that June arthropod abundances were substantially lower on the lightning-season (May) plots compared with the dormant-season ones. Arthropod abundances on all plots declined by the July sample period, but lightning-season plots supported significantly more individuals compared with the dormant-season plots. This pattern continued in August (Figure 3). In this study, only three orders (Collembola, Hymenoptera and Homoptera) were collected in sufficient numbers to permit evaluation; all three taxa showed the same patterns in abundance and were similar to the arthropod fauna taken as a whole.

Results from the Apalachicola NF sites indicate that by the end of the growing season, many components of habitat structure were apparently not significantly different between the two burn treatments. For example, by August, the mean percentage cover of wiregrass was similar on all sites (dormant season = 39.6 percent, growing season = 40.0 percent cover). As noted earlier, there were differences in flower abundance for some of the groundcover forbs (Figure 1). An additional difference may reside in moisture content of some of the groundcover species. Preliminary data suggest that, in August, plants on dormant-season fire plots had less moisture, per gram of wet biomass, compared with plant tissue from growing-season fire plots (Figure 3).

Migrating Butterflies as Species of Special Concern

Monarch butterflies (*Danaus* ***plexippus***) rely on nectar resources obtained during migration to support fall and perhaps spring movement to and from Mexico (Brower 1995). Monarch migration is the only ecological phenomenon of its kind granted a standing in CITIES documents (Wells et al. 1983). At a recent international meeting, biologists voiced concerns about diminishing habitat quality and resources for migrating butterflies. In the fall, critical resource elements are located in the Coastal Plain and prescribed fire effects directly influence the availability and quality of both assets (S. Hermann and T. Van Hook personal observation 1997). The Apalachicola NF plots are being used to study butterfly foraging and flower resources during the fall migration. The sites are part of a large migration route involving the entire eastern half of the United States. As noted above, results from the ongoing project indicate that season of burn may alter which plant species are available as nectar resources (Figure 1). Additional work examines whether monarchs and other migratory

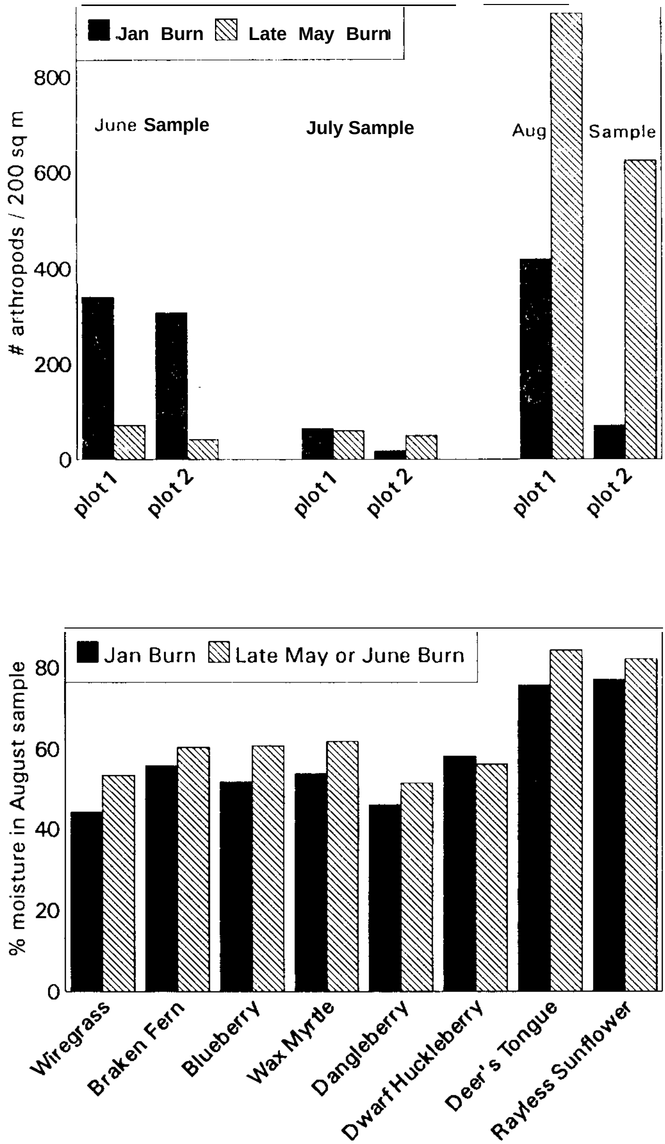

Figure 3. Data from season of burn plots in the Apalachicola National Forest (Hcrmann and Flowers unpublished). Arthropod numbers are based on 200- by l-meter transects, averaged over two transects per plot treatment. Plant biomass was collected in August, weighted wet, dried and re-weighted. Percentage moisture content of tissue was calculated by species, as (wet-dry)/wet. The consistently higher moisture in plant tissue from May/June burns may explain, in part, the observed difference in the August sample in numbers of arthropods on January- versus May-burned sites.

butterflies are affected by fire-induced differences in floral resources (Van Hook and Hermann unpublished),

Prescribed Fire, Season of Burn and Biodiversity

Implementation of ecosystem management has greatly expanded challenges for public land stewards. Today, agencies are required to promote not only game species, but also the full range of natural biodiversity. This means maintaining appropriate habitat for numerous species, including many of special concern. The dependancy of a dominant groundcover species, wiregrass, on lightning-season fire to trigger flowering has been known for 30 years. Over the last decade, information has begun to accumulate on other plant species. Walker (1993) noted that the majority of the nearly 400 plants of special concern that are indigenous to longleaf pine forests possess characteristics adapted to fire. As noted above, Platt et al. (1988) and Streng et al. (1993) demonstrated that different seasons of fire produced different patterns of flowering in the groundcover community (see also Figure 1). These alterations may in turn influence organisms such as migrating butterflies and other pollinators.

