Four Centuries of Changing Landscape Patterns in the Longleaf Pine Ecosystem

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ABSTRACT

Longleaf pine was exploited from first European settlement, but before 1700, dependence on navigable water for travel and trade limited impacts to coastal regions and belts along navigable streams. In these settled landscapes, effects of domestication included land clearing and establishment of saturation densities of open range cattle and hogs which fed on longleaf pine seedlings in nearby woods. Effects of commercial logging were negligible until introduction of the water-powered sawmill in 1714, but by the 1760s hundreds of these were turning out milled lumber. Still, deforestation was limited to narrow patterns defined by streams and rivers. By this time much of the eastern Piedmont was fully settled and the frontier had passed on almost to the Appalachians. By the Civil War, all the best land on the Atlantic slope was in fields and pasture, but much virgin forest remained on the Gulf coast. The naval stores industry began in Virginia, where boxing longleaf for crude turpentine was practiced all through the Colonial Period, and most of the longleaf there was decimated by 1840, but there had been little impact to the south, with the exception of stands along rivers in North Carolina. Then, in 1834, adaptation of the copper whiskey still to turpentine distillation made the process vastly more efficient and profitable. This activity, which left most of the primeval pine forest weakened or destroyed, swept south and then west along the Gulf, decade by decade, as northern stands were exhausted, reaching full swing in the last stands in Texas around 1900. Steam technology mushroomed by 1870, with proliferation of logging railroads, steam log skidders and steam sawmills, and virtually all remaining virgin timber in the South came down during the era of intensive logging from 1870 to 1920. The 1920s saw the beginning of conversion of unmanaged woodlands to pine plantation, now about 15% of southern uplands. The presettlement range of longleaf pine is estimated at 92 million acres, of which 74 million were longleaf dominant and 18 million had longleaf in mixtures with other pines and hardwoods. By 1946, longleaf pine had dwindled to 1/6 its original acreage. This decline has continued until only about 3% remains.

INTRODUCTION

From Virginia to Texas, much of the coastal plain landscape was once covered by a "vast forest of the most stately pine trees that can be imagined..." (Bartram 1791). The spectacular failure of the primeval longleaf pine forest (Figure 1) to reproduce itself after exploitation is a milestone event in the natural history of the eastern United States, at least equal in scale and impact to the elimination of chestnut from Appalachian forests by blight. This paper discusses presettlement vegetation and summarizes major events in decline of the longleaf pine ecosystem (Appendix I) and its displacement from 97% of the lands it once occupied.

Land uses ranging from 100 to 400 years of agriculture; open range grazing by hogs and other livestock; logging; production of turpentine, and elimination of naturally-occurring wildfires have left less than 3% of the upland landscape in entirely natural vegetation. While much has been made of the loss of some 10% to 30% of wetlands in the region (Hefner and Brown 1985), the elimination of natural vegetation on 97% of uplands (Table 1) has gone largely unremarked. The ability to reconstruct the long-term changes that have occurred in the southern landscape requires understanding what presettlement vegetation was like, how fire moves over the land, and the effects of 400 years of human intervention.

PRESETTLEMENT VEGETATION OF THE LONGLEAF PINE REGION

States bordering the Atlantic, and some of the Gulf Coast region lack the systematic data base of witness trees that were recorded when lands were

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Figure 1. Virgin longleaf pine savanna ten miles east of Fairhope, Baldwin Co., Alabama, August 13, 1902. Note the absence of woody understory and the classic bilayered structure (canopy/herb layer) of longleaf pine under a natural fire regime. Roland Harper (1913) commented that "...it may never be possible to take such a picture in Alabama again." (Photo from Harper 1913).

surveyed under the township, range and section system in the rest of the country, so there can be no statistically verifiable reconstruction of virgin forests from such data. Even where General Land Office survey records are available, interpretation is compromised because surveyors routinely failed to distinguish the various species of pine, just lumping them as "pine" on records and survey plats. There is, however, an exceptional narrative literature on the longleaf pine forests, dating from 1608 when Captain John Smith recorded the first export of pitch and tar made from pines near the new settlement at Jamestown, Virginia (Smith 1624).

Because of its primacy as the commercial tree of the South, longleaf became in the 1880's the first forest species to be studied in detail by early professional foresters and botanists. Major studies by Sargent (1884), Mohr (1896), Ashe (1894a) and Harper (1913, 1928) include literally hundreds of mentions and locations of longleaf pine as well as maps, lumbering records and calculations of acreage and board feet by state, allowing a reasonable approximation of its original range and abundance. Although widely scattered through the literature, numerous other historical references can be used to document original vegetation throughout the South. Figure 2 is a reconstruction of the original range of longleaf pine, using as a base a compilation of the state maps prepared by Sargent in 1881. Range maps and numerous locations provided by Ruffin (1861), Lockett (1870), Hale (1883), State Board of Agriculture (1883), Ashe (1894a), Mohr (1896, 1901), Harper 1905, 1906, 1911, 1913, 1914, 1923, 1928), Sudworth (1913), Mattoon (1922), Wakeley (1935), Wahlenberg (1946) and Little (1971) were especially useful.

In calculating figures for the presettlement range of longleaf pine, individual state maps of southern pine forests from Sargent (1884) were assembled into one large map, and compared with other longleaf pine range maps by Sudworth (1913), Mattoon (1922), Wakeley (1935), the 1935 Southern Forest Survey (in Wahlenburg, 1946), Harper (1928), Mohr (1896) and Little (1971). In addition, historical references and field locations for longleaf were used to reconstruct its original northern range in North Carolina and Virginia, where it once extended to within a mile of the Maryland border (based on an herbarium specimen, Moldenke pers. comm.). The resulting map (Figure 2) includes all areas indicated as having

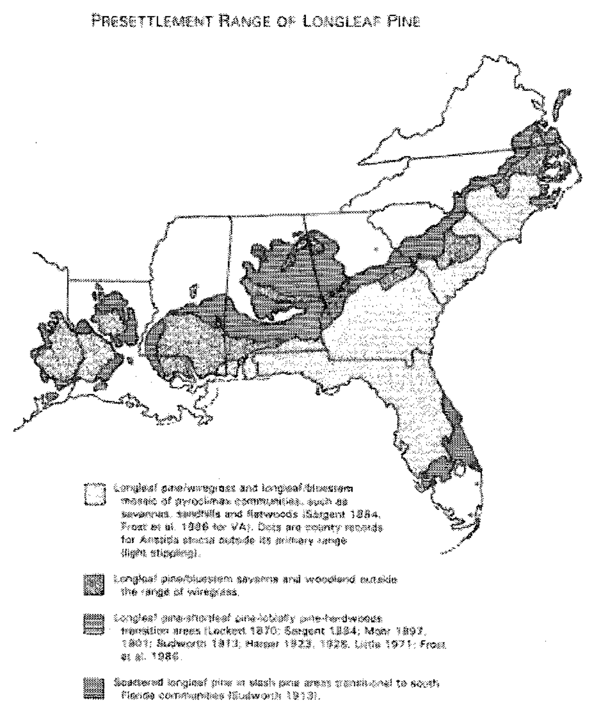

Figure 2. Presettlement range and major divisions of the longleaf pine ecosystem, showing the transition between frequent fire communities of the Coastal Plain and less frequently burned lands of the Piedmont.

Table 1. Distribution of natural vegetation and land use categories in presettlement forests, in 1900 and in 1990.