Robbins and Myers (1992) suggest that natural biodiversity will be promoted by including a variety of seasons of burn in long-term management plans. They acknowledge that burns in some seasons may be more difficult logistically than others and discuss some practical considerations related to lightning-season fires. Hall and Schweitzer (1992) comment on the apparent paradox in using a management tool (fire) to promote appropriate habitat for a species of special concern when the same tool may also kill individuals of the target species. Panzer (1988) suggests some techniques for safeguarding populations of immobile invertebrates. He recommends leaving some unburned areas each year to serve as refugia. This approach is valuable whenever unstudied and/or rare species are present.

Our review of available information suggests that thoughtful application of prescribed fire is vital to the conservation of natural diversity in pine uplands of the Coastal Plain. There is evidence that inclusion of lightning-season fires in management plans for public lands need not come at the expense of traditional management targets such as timber and game birds. Although dormant-season burns meet some needs for many species of groundcover plants and arthropods, our review suggests that prolonged periods lacking lightning-season fires may eventually have negative effects on the natural biodiversity of the region. Without lightning-season fire, some plant species may have little opportunity for reproduction. Even though many, if not most of these species are long-lived perennials, they need to produce seed, at least periodically. However, alterations in community composition or structure may not be observable for decades (cf. Glitzenstein et al. 1995a, Streng et al. 1993).

Agency staff charged with management of traditional natural resources have been hesitant to expand seasons of prescribed burns. In some cases, such reluctance is warranted; researchers have only recently begun to examine valid points of concern. There are many questions related to effects of lightning-season bums that have not been thoroughly studied, including 1) what members of the groundcover plant community benefit from tire at this time; 2) what affects do timing of bum within the lightning season have on plant flowering, and do these effects impact associated insects; 3) how frequently must different times of bum be applied to maintain natural biodiversity of native groundcover; 4) are there arthropod species' differences in response to time of bum; 5) what level of bird nest mortality is associated with lightning-season fire; and 6) how do game and other birds associated with groundcover use a landscape that includes both dormant and lightning-season bum areas?

Although these and many other topics remain to be studied fully, the results of the preliminary work cited above suggest that inclusion of expanded times of bums will have positive results for a broad range of management needs. To enhance prescribed fire goals, land stewards must monitor a variety of habitat responses to bum actions and adjust management activities accordingly, including providing refugia when needed. Increased knowledge of a wide range of organisms in the habitat will result in more effective application of prescribed tire and, consequently, better ecosystem management.

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Whither Wildlife Without Fire?

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Introduction

Fire is a major ecosystem process that has been pervasive across the southern forest landscape on an evolutionary time scale (Watts and Hansen 1988). Wildlife evolved in response to frequent lightning-ignited burns that shaped the biota of the Southeast. Despite the dominant role that fire has played on an evolutionary scale, the use of prescribed fire as a forest wildlife management tool remains limited and must be expanded.

In this paper, our objective is to use case histories from the scientific literature, along with previously unpublished data, to describe why use of prescribed fire is critical for the effective management of numerous wildlife species in southern forests. In our view, some of the major wildlife management "problems" (i.e., many endangered and/or declining species) in the southern U.S. are rooted in habitat loss resulting from a lack of adequate (either sufficiently frequent and/or widespread) applications of prescribed fire.

Despite recent wildlife management successes and currently abundant populations of white-tailed deer (*Odocoileus virginianus)* and wild turkey *(Meleagris gallopavo),* there are many southern forest vertebrates (i.e., northem bobwhite *[Colinus virginianus*], red-cockaded woodpecker *[Picoides borealis],* Bachman's sparrow *[Aimophila aestivalis],* fox squirrel [*Sciurus niger]* and gopher tortoise *[Gopher-us polyphemus])* that are undergoing severe population declines as a result, in part, from fire being eliminated or greatly reduced across the southern forest landscape. To describe how fire impacts wildlife and what happens to wildlife when fire is eliminated from southern forest systems, we present examples from research and field studies of threatened and endangered species, other species, and vertebrate communities. We use this information to build a case that points to a critical need for the continued and increased use of prescribed fire. Prescribed fire is an essential part of the management of southern pine forests, old fields and other native habitats throughout the South.

From the standpoint of wildlife management, we consider fire an essential, landscape-level factor in the context of: 1) ecosystem management; and 2) management strategies to maintain and, where appropriate, increase biodiversity of native vertebrates and the habitats they require.

Fire and Ecosystem Management

Any credible attempt at ecosystem management of upland pine forests in the South must include frequent (probably every one to five years, depending on soil conditions and management objectives) use of prescribed fire. In these habitats, it is critical to maintain stands with an open, park-like structure and an understory dominated by grasses and forbs.

An essential component of ecosystem management is the inclusion of actions that mimic natural ecosystem processes and/or disturbances. Fire is a classic example of such a disturbance process. Lightning-caused fire shaped the biota of southern forests throughout the millennia (Komarek 1964). Over time, human influences have fragmented southern forests to the point where it is impossible to rely on natural ignitions from lightning for specific management purposes. Therefore, prescribed fire (that is, bums purposefully ignited by humans in accordance with a predetermined range of conditions for specific management objectives) is the only practical way to mimic the lightning-ignited fires that once swept through vast regions of the South.

Fire and Wildlife

Wildlife biologists have maintained an evolutionary perspective about fire and wildlife since the science of game management was founded. For example, Leopold (1933) stated, “Fire has always been part and parcel of the evolutionary background of our present species in many regions.” Nearly 70 years ago, in his pioneering work on the life history of the northern bobwhite, Stoddard (1931) concluded that this bird “... was undoubtedly evolved in an environment that was always subject to occasional burning . ...” He generalized these conclusions to other plants and animals by stating, “... fire may well be the single most important factor in determining what animal and vegetable life will thrive in many areas.” Furthermore, and perhaps most importantly, he noted, “when fire is eliminated, the animal life, adjusted through the ages to the open pine forests, is evicted, along with the associated flora." Although many people thought these observations were heretical during the first half of this century, a large body of subsequent research has supported these basic natural history observations for many other ecological resources on continental and global scales (Pyne 1982, 1995).

Today, many southern forest wildlife species have a close affinity for habitat structure and resources that are maintained by frequent (every one to five years) fires (Table 1). Many of these wildlife species have been experiencing significant, long-term population declines, or are currently listed as rare, threatened or endangered, in part because fire has been eliminated from vast areas of the southern landscape (Table 1).

Table 1. Terrestrial vertebrates from southern pine forests and savannas that have affinities for habitats maintained by frequent fire.

Species (scientific name)	Current status"
Gopher frog (*Rana capito*)	declining
Flatwoods salamander (*Ambystoma cingulatum*)	declining
Striped newt (*Notophthalmus perstriatus*)	declining
Gopher tortoise (*Gopher-us polyphemus*)	threatened
Sand skink (*Neoseps reynoldsi*)	declining
Florida scrub lizard (*Sceloporus woodi*)	declining
Eastern indigo snake (*Drymarchon coruis couperi*)	threatened
Audubon's crested caracara (*Polyborus plancus uudubonii*)	threatened
Attwater's greater prairie-chicken (*Tympanuchus cupido uttwateri*)	endangered
Northern bobwhite (*Colinus virginianus*)	declining
Mississippi sandhill crane (*Grus canudensis pulla*)	endangered
Red-cockaded woodpecker (*Picoides borealis*)	endangered
Florida scrub-jay (*Aphelocomu coerulescens*)	threatened
Bachman's sparrow (*Aimophila aestivalis*)	declining
Florida grasshopper sparrow (*Ammodramus savannarum jloridanus*)	endangered
Henslow's sparrow (*Ammodrumus henslowii*)	declining
Cape Sable seaside sparrow (*Ammodramus maritimus mirubilis*)	endangered
Sherman's fox squirrel (*Sciurus niger shermani*) (no longer game status in Florida)	declining

"Endangered and threatened status according to U.S. Fish and Wildlife Service listed vertebrate species index, January 3 1, 1998. Declining status determined from various sources.

Direct Versus Indirect Effects of Fire on Wildlife

Fire can affect wildlife populations directly (by killing individuals) and indirectly (by altering habitats). In general, indirect effects of fire on wildlife populations (especially with respect to habitat alteration) are far more significant than direct mortality (Leopold 1933: 346, Brennan and Hermann 1994). This concept, unfortunately, has not been embraced by the general public. Messages from Smokey Bear and Bambi have, in many ways, misguided the public about the effects of fire on wildlife.

Elimination of Fire: The NB66 Experiment

There are relatively few experimental studies that document what happens to wildlife populations and communities when fire is totally eliminated from a forest system. One classic experiment began at Tall Timbers Research Station in Tallahassee, Florida during 1966 and continues to the present. During 1966, a decision was made to eliminate prescribed fire from an 8.6-hectare (360 by 240 m) plot (named NB66 to signify "not burned since 1966") of mature old field upland pine forest 30 kilometers north of Tallahassee. During the first 15 years of fire exclusion, changes in vegetation and breeding bird abundance were dramatic (Engstrom et al. 1984).

Tree canopy cover on NB66 increased from 43 to 91 percent; groundcover (forbs and grasses) decreased from 85 to 21 percent. Most changes in forest structure were related to widespread encroachment of deciduous trees (e.g., oaks [*Quercus* spp.] and hickories [*Carya* spp.]). The breeding bird community shifted from one dominated by open habitat species (e.g., eastern kingbird [*Tyrannus tyrannus*], loggerhead shrike [*Lanius ludovicianus*], blue grosbeak [*Cyanocompsa cyanoides*] and Bachman's sparrow) to one dominated by species typically associated with mesic hardwood forests (e.g., yellow-billed cuckoo [*Cozzyzus americanus*], wood thrush [*Hylochila mustelina*], red-eyed vireo [*Vireo olivaceous*] and hooded warbler [*Wilsonia citrina*]). From 1966 to 1986, the average number of individual birds detected per census on NB66 decreased from 32 to 18 (a 44-percent decrease). Although total species richness remained about the same on NB66 (between 24 and 28 species), species composition changed dramatically over 20 years of fire exclusion (Landers and Crawford 1987).

With respect to small mammals, the hispid cotton rat (*Sigmidon hispidus*), cotton mouse (*Peromyscus gossipinus*) and eastern harvest mouse (*Reithrodontomys humulis*) were abundant at the beginning of the NB66 study, but disappeared from the plot by 1986. In contrast, the southern flying squirrel (*Glaucomys volans*) did not appear on NB66 until 1975 (10 years after fire exclusion), but subsequently underwent a significant increase in numbers (Landers and Crawford 1987).