	Percent of Uplands	Percent of Region	ha x 1000	a x 1000
PRESETTLEMENT				
1. Longleaf Pine	52.0	36.0	22,852	56,430
2. Mixed (w/longleaf)	33.2	23.0	14,606	36,064
3. Mixed (w/o longleaf)	9.0	6.3	4,001	9,878
4. Upland slash pine	3.3	2.3	1,440	3,555
5. Beech-magnolia	2.5	1.7	1,108	2,735
11. Wetlands	0	30.7	19,496	48,137
	100.0	100.0	63,503	156,799
1900				
1. Longleaf pine	24.2	17.5	11,109	27,430
2+3 Mixed pyrophytic spp.	20.7	15.1	9,581	23,657
4. Upland slash pine	1.7	1.2	775	1,914
5. Beech-magnolia	0.4	0.3	166	410
6. Successional forests	25.0	18.1	11,501	28,399
7. Pine plantation	0	0	0	0
8+9 Pasture and Cropland	27.0	19.6	12,448	30,733
10. Developed	1.0	0.7	460	1,137
11. Wetlands	0	27.5	17,463	43,119
	100.0	100.0	63,503	156,799
1990				
1. Longleaf pine	2.1	1.7	1,050	2,592
2+3 Mixed pine-hardwood	0.5	<0.4	250	618
4. Upland slash pine	0.4	0.3	222	547
5. Beech-magnolia	0.4	0.3	222	547
6. Successional forests	44.0	34.6	21,963	54,232
7. Pine plantation	15.2	12.0	7,587	18,733
8. Pasture	6.4	5.0	3,165	7,814
9. Cropland	20.8	16.3	10,363	25,589
10. Developed	10.2	8.0	5,091	12,571
11. Wetlands	0	21.4	13,590	33,556
	100.0	100.0	63,503	156,799

Categories:
1 = Natural, fire-maintained communities dominated by longleaf pine.
2 = Natural, fire-maintained mixed species savanna and woodland (Longleaf, shortleaf, loblolly, pond pine, and sometimes hardwoods in various combinations).
3 = Pyrophytic pine and hardwood woodlands without longleaf pine.
4 = Natural, fire-maintained slash pine on uplands.
5 = Southern mixed hardwood forest (nonpyrophytic beech-magnolia).
6 = Successional mixed pine-hardwood forests resulting from logging, old field abandonment and fire exclusion.
7 = Pine plantation (all species).
8 = Pasture (included with cropland in 1900).
9 = Cropland.
10 = Cities, towns, roads, industry.
11 = All wetlands.

originally supported longleaf. In all, in the presettlement range of longleaf pine there were 412 counties in nine states.

Census statistics were compiled, county by county where available, for total area of each county, acreage in farms, acreage in forest land, improved farmland, crops, pasture and urban land (U.S. Censuses of Agriculture 1841, 1902, 1984). Areas of longleaf mapped as dominant or mixed stands were digitized. Table 1 includes adjustments made for wetlands, other vegetation types within the primary longleaf pine areas (stippled), and regional adjustments for areas such as the northern range in Alabama and Georgia, where there were substantial inclusions with little or no longleaf. Cross-checks were made using other data such as Sargent's and Mohr's board feet estimates, old and new published forestry data, county statistics from the Censuses of Agriculture and various regional studies.

Figures for Southern Mixed Hardwood Forest and slash pine on uplands (such as the proportion of the pine rocklands of Florida within the original range of longleaf pine) are estimates based on material in Delcourt and Delcourt (1977) and other sources. Since no county figures were available for wetlands, estimates were made based on the average of 25.2% wetlands for the region (U.S. Congress 1984, Hefner and Brown 1985), with some local adjustments where data was available. Wetland estimates for 1900 and presettlement forests were based on figures for a 20-year decline from the mid-1950's to 1970's (Hefner and Brown 1985). Since the modern era of major wetland drainage was enabled by passage of drainage district laws around 1900 (Lilly 1981), it was assumed that at least an equal amount was drained in the 50 year period 1900-1950, and again in the much longer 300 year period 1600-1900. Drainage of upland wetlands was reported as early as 1682 in Virginia (Clayton 1682). Failure to account for historical drainage would result in an overestimate of longleaf pine.

The U.S. Census of Agriculture supplied figures for cropland and pasture in 1900. The extent and nature of forested land categories were derived from data on rates of cutting in 1881 (Sargent 1884) and in 1896 (Mohr 1896). Condition and extent of hardwood forests were estimated from descriptions by Lockett (1870), State Board of Agriculture (1883), Mohr (1884, 1896), Harper (1906, 1911, 1913, 1914), Hale (1883) and others.

Recent land areas for cropland and pasture were obtained from the U.S. Census of Agriculture for 1982. Forest statistics were compiled county by county from individual state publications (Bechtold 1985, Bechtold and Sheffield 1981, Cost 1976, Murphy 1976, Sheffield 1979, Southern Forest Experiment Station 1978, 1985, Tansey 1983, Thomas and Bylin 1982). Area of pine plantation (all species) was derived from data in Boyce (1979) and estimated further by regression from 1952 to 1986, with the assumption that all plantation older than 30 years had been harvested.

Amount of longleaf pine in presettlement forests

The final estimate of 92 million acres (37 million hectares) of lands with some longleaf pine in presettlement forests can be broken down into 74 million acres of longleaf dominant and 18 million with longleaf in mixed-species stands. Table 1 shows an estimated 36 million acres in mixed communities with longleaf, based in part on Sargent's transition areas. From observations in the transition regions in Alabama, North Carolina and Virginia (Frost unpubl.), it is apparent that these areas contained two kinds of mixtures: first, were pure stands of longleaf on south slopes and ridges, in a landscape with other pine and hardwood communities lacking longleaf; and second, natural stands in which longleaf occurred mixed with other pines and a few hardwoods (Sargent 1884, Ashe 1894a, Frost in prep.). If we allow for half these stands to be nearly pure longleaf, then the total would be around 74 million acres of longleaf-dominant stands.

The earliest estimate of the entire range of longleaf pine was made by Mohr (1896) who suggested that the original acreage of "southern pines" was 100 million acres. By his definition this included all the range of longleaf pine plus "the shortleaf pine belt". To this must be added at least 1 million acres of longleaf that escaped his notice in Virginia because of their elimination from the landscape during colonial times. Subtracting the estimate of 92 million, which was arrived at independently, from 101 leaves 9 million for the shortleaf pine belt. No closer comparisons can be made because Mohr gave no sources for his estimates nor separate figures for the different regions he considered. Emerson (1919) estimated the size of "the long-leaf pine belt" at 250 million acres, but there are only 156 million acres possible in the range from Virginia to Texas even if all the wetlands were included (Table 1).

Amount of longleaf remaining in 1994

Outcalt and Outcalt (1994) arrived at an estimate of 3.3 million acres remaining in longleaf, using U.S. Forest Service's forest inventory and analysis data. Of this, 11%, or 363,000 acres was estimated to be plantations. Because of the cycle of reporting by states, the data were 2-6 years old, and initial reports from the Florida survey suggested an additional 100,000 acre loss. Since Florida comprised 29% of the total longleaf this would be equivalent to an additional range-wide loss of 245,000 acres. Subtracting this figure and the acreage in plantation leaves 2,592,000 acres in naturally-regenerated longleaf pine.

Of the remaining longleaf, there is extreme variation in stand structure and quality. Of 352 longleaf pine remnants examined in North Carolina, only 91 stands (26%) were being maintained by fire, while the rest (74%) were fire-suppressed and in transition to other forest types (Frost unpubl.). The suppressed stands were heavily invaded by hardwoods and loblolly pine, and instead of the two-layered structure typical of natural longleaf communities, there were heavy shrub and midstory layers of loblolly pine, scrub oaks and southern red oak. The resulting shade, along with a deep pine needle litter and duff accumulation had completely eliminated wiregrass and the rest of the herb layer on many sites (Frost in prep.). If this ratio of burned versus fire-suppressed stands holds true for the rest of the range, only about 674,000 acres or less than 0.7% of the original extent, remain in good condition rangewide.

Fire relations of the original forests

Historically, agents of fire included lightning, Indians and European settlers. Agents of fire suppression were bodies of water, topography (steep slopes, islands, peninsulas [Harper 1911]), and government agencies (Sherrard 1903). Varying effects of fire in the landscape mosaic have been attributed to fire frequency, fire intensity, and season of burn (Garren 1943, Komarek 1974). Given that lightning fires would have been growing season fires, fire frequency must have been the most important fire variable in presettlement vegetation.

Mattoon (1922) commented that longleaf lands experienced fire at an average of every 2-3 years over millions of acres. On the Pamlico Terrace and other terraces of the lower Coastal Plain from Virginia to Texas, there were numerous tracts of land from several hundred to over a thousand square kilometers in size without a single natural firebreak. In Florida, Komarek (1965) reported one single summer day when 99 wildfires were started by lightning. On the Pamlico Terrace, where a single ignition might burn 1000 km^2, a few ignitions in each state might be sufficient to burn most of the landscape. On the other hand, fire frequency should decrease inland on the more dissected upper Coastal Plain and Piedmont, where numerous separate ignitions would be required to burn the decreasingly smaller fire compartments. The resulting decrease in fire frequency might explain the admixtures of other pine species and hardwoods with longleaf in the transition regions (Sargent 1884).

Before immigration of Indians into the Southeast during the last half of the Wisconsin glaciation 12,000 to 20,000 years ago, essentially all fires would have been caused by lightning. Komarek (1964, 1965, 1968, 1974) has martialled convincing evidence to support the idea that lightning alone is adequate to account for evolution of pyrophytic vegetation, the antiquity of which probably far exceeds the appearance of aboriginal peoples on the scene.

Accounts from the Colonial Period describing Indian burning practices (Smith 1624, Lawson 1709, Byrd 1728, Martin 1973) indicate that use of wildfire by the southeastern Indians was largely limited to fall and winter when fires were set to drive game. On the outer Coastal Plain where annual summer lightning fires preempted fuel, the effect of any Indian burning may have been only a slight increase in coverage of land area, by the inclusion of peninsulas and patches of uplands that otherwise were naturally protected from fire. On the other hand, Indian influence may have been much more significant on dissected inland terraces and the Piedmont, where their primary effect, in compartments missed by lightning, would have been a net increase in fire frequency.

Distribution of Major Communities in Presettlement Forests

Sargent (1884) divided the range of longleaf pine into two regions. In Figure 2, the stippled areas were compiled almost exactly as drawn on his individual state maps. In these lands he described longleaf as the "prevailing growth" on the uplands. This included a diverse mosaic of pine savannas, sandhills and flatwoods, with variants in other habitats, such as riparian sand ridges, Carolina bay sand rims, coastal scarps and dunes, as well as more fertile rolling lands and hills of the interior (Peet and Allard 1993, Harcombe et al. 1993). In Figure 2, this first region is divided into two, depending upon presence or absence of wiregrass. Wiregrass in North Carolina and the northern third of South Carolina is *Aristida stricta*, that from southern South Carolina to Mississippi is *A. beyrichiana* (Peet 1993). The lighter stippling, along with outlying dots, indicates the known historical range of wiregrass, based on herbarium records (Parrott 1967, Peet 1993) and a few other historical records. For instance, both Harper (1913, 1928) and Mohr (1901) included Houston County, Alabama in, "...the counties of Alabama east of the Perdido River, along the Florida state line, known as the 'wire-grass counties,' where on the loose white Ozark sand it almost alone forms the grassy covering" (Mohr 1901, p.113). Ellicott (1803) said that wiregrass was found in Washington and Clarke Counties, Alabama as far upriver as St. Stephens: "the upland on these rivers is of an inferior quality from their mouths up to the latitude of Fort St. Stephens, and produces little besides pitch pine [longleaf] and wiregrass...." The original limits of wiregrass may never be known, much of the perophery of its range having been farmed or fire suppressed long ago.

Sargent's second major assemblage of communities was the transitional forest between coastal plain regions dominated by nearly pure stands of longleaf, and the oak-hickory-shortleaf pine woodlands of the Piedmont. Sargent described the transition regions as "long leaved pine (*Pinus palustris*) with hardwoods in about equal proportion" in the Gulf states and "short leaved (*Pinus echinata*) and loblolly pine (*P. taeda*) intermixed with hardwoods and scattered long leaved pine" in the Atlantic states. The transitional woodlands, on the east side of the primary longleaf range in Virginia and North Carolina, not described by Sargent, were a variant in which pond pine (*Pinus serotina*) was added to the mixture (Ashe 1894a, Frost in prep.).

Mixed patches versus mixed species

In Sargent's transition regions it is also necessary to distinguish the difference between mixed patches (of pure longleaf on south slopes and ridges) in a landscape with other forest types, and true mixed-species stands.

Mohr (1896) and Harper (1905, 1923, 1928) describe pure stands as well as mixed stands. They pictured the mixed pyrophytic types as open woodland with a geographically varying mixture of the dominant trees, which were longleaf, shortleaf and loblolly pine, post oak, white oak, southern red oak, hickories and various scrub oaks. Presumably these were bi-layered communities, having a tree canopy and a savanna-like grass-forb understory, since longleaf is not known to reproduce in mesic habitats without a nearly continuous flammable herb layer to carry fire. These complex communities, with all their geographic variation, were never adequately described. Sargent's 1884 maps are unique in that they are the first detailed range maps for a tree species in the South and because they distinguish between two major natural community groups based on different fire regimes.

Natural old-growth longleaf with a minor component of old-growth loblolly exists on lands in Beaufort County South Carolina (pers. obs.), and there is a photo of a similar stand near Slidell, Louisiana (Ware et al. 1993). Other small examples of mixed species stands can be found in the Croatan National Forest, and in Pamlico County, North Carolina (LeGrand et al. 1992). These natural mixtures include longleaf, loblolly, pond pine, and shortleaf in various combinations depending upon soil texture and moisture (Frost in prep.). Historical examples of each combination were described a century ago in the same region by W.W. Ashe (1894a). The existence of natural mixed species stands has been overshadowed by the remarkable pure longleaf stands that dominated most of the southern uplands, and by the fact that the mixed stands occurred on the moister and finer textured, more fertile soils, the preponderance of which were cleared for farming long ago (Williams 1989).

Hardwoods in presettlement forests

Besides the dominant fire communities, small areas of non-pyrophytic types such as Southern Mixed Hardwood Forest, dominated by beech, magnolia, semi-evergreen oaks and other hardwoods, may have been confined to very limited and specialized habitats within the primary range of longleaf pine (Harper 1911). Old-growth stands can be found on slopes, islands in swamps, and a few upland flats on peninsulas. In many places, mesophytic species like beech now are escaping from these fire refugia onto the uplands (Ware 1978). Studies by Delcourt and Delcourt (1977) in the Apalachicola bluffs region of Florida suggest that Southern Mixed Hardwood Forest occupied less than 1% of the presettlement landscape. In the transition region, however, with its more varied topography, there may have been locally extensive stands. Mohr (1884) mentioned one such locality near Vicksburg, Mississippi where "Beyond the Blackwater (Big Black River) in the hilly region of the bluff formation, the great magnolia covers the hillsides...."

LANDSCAPE CHANGES 1565 TO 1900

Ecosystem changes in the early Colonial Period

While the landscape that greeted the first two major groups of european settlers, English and Spanish, held immense forest resources, neither were well equipped to exploit them and the two cultures used radically different approaches in exploitation of the new world.

DeSoto set out in 1539 to explore the Gulf Coast interior, an epic overland journey, complete with army, horses and droves of hogs, that took him as far north as the Cherokee towns of North Carolina, and west to beyond the Mississippi River (Bakeless 1961). While the Spanish, disappointed with the scarcity of appropriate conquest and pillage, lost interest in the north Gulf interior, they continued to control access to much of the vast region from Florida to Texas. What is significant for landscape history is that during their 256 year tenure, from establishment of St. Augustine in 1565 until cession of Florida to the United States in 1821, the Spanish blocked settlement of the Gulf Coast interior, leaving forests of much of the region in pristine condition well into the 19th century (see Reed 1905). With exception of a handful of coastal villages such as St. Augustine and Pensacola, they never seriously pursued immigration and settlement of the land. At the end of their occupation in 1821, the entire European population of Florida was only a little over 20,000 people, scarcely enough for a reputable town. Note the contrast in settlement patterns between Spanish lands and English settlements along the Atlantic in Figure 3.