Effects of Seasonal Fire Applications on Wildlife

Most applications of prescribed fire for wildlife management during the past 70 plus years have occurred during the latter part of winter (February or March). The tradition of late winter burning has stemmed from a number of ecological and cultural factors.

Ecological factors that stimulated use of dormant-season fire. Many upland pine forest stands throughout the South represent the "second forest" of this region. In the case of lands managed with intensive plantation forestry, these stands can be the third or fourth forests that have grown on a site. The original, highly pyrophillic groundcover vegetation (dominated by wiregrass [*Aristida* spp.] and 400+ associated species) in southern pine (primarily longleaf pine [*Pinus palustris*]) was lost when the original forests were cleared and planted to row crops prior to the Civil War. Old-field succession resulted in a dramatic change in species composition, especially in the groundcover vegetation. Today, most of the forest understory vegetation in this region is dominated by native ruderal species, such as broomsedge (*Andropogon* spp.), ragweed (*Ambrosia* spp.), blackberry (*Rubus* spp.) and many other forbs and shrubby plants that are relatively succulent (compared with wiregrass) and bum poorly during the peak growing season when lightning originally ignited most fires. Early wildlife managers, including Stoddard and his contemporaries, found the "old-field" vegetation that dominates vast areas of southern pine forests bums best during late winter, after the frosts had killed and dessicated most of the grasses and forbs.

Cultural factors that stimulated use of dormant-season fire. Late winter is a pleasant time to apply tire in the woods because temperatures are cool and frost-killed, old-field vegetation burns easily. Furthermore, most quail hunting seasons end by early March. The fact that quail and other desirable ground-nesting birds such as wild turkeys had not yet begun to nest during February or March was an added bonus for burning at this time of year. Conventional wisdom of the time dictated that fire during the nesting season would spell disaster for ground-nesting birds. Hence, a tradition of February and March fire emerged and became deeply ingrained in the culture of the Southeast.

Increased interest in lightning-season fire. During the past decade, much interest in applying prescribed fire during the lightning (or growing) season (May to August) has emerged (Robbins and Myers 1992). Again, the reasons for this are both ecological and cultural. Ecological reasons for applying lightning-season fire stem from natural history observations that wiregrass must be burned during this time of the year to flower and set viable seed (Robbins and Myers 1992). Furthermore, intensive lightning-season fires (as opposed to relatively cool winter fires) can be useful for generating extensive top kill (and hence control) of invasive hardwoods (Robbins and Myers 1992). However, (Glitzenstein et al. 1995) showed that fire intensity was a more important factor than seasonality with respect to hardwood mortality.

Effects on ground-nesting birds. In a comprehensive review of seasonal fire effects, Robbins and Myers (1992: 57) stated no one really knows what the long-term effect [of lightning-season fire] would be on quail, turkey and other ground-nesting birds. Recently, scientists at Tall Timbers have undertaken a series of field experiments to examine the effects of dormant- versus lightning-season fire on wildlife. Over the short-term (three to four years), seasonal fire effects on birds are subtle and mostly insignificant at the population level for quail (Brennan et al. 1997, 1998, Carver et al. 1997), turkey (Sisson and Speake 1994) and many passerine birds in both the northern Florida and North Carolina Sandhills regions (Engstrom et al. 1996). Applications of lightning-season fire do not seem to “upset” breeding quail (Carver et al. 1997) or turkeys (Sisson and Speake 1994) from the standpoint of altering their movements. In fact, lightning season fires apparently provide patches of recently burned habitats that attract turkeys and quail, perhaps because arthropods are more available in these areas. Additionally, such fires may provide more open ground which results in increased access to food and easier travel. Further research on effects of lightning-season fire on demography, reproduction and survival of ground-nesting birds will be required to gain a long-term assessment of the tradeoffs between dormant- and lightning-season fire effects.

Effects on songbirds. Ongoing results from field experiments in Florida and North Carolina have yet to demonstrate differences with respect to avian populations on plots burned during the dormant versus lightning season (Engstrom et al. 1996) (Table 2). Potential, long-term effects of dormant- versus lightning-season fire applications will be assessed at the North Carolina Sandhills site over the next six to seven years.

Table 2. Average numbers of bird territories and nesting success on dormant- and lightning-season burned plots in the Sandhills region of North Carolina, 1996, 1997. For list of species, see Engstrom et al. (1996).

		Type of fire application			
		Dormant season		Lightning season	
Location	Year	Number of territories	Percentage nest success	Number of territories	Percentage nest success
Sandhills					
Gamelands	1996	26.5	66.0	29.0	62.5
	1997	20.0	53.0	23.0	58.5
Fort Bragg	1996	37.5	75.0	30.5	67.5
	1997	30.0	63.5	26.5	71.5
Averages		28.5	64.7	27.3	65.0

Can Herbicides Substitute for Fire?

In the simplest sense, fires oxidize vegetation. However, fire provides myriad other ecosystem services such as releasing nutrients, scarification of seeds for germination, and fertilization from ash and carbon. Fires reduce understory litter, which results in more sunlight on the ground and, thus, opportunities for many grasses and forbs to thrive where soil temperature and moisture conditions are changed in their favor. Like fire, herbicides also eliminate vegetation. However, many of the other ecosystem services provided by fire are lacking from herbicide applications.

Use of herbicides for silvicultural applications (primarily to control competing vegetation and to favor planted pine) has greatly increased during the past several decades. One outgrowth of the dramatic increase in herbicides for forest management, especially in the South, is that these chemicals are being perceived as an adequate substitute for prescribed fire. The rationale is that they eliminate undesirable and/or competing vegetation, *just like fire.* People often argue that the only difference between herbicides and fire is herbicides take a little longer than fire to work. However, this view is naive and shortsighted, given the other ecosystem services provided by fire. Still, herbicides remain popular, and their use will continue to increase. Factors such as smoke management (Ottmar et al. 1996) have also caused herbicides to become an attractive alternative to fire for forest management objectives.