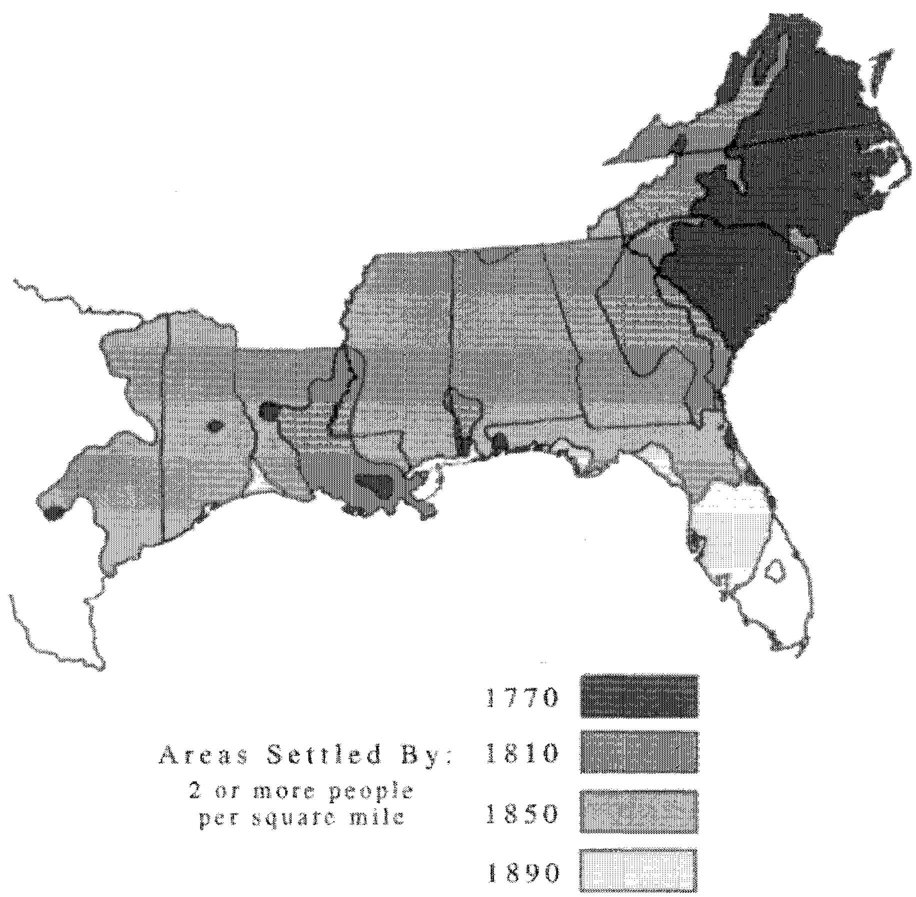

Figure 3. Pattern of settlement in the Southeast to 1890. Note the three small centers of population in Florida, which comprised most of its sparse population until 1821. With exception of the new cotton plantation regions, most virgin forest of the interior of the six Gulf states remained intact in 1850. Map redrawn from Hammond Inc., Maplewood, NJ.

In contrast to the Spanish outposts, English settlements were commercial ventures financed by corporations of wealthy stockholders. Backers of the 1607 Jamestown, Virginia expedition under John Smith invested in settlement and domestication of the land, with intent to establish a productive populace from which they could harvest taxes, agricultural produce and whatever natural products the land could supply (Smith 1624).

For the first 150 years, dependence on water for travel and trade limited settlement to the nearest high lands along sounds, bays and the tidal portions of major and minor streams (Hart 1979). The tidewater area included at least 10,000 miles of shoreline from Virginia to Texas and until this distinct coastal zone was thoroughly populated there was little incentive to push inland. Effects of domestication of the coastal regions included land clearing and establishment of saturation densities of open-range hogs and other livestock which fed on longleaf pine seedlings in nearby woods.

In the absence of machinery, timber was essentially worthless except for local use in fencing and log cabin construction. The only milled boards were laboriously sawed by hand with cross-cut saws, using one man in a pit and another above (Hindle 1975). A very early exception, a water-powered sawmill built at Henrico on the James River in Virginia in 1611, was destroyed by the Indians a few years later (Hindle 1975). Port records from the British Public Records Colonial Office from the early 1600s show that while lumber was a frequent item in ship's cargos, the quantities were small. Cooperage stock—barrel staves and wooden water pipes made from oak and white cedar, supplied practically the only manufactured items for export for the first hundred years (British Public Records 1607-1783).

The colonists killed trees by girdling and the land was then burned and grazed, or planted in corn and other crops beneath the dead timber (Beverley 1705). The principal early demand for timber was for fencing, and most livestock were allowed to graze on open range in the woods and were fenced out of the small crop patches (Beverley 1705). Of great importance to natural savanna and woodland communities, though little remarked historically, was the introduction of huge numbers of hogs, cattle, horses, mules, sheep and goats onto open range in all of the settled areas. Of these grazing herds, hogs in particular were to play a major part in decline of the longleaf pine ecosystem.

Naval stores and the original northern range of longleaf pine in Virginia

The early history of naval stores and the northern range of longleaf pine have been all but lost, since the species was commercially extirpated in Virginia by 1850. Even Mohr (1896) states that the naval stores industry began in North Carolina. Such was not the case however; longleaf pine once extended almost to the Maryland border (Figure 4), and tar and pitch were produced in Virginia for over 200 years before the boom in North Carolina which gave the Tarheel State its nickname. We know of the early trade, the extent of which has never been thoroughly investigated, only through scattered records.

The southern naval stores industry began in 1608 when John Smith exported the first "tryalls of Pitch and Tarre" (Smith 1624). The next year the Jamestown, Virginia colony exported some 3 or 4 dozen barrels to England. To all indications, longleaf was sparse on the north side of the James River where Smith reported finding only a tree here and there "fit for the purpose" [of making naval stores].

Tar, pitch, rosin and turpentine were collectively called naval stores (Ashe 1894a, Mohr 1896) and were produced in the Southeast almost exclusively from longleaf pine, although smaller

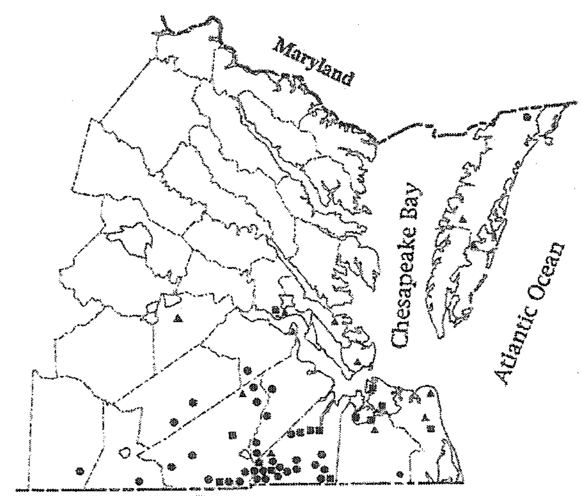

Figure 4. Original range of longleaf pine in Virginia. Circles indicate herbarium specimens or living trees seen from 1960 to 1994, or reported to me by local foresters (also includes two tar kilns visited in Suffolk and Chesapeake). Squares denote clear historical records, some from the early colonial period, but lacking herbarium specimens. Triangles are used for naval stores place names like Pitch Kettle Road, Lightwood Swamp, Pitch and Tar Swamp, Tar Pit Swamp, Tar Bay. This group also includes uncertain records: exact location not available or uncertain whether tree was native.

amounts were made from slash pine, shortleaf and sometimes even loblolly (Michaux 1871). These were absolutely essential commodities until the development of petroleum-derived substances in the mid-1800s. Wagons could not move without tar to grease the axles, and ships could not sail without tar and pitch for waterproofing cordage and sails, for caulking leaks, and for coating hulls to prevent destruction by shipworms (Wertenbaker 1931). During the Revolutionary war, a Captain H. Young (1781) wrote to his colonel "...let me entreat you once more to lay before the Council my distressed situation for the want of two Barrels of Tar." "I have offer'd Brown (who is the only one that has Tar) his price in specie, or two barrels of Tar for one, both of which offers he has refused. Our waggons can't run for the want of tar" (Young 1781 [1881]). Colonel Davies had his own problems with the recalcitrant Mr. Brown, while trying to ship 30 cannon to prevent their capture by the British: "Our own vessels are all in readiness, except for some slight repairs, for the finishing of which some small quantity of tar is necessary, tho' not more than a barrel at the utmost—We cannot procure this quantity under some time unless we obtain it from Mr. Brown, who will not part with it upon any other terms than for specie, of which the State has none to pay" (Davies 1781 [1881]).

Early naval stores production concentrated on burning tar kilns for tar and pitch. Tar kilns were earth covered mounds of several cords of collected dead pine "lightwood" which were burned under controlled conditions by carefully regulating the amount of air let into the mound. This sometimes dangerous process took up to 2 weeks of continuous management—from the first drops, which did not appear for several days, until the tar ceased to flow into the barrels placed below (Catesby 1731, 1743). The much thicker pitch was simply tar burned down to about 1/3 its original volume. The second, more destructive method was boxing of live trees for the crude gum which was then shipped to New England or Europe for distillation of spirits of turpentine in crude iron retorts. While boxing was practised as early as 1608 (Smith 1624), the necessity of shipping the bulky crude gum long distances limited the price and demand for the first hundred years.

While tar and pitch were made from 1608 on, most seems to have been consumed locally until around 1700. In 1697, Governor Sir Edmund Andros said that Virginia produced no naval stores for sale except along the Elizabeth River [Norfolk County], where about 1,200 barrels of tar and pitch were made annually" (Pierce 1953). This would have had ready market at the port of Norfolk just a few miles downstream. The industry was carried on by poor men who built their kilns unassisted by servants or slaves, and considered a few dozen barrels a year an excellent output (Wertenberger 1931). F.A. Michaux, writing about his own observations made around 1802, notes that, "toward the north, the Long-leaved Pine first makes its appearance near Norfolk, in Virginia, where the pine-barrens begin" (Michaux, 1871).

In 1704 Jenings (1704 [1923]) reported some 3,000 barrels of tar produced in Princess Anne and part of Norfolk counties. The disposition was split three ways: between local consumption, sale to ship's masters, and export to the West Indies. Customs records on file for ports from around the Chesapeake Bay, list barrels of naval stores as one of the most common exports from the colony from the late 1600s until the Revolution (British Public Records). In a typical entry, the customs official at Hampton, Virginia noted on April 12, 1745 "Cleared at Hampton, the snow John and Mary, Thomas Bradley, for Liverpool with 106 hhd. tobacco, 500 bbl tar, 60 walnut stocks and 5600 staves." (A snow was a square-rigged sailing vessel, one of the most frequently mentioned trading ship designs in early 18th century records.) The exact site of origin is seldom determinable since ships often stopped at plantations up and down the rivers to pick up cargo and then might be cleared through customs at Hampton or Norfolk. Most tar, pitch and turpentine apparently originated from counties along the south side of the James River and south of Norfolk, where there is evidence of very extensive longleaf pine forests (Frost and Musselman 1987).

The export trade had increased by 1726 such that, from March 25 to September 29, 1726, 17 vessels were cleared from Hampton, only one of the ports, with 1,194 barrels of pitch and 6,004 barrels of tar. One ship by itself carried 1,580 barrels of tar and 130 of pitch (microfilm of British Public Records, 1726). By 1791 the port at Norfolk exported 29,376 tons of naval stores (La Rouchefoucauld 1799). By 1803, the number of ships cleared for foreign ports from Norfolk and Portsmouth reached 484, and it was reported that Virginia was no longer able to meet the export demand for yellow pine (Wertenberger 1931). The designation "yellow pine" most often meant lumber from longleaf pine in the early trade.

Early channels of trade in tar and pitch in Virginia were the Elizabeth and Nansemond Rivers, with their tidal tributaries interpenetrating the lands in the interiors of Norfolk and Nansemond Counties. Not a single tree remains within the watersheds of these two stream systems today. The only evidence remaining of this early resource in the vicinity are a few remnants of tar kilns and a few isolated trees in Suffolk. Longleaf forests in Virginia appear to have been largely exhausted by 1840, after which no further naval stores production was listed (U.S. Census Office 1841). The census for that year listed 5,012 barrels produced from five counties. The species no longer occurs in two of these and I was able to find fewer than 50 mature trees left in this state, where once there were around 2,000 square miles dominated by longleaf pine. In 1893, forester B.E. Fernow concluded that, "In Virginia the long-leaf pine is, for all practical purposes, extinct."

In Southampton County, Virginia I met a farmer, 84 years old, whose recollection did go back to the days of "longstraw" pine. Perhaps the last person in the state to remember that term from daily use, he took me to see three trees that he had ordered to be left when his land was logged. Longleaf pine has been completely extirpated from 11 of the original 15 counties of its range in Virginia. A few remnant trees can now be found only in Isle of Wight, Southampton, Suffolk and Greensville counties.

Southward migration of the naval stores industry, North Carolina to Texas

In 1622, John Pory traveled overland from Jamestown to the Indian town of Chowanoc, passing through "great forest of Pynes 15. or 16. myle broad and above 60. mile long, which will serve well for Masts for Shipping, and for pitch and tarre, when we shall come to extend our plantations to those borders" (Powell 1977). These were the great pine barrens of western Isle of Wight and Nansemond counties, Virginia, and Gates and Chowan counties, North Carolina. The first record of naval stores produced in North carolina was in 1636, 17 years before the first settler set up a house and trading post in 1653. A visitor from Bermuda to the Chowan region was surprised to discover a large number of men there busily producing "sperrits of rosin" (Clay et al. 1975). This was in the vicinity of what has long been called the "Sand Banks" of western Gates County. The crew had apparently come overland from the settlements, only a few years old, along the James River in Virginia. Frost et al. (1990), were only able to locate about 25 old longleaf trees, most of which occurred in a region in the western part of the county called the Sand Banks. Frost (unpubl.) counted annual rings when some of these were logged around 1980. The largest was 308 years old and only 23.5 inches diameter on the stump when cut in 1981.

Schoepf (1788) travelling down the coastal plain from Virginia to South Carolina observed that "...the greatest and most important part of the immense forests of this fore-county consists of pine....", and commented on "...the opportunity for considerable gain from turpentine, tar, pitch, resin and turpentine-oil". The history of naval stores in North Carolina has been reviewed by Merrens (1964)

In the northern tier of counties besides Gutes,only two trees are known to remain in Hertford County, North Carolina, and one tree in Perquimans County. The last stand of longleaf in Northampton County was logged around 1980 and longleaf pine has also been extirpated from Currituck, Pasquotank, Washington and Tyrrell counties.

Fernow (1893) observed that, "in North Carolina, in the division of mixed growth and in the plain between the Albemarle and Pamlico Sound, the long-leaf pine has likewise been almost entirely removed and is replaced with the loblolly." In the central part of the state, there was considerable turpentining activity along the Tar River in the central Coastal Plain by 1732, and by 1850 the state was the world's leading supplier of naval stores (U.S. Census of Manufactures). Agriculturists complained that the entire labor force of the Coastal Plain was employed in the turpentine orchards, to the neglect of agriculture (Ruffin 1861). By 1900 longleaf had been decimated in North Carolina and the industry had passed on to the south, leaving vacant land or scarred survivors. Ashe (1894b) commented, "In North Carolina most of the trees which now bear seed are boxed and have been in this condition for 50-100 years,..".

Introduction of the copper still in 1834 allowed concentration of the final product into distilled, "spirits of turpentine" making the process highly efficient, slashing shipping costs, and touching off a wave of commercial exploitation which swept south from North Carolina to Texas decade by decade, decimating the longleaf pine region within 80 years (Mohr 1896). Sargent's state maps (1884) for Louisiana and Texas show the extent of turpentine orcharding being carried into the virgin pine forests. Thomas Gamble (1921) and Thomas Croker, Jr. (1987) have reviewed the history of naval stores for the rest of the South.

Few mature trees escaped the turpentine boxing procedure. Using 19th century methods, virgin stands often produced for only about four years (Mohr 1896). Large trees were boxed on three or even four sides (Schoepf 1788), with deep wedges cut into the base to collect the resin (Figure 5). Crude gum was dipped from the box six to eight times a season and transported by cart or boat to the nearest still (Figures 6, 7, 8). Casks of distilled spirits of turpentine and barrels of rosin, the residue after distillation, then were shipped to the nearest port (Figure 9). Weakened trees in abandoned turpentine orchards often were blown over or killed when the next ground fire set the residue ablaze in the boxes (Figure 10).

Figure 5. Boxing trees for turpentine. Bark and cambium were removed and large boxes were chopped into the base to collect the crude gum. Photo courtesy of U.S. National Archives.

Figure 6. Gum was collected every few weeks by dipping with large spoons. Barrels were crafted locally from white oak. Photo courtesy of U.S. National Archives.

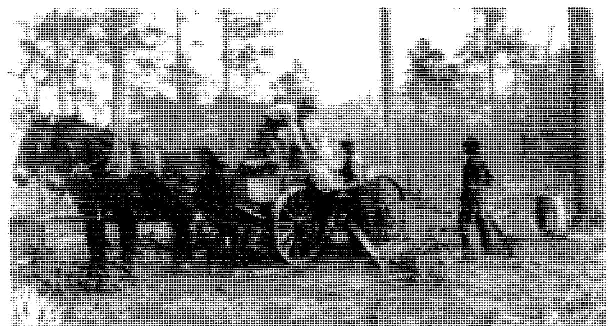

Figure 7. Barrels of crude gum were taken by boat or wagon to the nearest still. Photo courtesy of Forest History Society.

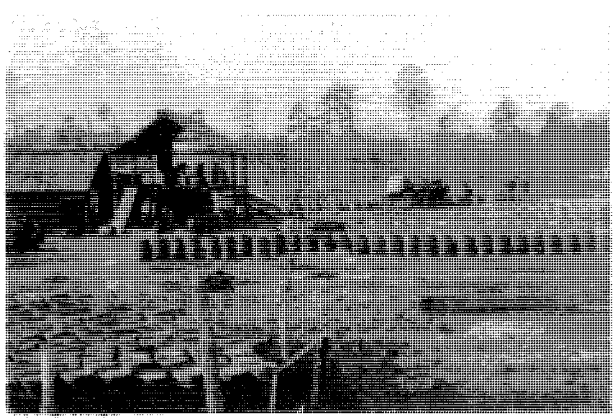

Figure 8. Introduction of the copper still into the woods in 1834 permitted reduction of crude gum to spirits of turpentine, saving shipping costs and making the process immensely more profitable. Photo courtesy of U. S. National Archives.