In our view, the direct substitution of herbicides for prescribed fire in the context of wildlife management is ill-informed and perhaps even dangerous when it comes to endangered species management. For example, in mixed-pine forests of eastcentral Mississippi which are occupied by the endangered red-cockaded woodpecker, the use of herbicides to reduce invasive hardwoods (with applications of fire approximately every five to seven years) resulted in only limited habitat improvement for the woodpecker. In contrast, frequent (about every two to three years) applications of prescribed fire (following hardwood midstory removal via logging) resulted in improved habitat for the woodpecker, as well as a positive population response from more than 12 other species of terrestrial vertebrates (Brennan et al. 1995). Recent work by Burger et al. (in press) provides substantial evidence that a suite of regionally declining grassland birds benefit from an enhanced tire regime associated with red-cockaded woodpecker habitat management.

Herbicides can be used for managing wildlife habitats. Compounds that selectively eliminate invasive, woody species, while maintaining pines and native legumes, have the potential for long-term (10 to I5 years) control in situations where managers struggle to control invasive hardwoods. However, we believe the greatest benefits to be derived from herbicides for managing wildlife habitats in southern pine forests occur when such chemicals are used in conjunction *with* prescribed fire, rather than instead *of* fire.

Fire and Management for Natural Diversity

Management for biological diversity, especially in the context of ecosystem management, has emerged as a dominant resource management theme during the last five years. There are numerous ways that management for "diversity" can be co-opted and twisted to meet virtually any management objective. For example, a weedy field dominated by 15 exotic, invasive species of plants is more diverse than a patch of natural forest that contains only 10 species. Clearly, the concept of diversity does not always equate to one of desirability. Hence, any consideration of diversity must be addressed in the context of desired future conditions, native versus exotic species and, ultimately, improved land use and stewardship.

Management for Game Versus Management for Diversity

Although contemporary application of prescribed bums generally is accepted in the context of game management today (especially for quail and wild turkey), the fire agenda reaches far beyond traditional game habitat management. Today, prescribed fire professionals seem to be split into two camps: those with an agenda related to game management, and those with an agenda related to biodiversity objectives. Although dialogue between these two groups has been limited, enhanced communication may produce significant benefits. For example, frequent applications of prescribed fire for quail management has resulted in the maintenance of significant populations of red-cockaded woodpeckers on private lands in Florida and Georgia (Landers et al. 1989). On some public lands in Mississippi, use of fire for red-cockaded woodpecker habitat management resulted in improved habitat conditions for bobwhite (Brennan et al. 1995). Conversely, frequent burning for quail results in high-quality habitat for dozens of threatened and endangered species (Landers et al. 1989, Block et al. 1995). The point here is that while management goals may differ, resource and ecological managers must cooperate to obtain the greatest, positive impacts from applications of fire and understand how nontarget resources are affected (Landers et al. 1989, Hunter 1990).

Future Landscapes of the South: Pockets of Fire in an Unburned Landscape

Trends in prescribed burns: State perspectives. Data from the past decade show that applications of prescribed fire have remained more or less stable across six southern states (Figure 1). However, the total amount of land managed with prescribed fire remains relatively small, compared with the total land base in the Southeast. For example, only Georgia and Florida have had years where more than a million acres (about 2.6 percent of the land area in each state) were burned by prescription. In states such as Mississippi or the Carolinas, only about 0.3 percent of the total land area is burned annually. Furthermore, approximately 35 to 60 percent of these applications of prescribed fire were for hazard reduction or silvicultural objectives rather than for wildlife habitat management.

Implications of current trends. Because relatively little land is currently managed with prescribed fire in the Southeast, we need more use of fire on the landscape scale. What we will probably see during the next few decades is more use of fire on public lands and a continuing reduction in fire use on private lands. For example, the USDA Forest Service has made increasing applications of prescribed fire one of their highest management priorities at the national level. In contrast, some large industrial forestland owners have reduced or eliminated the use of fire, based on the belief that herbicides are much more appropriate than fire for maximizing tree growth and economic returns. The nonindustrial private landowner is caught somewhere in the middle of this continuum. Several states (most notably Alabama, Florida and Georgia) have implemented "right-to-bum" legislation designed to protect the private landowner from liability when they apply fire responsibly and within permitted prescription parameters. However, there are few incentives and many disincentives for use of fire by small, nonindustrial private landowners, who are often discouraged from using fire because of smoke management concerns (National Research Council 1976, Ottmar et al. 1996) and other liability issues. Additionally, a proposed reduction in allowable sizes of particulate matter (U.S. Environmental Protection Agency 1997) could result in a major resource policy conflict between the Clean Air Act and the Endangered Species Act if allowances are not made for prescribed fire.

Thus, when taken as a whole, we predict that the southern landscape of the foreseeable future will continue to evolve in the following direction. There will be pockets of public land that will be subjected to relatively frequent applications of fire. These lands will be distributed throughout a broader matrix of private lands (both industrial and nonindustrial) that will increasingly be fire excluded. From the standpoint of wildlife populations and communities, the frequently burned public lands will most likely serve as limited refugia for species that require open, park-like upland pine habitats. It remains to be seen whether the frequently burned patches of public lands will be sufficient to provide the area required to keep species with such habitat requirements from declining or becoming extinct. In any event, this broad-scale land use experiment has begun and will continue well into the next century. We hope managers and researchers will learn from this experiment as it develops.

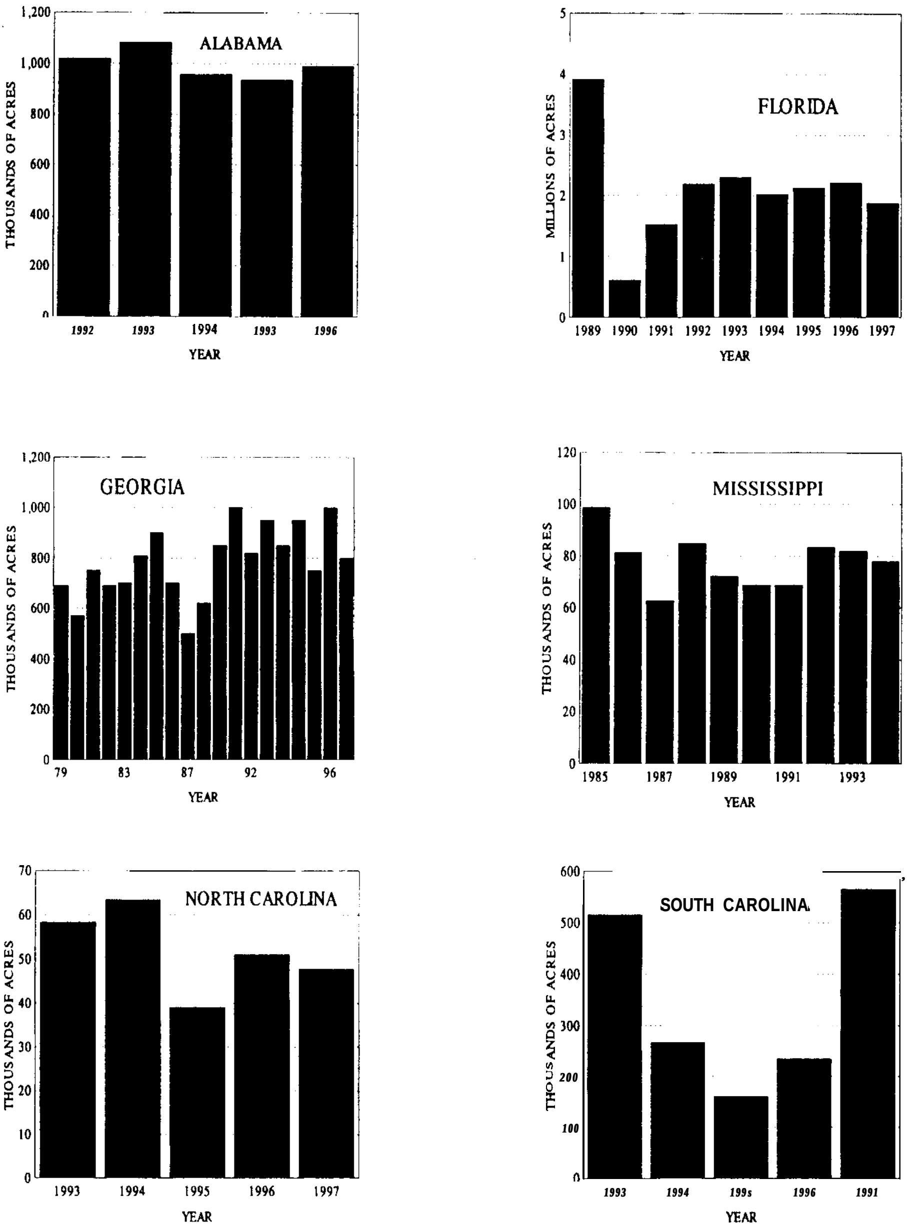

Figure 1. Acres of prescribed burns in six southeastern states during recent years. Data provided by Alabama Forestry Commission; Florida Division of Forestry; Georgia Forestry Commission; Mississippi Forestry Commission; North Carolina Department of Environment, Health, and Natural Resources; and South Carolina Forestry Commission.

Whither Wildlife Without Fire?

To modify a biblical perspective (with apologies to Ruth 1: 16), it is safe to say that "Whither fire goest, wildlife will go . ..." Drastically reducing fire on the southern landscape has resulted in the decline and loss of many wildlife species that we not only find highly desirable, but are also central to our natural heritage. We are presently witnessing broad-scale declines in many species that require open, park-like pine forests because frequent fire and the forest structure maintained by frequent fire are being lost.

There is no substitute for fire as a forest management tool for wildlife. Herbicides and mechanical methods of removing vegetation are poor or marginal substitutes for fire, although these methods may be useful when applied in conjunction with fire. Results emerging from seasonal fire experiments suggest that effects of dormant- versus lightning-season fire applications are relatively subtle, especially when compared with fire suppression. Although initially counterintuitive, it can be argued logically that fire is not a disturbance, per *se*, but rather a necessary process for the proper management of southern forests for wildlife. The elimination of fire is actually more of a disturbance (and hence, a real catastrophe) than the actual effects of the fire itself (Landers et al. 1989).

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The Smoke Dilemma: A Head-on Collision!

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A head-on collision is imminent! The drivers are people. The vehicles are special interests. The road is smoke! Those concerned about air quality ride in the first car; those concerned about natural resource management ride in the second.

In this paper, we look at what smoke is and why it is sometimes dangerous, factors leading to a collision, and what we can do to avoid a collision.

What is the Road?