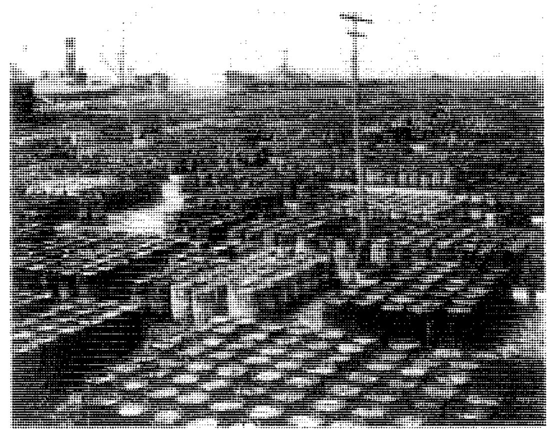

Figure 9. The rosin yards at Savannah, Georgia in 1893. Every 50 gallon barrel of distilled turpentine contained the entire life's production of 33 virgin longleaf pine trees, with a byproduct of 4 barrels of rosin. Net profit per tree was 20 cents (Mohr 1893). Photo courtesy of U.S. National Archives.

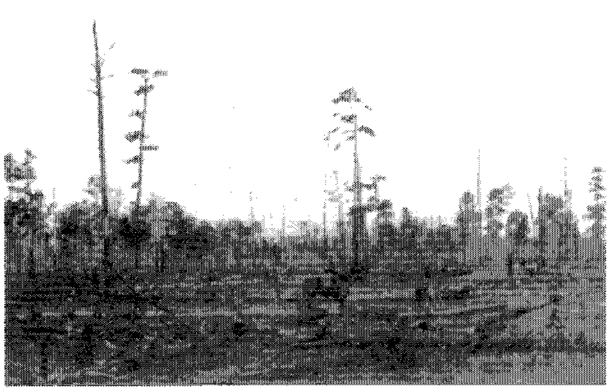

Figure 10. This virgin longleaf stand in Beaufort Co., South Carolina had been boxed for turpentine. Fires further weakened the trees by setting the boxes ablaze and in coastal areas, hurricanes often finished the job. Photo, Sherrard 1903.

Much of the virgin timber thus was wasted until around 1870, when narrow-gauge logging railroads were extended into upland forests. As forests of each state were exhausted the industry moved south, and by 1890 foresters raised the alarm that without provision for reforestation the turpentine industry would soon come to an end (Ashe 1894b). Mohr (1896) described the situation; "...the forests invaded by turpentine orcharding present, in five or six years after they have been abandoned, a picture of ruin and desolation painful to behold, and in view of the destruction of the seedlings and the younger growth all hope of the reforestation of these magnificent forests is excluded". This grim prediction was largely fulfilled when the last of the virgin forests were depleted in the 1920s.

The spread of Agriculture in the longleaf pine region

Indians were the first farmers, and the full extent of Indian agriculture in the South has never been delimited. Bartram (1791) described "tallahassees" or Indian old fields from shifting agriculture in north Florida. To the north, the hunter-gatherer cultures of North Carolina and Virginia farmed on a very small scale in patches adjacent to villages, while much of the diet came from fishing and hunting (Harriott 1590, Smith 1624). In the Creek country of Alabama, however, Bartram traversed a region of Indian farmland broken only by small tracts of woods between the outlying agricultural lands of one village and the next (Bartram 1791). Clearly a portion of the longleaf pine region had already been domesticated before arrival of the first Europeans.

Along the Atlantic slope, settlers finally began moving out of the tidewater region in the 1730s (Clay et al. 1964) and, with later waves of immigrants, settled the Piedmont, reaching the foothills of the Appalachians by the 1790s (Figure 3). During the period 1750-1850 virtually all longleaf communities of the more fertile soils were converted to farmland and pasture (Williams 1989). Both the American Revolution and the Civil War interrupted agriculture for a number of years, however, and in 1795 it was reported that "all Tidewater Virginia was full of 'old fields' reverting to timber." (Wertenberger 1922).

The longleaf pine region was fully settled by 1750 with exception of Florida, Texas and the interiors of Alabama and Mississippi (Figure 3). As late

Figure 11. Virgin longleaf stands of the interior hills of the Piedmont and southern tip of the Appalachians were nearly as open as those of the Coastal Plain. Boxes have just been chopped into the bases of these trees for the turpentine process, which had just reached the hills in 1905. Bibb or Coosa Co., Alabama. Photo, Reed 1905.

as 1820 the vast longleaf forests of the interior of Alabama, Mississippi, Louisiana and east Texas remained essentially untouched. In 1821, however, cession of Florida to the United States by Spain, and major land purchases from the Creek and Choctaw Indians, opened this region to settlement. By 1850 the fertile Black Belt region of central Alabama and Mississippi had been plowed and converted to cotton plantations by large slave-holding planters. A map compiled from the Census of 1840 (Williams, 1980) shows the distribution of major cotton plantations in three dense regions: coastal South Carolina and Georgia, the lower Mississippi River valley, and the Black Belt.

By the Civil War, nearly all lands optimally suitable for agriculture were in production. By 1900, 30.7 million ac (12.5 million ha) or about (27.0%) of the longleaf pine upland was listed as "improved" farmland, a category that included pasture, roads and buildings as well as cropland (U.S. Census of Agriculture 1902). While there were no separate figures for land in pasture in 1900 (U.S. Census Office 1902), it was necessary to maintain pasture or range on every farm for horses, mules, and oxen used for plowing and transportation, and until around 1880 much livestock was still maintained on open range in the woods.

History of logging, from hand power to water power to steam

Effects of timbering were minor through the early Colonial Period (from 1607 in Virginia, 1565 in Florida) to the mid 1730s, when logging was done by hand, using horses, mules and oxen to drag the logs. Commercial logging was limited to the vicinity of streams where the harvest could be transported. While water power was tried as early as 1611 in Virginia, this technology did not take hold until around a century later, with introduction of water-powered sawmills in Louisiana around 1714 (Hindle 1975) and the Cape Fear region of North Carolina in the 1730s. In 1732, Governor Burrington reported that an abundance of sawmills was being constructed along the Cape Fear River. In 1764 Governor Dobbs reported that forty sawmills had been completed on branches of the Cape Fear, and Governor Tryon reported that the number had risen to 50 by 1766 (Merrens 1964).

Water power opened up the first real possibility of commercial lumber production. Steel saw blades were imported from Holland where the technology had been worked out, and sawmills proliferated rapidly along streams in settled areas. Still, these were slow acting, straight-bladed reciprocating saws (slash saws), with an up and down action, mimicking the human-powered pit saws: the circular saw and band saw were still 100 years away, not coming into general use until after the Civil War (Hindle 1975). Many of these small mills operated only part time—when there was enough water in the mill pond in winter and spring to turn the wheel. Many were plantation-owned, producing boards for local use, with a little surplus shipped downstream to coastal towns.

While water power helped the clapboard house to replace log construction, commercial logging remained a constant but minor industry from 1730 to around 1850. Until that time, most logging was along streams where logs were skidded out in various ways by horses, mules and oxen. The giant wheeled "carry-log" (or "caralog", Figure 12) was important from this time until the late 19th century when it was supplanted by logging railroads and steam skidders. Logs were transported

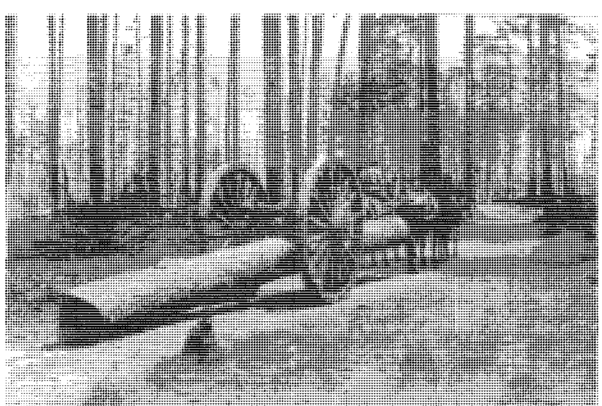

Figure 12. A "carry-log" drawn by mules. Economical range of this kind of transport was less than 4 miles (Croker 1987). Photo courtesy of U.S. National Archives.

this way to the nearest water and then rafted downstream to mills. The maximum effective distance for this kind of overland transport was only 3 or 4 miles (Croker 1987), and so commercial exploitation was still limited to narrow zones along navigable streams.