What is smoke? Two sources of health and visibility hazards produced by forestry smoke are of interest to us today-water vapor and particulate matter. Researchers analyzing the chemistry of smoke from southern prescribed fires have found that more than 90 percent of the mass emitted is in carbon dioxide and water vapor (USDA Forest Service 1976). Water vapor is important because it can affect visibility near a fire. At night, near the ground, when a cooled airmass is already near saturation (relative humidity = 100 percent), water vapor injected from smoldering fuels can cause the airmass to become supersaturated, that is, the relative humidity will briefly exceed 100 percent. If sufficient hygroscopic nuclei (particles that water can condense on) are present (and in the South, there almost always is an abundance of these particles), the supersaturated airmass can flash into a super-dense fog.

Particulate matter is defined as any dispersed aggregate matter, solid or liquid (other than water), that is larger than 0.0002 micrometers (urn) in diameter, but smaller than 500 um in diameter. Particulate matter makes up approximately 1 to 3 percent of the total mass released in forestry smoke (USDA Forest Service 1976). Particles greater than IO to 20 um in diameter will fall out of the atmosphere within 0.5 to 1 .0 mile from the source of production. This is especially the case during near-calm wind conditions.

Smoke emissions from prescribed burns can release large amounts of particles-about 90 percent are 10 um (PM-10) or less, and 70 percent are 2.5 um (PM-2.5) or less. These are the particles that scatter headlight beams from automobiles and create health hazards for people when inhaled.

Toward a Collision on Smoke

Increasing Population and Air Quality

Not only are the cars heading toward a collision, they are accelerating! Pressing the gas pedal in the first car is population growth. The mild, mostly snow- and ice-free winters make the southern climate ideal for the development of retirement communities. Thousands of older people, some with respiratory problems, have relocated into these communities. Many of these retirees have little or no experience with forestry practices and, therefore, may not be receptive to frequent incursions of smoke into their communities. Human health concerns and issues of nuisance smoke have led to increased regulation.

The U.S. Environmental Protection Agency (EPA) has the responsibility under the Clean Air Act to propose, revise and promulgate National Air Quality Standards (NAAQS) for airborne pollutants. Implementation and enforcement of NAAQS are the responsibility of state, local and tribal air pollution agencies. These agencies develop implementation plans which describe techniques and strategies to implement the NAAQS.

New NAAQS for particulate matter have been proposed. The revised standard focuses on particulate matter which are PM- 10 and PM-2.5. The EPA claims the added standards for PM-2.5 will provide better health protection. Those with heart and lung problems, including asthma sufferers, particularly among children and the elderly, have been statistically correlated to more health problems than people living in areas with lower PM-2.5 concentrations.

According to the EPA, the new PM-2.5 standard would also improve visibility in wildernesses and national parks designated as Class I air quality. The Clean Air Act Amendments of 1977 specifically mention that visibility should not be impaired by human releases of air pollution. The regulations require action to make reasonable progress toward improving visibility where impairment exists, such as found in some areas of the eastern U.S. and in many areas of the western U.S. The PM-2.5 size class of particles are primarily responsible for visibility impairment (regional haze) in Class I areas.

Roadway Hazards and Smoke-related Accidents

In the southern United States, there exists an extensive road network that connects the many cities, towns and villages that grew up in the old agricultural South. As population increases and the number of tourists driving to resort areas increases, the number of highway accidents related to smoke and smoke/fog could also increase. Visibility reductions caused by smoke or a combination of smoke and fog already have been implicated in multiple-car pileups, numerous physical injuries, heavy property damage and fatalities.

Most of the serious accidents have occurred at night or around sunrise, as smoke trapped in stream valleys and basins is carried across roadways. Several attempts have been made to compile records of smoke-implicated highway accidents. The available accident data is admittedly incomplete. The most comprehensive study was undertaken by Mobley (1989) for the 1 O-year period from 1979 to 1988. He reported 28 fatalities, more than 60 serious injuries, numerous minor injuries and millions of dollars in lawsuits. Using less-complete data from 1989 to March 199 1, Mobley recorded five additional fatalities.

During the period from October 1996 through June 1997, eight smoke on the highway incidents that ranged from minor accidents to road closures were reported in South Carolina. The record was admittedly incomplete. Based on South Carolina data, similar smoke incident frequencies can be estimated for other southern states. If the South Carolina data are modified for areas devoted to forestry and agriculture in other states, the number of smoke-induced highway incidents throughout the South can be estimated conservatively to be more than 150 annually.

We also examined legal computer data bases (Westlaw and Lexis/Nexis) to identify published judicial decisions involving any alleged problems associated with prescribed burning conducted in conjunction with forestry management operations. This investigation does not reveal all cases on the subject. On the state level, many trial court level decisions are not reported (on Westlaw, Lexus, or any other readily accessible source). The outcomes of these cases often arc reported only if trial court level decisions are appealed and there is a resulting decision on appeal prior to settlement. In federal courts, not every decision of the trial court (i.e., district court) is reported. Additionally, the majority of cases filed in state and/or federal courts are settled prior to trial; thus, there are no reported decisions for these cases.

The primary legal theories that could be associated with a lawsuit alleging that smoke or fire from a controlled burn caused damage include, but are not limited to:

- *Negligence*—based on the allegation that the controlled burn was conducted in an unreasonable manner causing damage.
- *Nuisance*—based on the allegation that the controlled burn was conducted in an unreasonable manner that interfered with another person's use and enjoyment of their property.
- *Strict Liability*—based on the allegation that controlled burning is an ultrahazardous and/or inherently dangerous activity, and this activity caused damage.
- *Trespass*—based on the allegation that the defendant intentionally, willfully and/or with reckless disregard caused fire or smoke to invade a neighboring property, thereby causing damage.