Prosperous South Carolinians were fascinated by steam power and in 1833 constructed the first railroad in the United States, connecting Charleston and Hamburg, S.C. In 1856, the first steam-powered dredges were used in Norfolk Co., Virginia, to build the Albemarle and Chesapeake Canal (Ruffin 1861), and the period 1850-1870 saw explosive proliferation of steam technology for logging railroads, steam skidders (Figure 13) and steam powered sawmills (Anon. 1907). By the end of the Civil War, with resumption of intensive turpentining throughout the longleaf forests of North and South Carolina, and with steam logging methods perfected, the stage was set for cataclysmic decimation of the longleaf ecosystem.

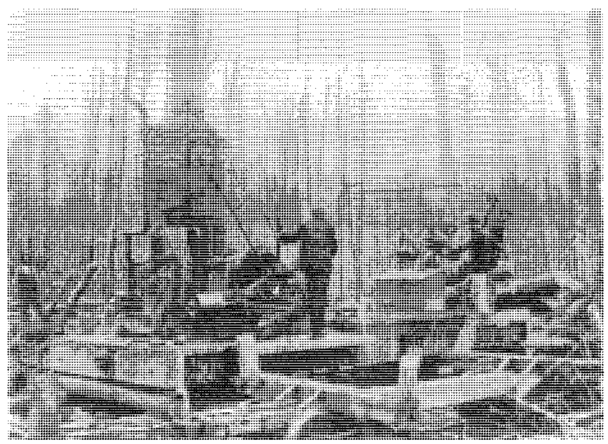

Figure 13. Steam skidders used cables to winch logs out of the woods to loading platforms. Note narrow-gauge logging car in foreground. Juniper Swamp near Roper, Washington Co., North Carolina. Photo, American Lumberman 1907.

After the war, there were sales of huge tracts of southern lands to northern railroad companies (Figure 14), often with subsequent sales by railroads to logging companies. Lands sometimes changed hands at the rate of 100,000 acres or more, at prices of $1.25 per acre (Napier 1985). The decade 1880 to 1890 saw standardization of track sizes and concatenation of isolated railroad lines, making overland transport of lumber cheap and efficient (Anon. 1907, Hale (1883). By 1880, all commercial timber had been removed from lands within a few miles of streams and railroads. Tapping of virgin forests of the interior had just begun, but huge volumes of lumber were being produced. Sargent (Table 2) reported an annual cut of over a

Figure 14. Clearing right-of-way through virgin longleaf forest in Mississippi for Natchez, Columbia and Mobile Railroad in 1907. All timber was soon cut within several miles of railroads and more distant lands were sold to logging companies. Photo, American Lumberman 1907.

billion board feet in 1884, increasing to 3.7 billion board feet by 1896 (Mohr 1896). The phase of intensive logging from 1870 to 1930 saw removal of virtually all remaining virgin forest in the South. By 1900, it was apparent that many cutover longleaf areas, particularly those on better soils, were being occupied by scrubby second growth of other species, while others remained open and nearly treeless. Longleaf pine replaced itself only sporadically in a small percentage of its former landscape (Mohr 1896).

THE DISAPPEARANCE OF LONGLEAF PINE

Historical records suggest a combination of three factors to explain the disappearance of longleaf pine. First, regenerative failure of longleaf forests may have been due in part to their inherently low rate of restocking under a natural fire regime, which, on extreme sites, might take more than 300 years for return to original stand structure after logging. On other sites, however, longleaf may reproduce adequately, even under an annual fire regime (T. Sharpe pers. comm.).

The second factor was the fondness of feral livestock, especially hogs, for the seedlings (Mohr 1896, Hopkins 1947a, 1947b, 1947c). Unlike other pines, longleaf seedlings have a non-resinous, carbohydrate-rich meristem which, while in the grass stage, is vulnerable to grazing for 5 to 7 years or more. Hogs have been observed to feed heavily on longleaf seedlings, consuming up to 400 each in a day (Hopkins 1947a, 1947c). The third and final factor was 20th century fire suppression.

Failure of longleaf pine regeneration after logging

By the 1890s foresters saw clearly that, over large expanses of the landscape, longleaf was not replacing itself after logging (Ashe 1894a, 1894b, Mohr 1884, 1896). Mohr commented, "on the lowlands of the Atlantic coast toward its northern limit this pine is almost invariably replaced by the Loblolly Pine." "In the stronger soil of the upper division of the maritime pine belt, the region of mixed growth, where seedlings of the Longleaf Pine spring up simultaneously with the hard wood trees and the seedlings of the Shortleaf Pine, these latter will eventually gain the supremacy and suppress those of the Longleaf Pine." "It is evident that the offspring of the Longleaf Pine is rarely seen

Table 2. Quantities of virgin longleaf pine remaining, and annual cut in 1880. Figures are only for major longleaf pine regions and major logging companies. While virgin growth had been depleted in Virginia and exhaustion in the Carolinas was imminent, stands in Louisiana and Texas still were largely untouched (Sargent 1884).

	Merchantable Longleaf Pine (board feet)	Annual Cut for 1880 (board feet)
Virginia	No reported commercial production.	
North Carolina	5,229,000,000	108,411,000
South Carolina	5,316,000,000	124,492,000
Georgia	16,778,000,000	272,743,000
Florida	6,615,000,000	208,054,000
Alabama	18,885,000,000	245,396,000
Mississippi	18,200,000,000	108,000,000
Louisiana	26,588,000,000	61,882,000
Texas	20,508,000,000	66,450,000
Totals	118,119,000,000	1,194,428,000

to occupy the place of the parent tree, even in the region most favorable to its natural renewal, and that final extinction of the forests of the Longleaf Pine is inevitable unless proper forest management is applied." To Mohr's mind that meant eliminating all fire and then "bringing in", 15 to 20 years later, shade-tolerant tree species below the longleaf to build up a humus layer "to secure improvement and permanency of favorable soil conditions." These sentiments were echoed by Sherrard (1903). Unfortunately this was a prescription for extirpation of longleaf pine, the herb layer and the two-layered structure typical of fire communities.

The question that dogged foresters was, why didn't longleaf reproduce, at least on those lands where nothing else was done other than logging of the virgin timber? Contemporary with Mohr, one of the first foresters to wrestle with this problem was W.W. Ashe, who noted that not only was the longleaf seed crop produced in irregular mast years, but also that the seeds were descended upon by a variety of predators: "...its large and sweet seeds are eaten in large quantities by fowls of various kinds, rats, squirrels, and by swine, which prefer them to all other kinds of mast, and when there is enough long leaf pine mast become very fat on it" (Ashe 1894b). This had been noticed as early as 1728 by William Byrd during the survey of the Virginia-North Carolina line and Ruffin (1861) commented that "They are so eagerly sought for by hogs that scarcely any are left on the ground to germinate." Ashe was one of the first to report the fondness of hogs for the larger seedlings. "No sooner, however, has the young pine gotten a foot high and its root an inch in diameter than the hog attacks it, this time eating out the roots, which until 2 inches in diameter, are very tender and juicy, pleasantly flavored and free of resinous matter."

Like most foresters of his time, Ashe regarded fire as the unrelenting enemy of forest regeneration, even going so far as to insist that in North Carolina "...the burnings of the present and future, if not soon discontinued, will mean the final extinction of the long leaf pine in this state" (Ashe 1894b). This opinion echoed that of Mohr (1884) and others on the destructive nature of fire. The groundwork for the field of fire ecology had clearly not yet been laid.

After consideration of all factors, Ashe concluded that the chief agencies preventing regrowth of longleaf pine were fire and hogs. While fire destroys first year seedlings and under certain circumstances can even kill mature trees, later authors asserted the actual dependence of the species upon fire to prevent site appropriation by shade-tolerant pines and hardwoods (Harper 1913). When some of the early assertions were tested, longleaf pine was found to be replaced by slash pine when both fire and hogs were excluded (Sherrard 1903), and studies in 1935 showed only 8% fire mortality in two year-old longleaf plantations in Louisiana, versus 53% for seven year-old loblolly (Wakeley 1935). If fire is excused as one of the two principal culprits, that leaves hogs conspicuously in need of closer scrutiny.