Reported cases directly involving prescribed burns in the forestry setting are limited. These cases primarily involve instances where fire from a prescribed burn escaped the controlled setting and damaged adjacent property, or where smoke from the controlled burn drifted across a road or highway, obscured drivers' vision and resulted in an accident. The issues in these cases generally appear to be whether the damage occurred as a result of unreasonable behavior (i.e., negligence) on the part of the individuals responsible for controlling the prescribed burn.

Increasing Demand for Habitat Management

Pressing the gas pedal in the second car is growth in the need for prescribed burning of southern forestland. Prescribed tire is a tool of choice for managing forests for game and non-game wildlife (Landers 1987). Prescribed fire eliminates species that compete for nutrients and reduces buildup of dead and live fuels that increase the hazard of destructive wildfire.

The Endangered Species Act requires land managers to manage habitat to preserve or increase populations of threatened and endangered species. For fire-dependent ecosystems such as longleaf pine this means an expansion of prescribed burning. For example, prescribed fire is used in the coastal plains and Piedmont regions of the Southeast to improve habitat for the endangered red-cockaded woodpecker (*Picoides borealis* Vieillot).

Another example of the pending collision between conflicting legislation is found in the Southern Appalachians. There, a low-growing shrub species called *Hudsonia* ***montunu*** Nuttall is listed as a threatened species under the Endangered Species Act. ***H. montanu*** is dependent upon fire for survival. Including prescribed burning in a recovery plan would be straightforward except that the largest populations of ***H. montunu*** are found within and adjacent to the Linville Gorge Wilderness, a Class I area.

Rebuilding the Road

Policy

The EPA recognizes that conflicts between resource objectives and air quality objectives can exist. Therefore, the agency released a draft wildland fire/air quality policy in late 1997. If implemented, state and local air pollution control agencies could establish smoke management programs. Bum plans provided by the land management agency would be used by the air pollution control agency before a burn is authorized. The EPA would then use its discretion not to designate an area as nonatainment if a prescribed bum significantly contributed to a PM-2.5 or PM-10 NAAQS violation, and the air pollution control agency authorized the burn under a smoke management plan. Implementation of EPA policy should allow land managers to achieve their resource objectives, but the resource agencies will need to work even more closely with air pollution control agencies so that public health and welfare are protected from the harmful effects of air pollution.

A number of southern states (Alabama, Georgia, Mississippi, Florida) have adopted new legislation aimed at reducing the liability of "certified" prescribed burners. To become certified, a burner must attend training and pass an examination. Some of these laws contain language that asserts a landowner's right to use prescribed burning. For example, Alabama's new law (1995) declares, "that the application of prescribed burning is a landowner's property right and a land management tool that benefits the safety of the public, the environment, the natural resources, and the economy of Alabama . ..."

Science and Technology

Unless more prescribed burning is done during marginal burn conditions, increasing the use of prescribed fire for managing fire-dependent ecosystems will add smoke to that already produced by existing burning programs. There will be either an increase of atmospheric "loading" of smoke leading to NAAQS violations during favorable burn periods or a decrease in overall burning as various agencies compete for available burn times. The probability of smoke "incidents" (NAAQS violations, nuisance complaints or highway accidents) rises in either case. Thus, for the South, the Clean Air Act (less smoke) meets head-on with the Threatened and Endangered Species Act (more fire).

Can science change the road to avoid the collision or to reduce the impact? Clearly, science cannot make smoke go away nor can science produce a forestry burn that does not produce smoke. However, new developments in science and technology will make available to land managers tools which can significantly improve their management of smoke.

The National Center for Environmental Prediction (NCEP) of the National Weather Service continuously improves the computer models that predict weather over the globe and develops new models as computer resources and other technology permit. In 1998, a new model will become operational that will allow routine resolution of weather systems on a much finer scale than in the past, providing better resolution of wind fields over complex terrain such as mountains and coastlines. More accurate prediction of local winds and timing of wind direction and speed changes will also be possible.

Florida has implemented a pilot study to use a research computer weather model to predict local winds over the state (Herbster 1998). This model is able to resolve the formation and timing of local sea breezes and other winds that frequent the Florida peninsula. Winds generated by this model will be input into smoke dispersion models and made available to land managers, thus giving them information *relevant to the time and location of their specific burn*.

Recognizing that most smoke-implicated personal injury and property damage occurs during highway accidents at night, researchers with the USDA Forest Service have developed PB-Piedmont, a smoke movement model that has successfully tracked smoke moving along the ground at night at scales as fine as 90 feet (30 m) (Achtemeier 1994). The model, which is undergoing user tests, monitors the movement of smoke in real time. A future version will couple with the new NCEP models to give 12- to 24-hour predictions of smoke movement along the ground. Thus, where smoke might go after dark will become a factor in land managers' decisions on whether to burn or where follow-up monitoring may be required.

Plans are to create a Coastal Plain version of the model. PB-Piedmont, PB Coastal Plain and other dispersion models for daytime smoke such as VSMOKE (Lavdas 1996) should give forest managers an additional "edge" in maximizing the number of favorable burn days and minimizing the rise of unfavorable smoke incidents.

Conclusion

A head-on collision involving smoke impacts on air quality is imminent. The collision threatens to curtail the use of prescribed fire for wildlife and other land management purposes. We have summarized some factors which contribute to the pending collision and some reasons why we can lessen the impact, if not avoid the crash.

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