In 1539, DeSoto made the first introduction of swine to the South (Bakeless 1961). Later, English settlements brought with them starter livestock (Strachey 1610, Smith 1624). Hogs showed an astounding reproductive potential, and demonstrated an ability to fend entirely for themselves in the woods with no attention from their owners (Beverley 1705, Blakeley 1812 [1910]). The capacity of the landscape to support open range hogs has never been investigated, but there is considerable evidence to suggest that they quickly reached saturation density within a few decades after settlement. By 1617 the log palisades with which the town was walled off were not sufficient to keep the hogs out of the streets of Jamestown, Virginia. Capt. Samuel Argall and James Rolfe on landing there in May of that year commented on the "innumerable numbers of swine" (Smith 1624).

Evidence for early saturation of the landscape by hogs in coastal regions

Both the Spanish and English experiences demonstrated the potential of hogs to increase from a handful to thousands in two or three years under conditions of complete neglect on open range. By 1702 a Swiss visitor to coastal Virginia declared that "Pigs are found there in such numbers that I was astonished" (Michel 1702 [1916]). This was corroborated by Beverley (1705) who stated that, "Hogs swarm like Vermine upon the Earth, and are often accounted such, insomuch that when an Inventory of any considerable Man's Estate is taken by the Executors, the Hogs are left out, and not listed in the Appraisement. The Hogs run where they list, and find their own Support in the Woods, without any Care of the Owner; and in many Plantations it is well, if the Proprietor can find and catch the Pigs, or any part of a Farrow when they are young, to mark them...."

A few years later, Brickell (1737 [1968]) reported similar conditions in northeastern North Carolina where he saw, "...swine, breeding in vast numbers...." A considerable meat packing business had sprung up in Norfolk, Virginia, the major port in the mid-Atlantic region, to supply salt pork and other provisions to sailing ships. The first direct evidence that hogs had reached saturation density in North Carolina is provided by reports of Governor Barrington in 1733, that about 50,000 hogs were driven annually to the Norfolk market from the Albemarle region of North Carolina (Wertenbaker 1931). The first census figures from these counties, showed no increase from 1840 to the Civil War, indicating that saturation density had been reached, with an average of 14,800 hogs on open range in each of the six counties south of the state line within hog driving range of Norfolk. This gives an average of 10.7 acres per hog (U.S. Census of Agriculture 1841). For the 1890 census only, unique figures were kept for hogs consumed or hogs which died, in addition to total numbers. In Alabama, which still had hogs on open range, an annual number equal to 45% of the total hogs alive were consumed and 23% died. This gives us an approximation for surplus hogs that could be harvested when populations were near capacity (U.S. Census of Agriculture 1895). If the total number of hogs in the six North Carolina counties mentioned above, were at carrying capacity in 1750, the numbers should be nearly the same as in 1840 (88,850 hogs), then the surplus should have been 45% or 40,000 hogs. The fact that the reported surplus of 50,000 fully-grown hogs driven to market in Virginia exceeds our estimate of 40,000 strongly suggests that carrying capacity had been reached in this region sometime before 1733. These counties were settled between the years of 1655 and 1700 so there had been from 35 to 78 years for hogs to reach saturation density.

While hogs spread inland from southeastern Virginia and northeastern North Carolina, other introductions were made along the Atlantic and Gulf coasts. Explorers stepping ashore on the barrier island at Cape Fear, North Carolina, in 1663 were astonished at being offered pork for sale by the Indians, livestock having been placed on the islands a few years earlier by stockmen from New England (Lawson 1709 [1967]). Lawson also commented on hogs at the town of Charleston, South Carolina in 1700. Mobile, founded in 1711 (Hamilton 1910 [1976]), was the first permanent city on the Gulf, and in 1812, free-ranging hogs were kept on three islands of about 4,000 acres each at the head of Mobile Bay. Josiah Blakeley, the owner, wrote that: "Cattle and hogs do well upon them, and no expense. Upon them I have about 30 head of cattle and hundreds of hogs, the hogs wild. I shoot or catch them with a dog (Blakeley 1812 [1910])." There is little evidence, however, that hogs spread very far beyond the frontier, where Indians and other predators may have kept them under control.

From the descriptions above, it seems likely that tidewater Virginia was saturated with hogs by around 1700, and the whole coastal plain of Virginia and the portion of North Carolina north of Albemarle Sound by 1730. The first regularly-kept figures, however, were not available until a century later with the 1840 Census of Agriculture. The lower line in Figure 15 shows the total number of hogs from the fifteen Virginia counties within the original range of longleaf pine from 1840 to 1900. The plunge in numbers occasioned by famine during the Civil War is characteristic of all the southern states and is closely paralleled by figures for cattle and other livestock (U.S. Censuses of Agriculture 1840-1900). Note that the population curve for the decades preceding the Civil War is relatively flat, and recovers to a relatively flat slope within two or three decades afterward. This supports the notion that carrying capacity had been reached some time before such records were kept.

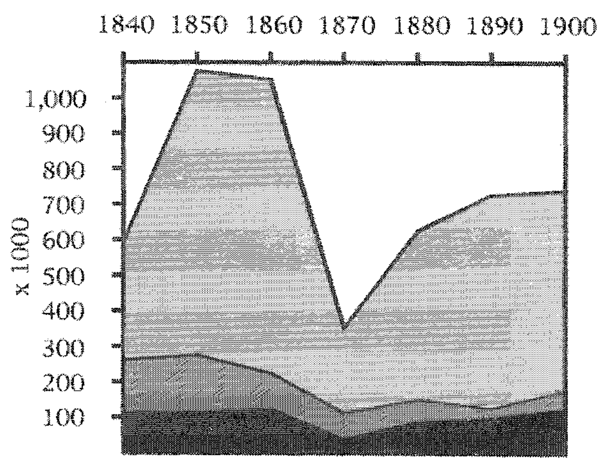

Figure 15. Evidence for saturation of the landscape by feral hogs. The lower curves represent stable hog populations in coastal regions long-settled by 1840—more than 200 years for coastal Virginia (bottom line) and over 100 years for coastal Alabama (middle line). The vast regions in central Alabama, only opened to settlement in 1821, had just reached carrying capacity in 1850, with over a million hogs on open range. Data from U.S. Census of Agriculture.

In contrast, figures for Alabama indicate that only the coastal region was saturated by 1840. The middle line in Figure 15, which parallels that for Virginia, represents the seven old, long-settled coastal counties around and just upstream from Mobile. The upper line represents the middle counties. The interior remained Spanish territory until its session to the United States in 1821, when settlers from Georgia and the coast were poised for entry (Figure 3). By 1840, only 19 years after opening of the territory, immigration was in full swing but the country was as yet sparsely settled. Figure 15 shows increasing numbers of hogs in the central counties, but leveling off after 1850, within 19 years of 1821. The flattening of the curve again suggests carrying capacity had been reached, and suggests that hogs could saturate a vast landscape in about 20 years (the large numbers for the central counties reflects the much greater land area).

Hogs were not the only competitor for forage on open range however. While hogs were consistently the most abundant livestock species listed, the range was shared by cattle, horses, mules, sheep and goats, whose numbers collectively equalled those of hogs (U.S. Censuses of Agriculture 1841-1902). One writer estimated that 12 to 25 acres of unmanaged woodland was required to support one cow, 2 acres of good pasture would suffice (Gardner 1979).

No figures were ever determined for carrying capacity of southern range for hogs (Grelen pers. comm.). As noted above the apparent saturation density of hogs in 1840 in northeastern North Carolina was 10.7 acres. While this might seem an abundance of land per hog, keep in mind that county areas included water, areas from which hogs were fenced out, and large areas of upland forests where there may have been little forage except for the fall mast crop of acorns and pine seeds. There was stiff competition for the mast crop from birds and other animals (Ashe 1894b, Wahlenberg 1946). Longleaf pine seedlings, on the other hand, were available and vulnerable all year round.

Wakeley (1954) noted that cattle do negligible damage to longleaf pine except where heavy concentrations trample new plantations, and light grazing may reduce fire intensity by removing potential fuel while it is still green. Sheep and goats are more serious, biting out terminal buds, sometimes resulting in more than one stem from a base. Biting retards height growth but does not kill most trees. Nevertheless, densities of one sheep per 47 acres seriously damaged some young longleaf stands, and 1 sheep per 13 acres injured up to 86% of seedlings (Wahlenberg 1946). While birds have been reported to consume from 8% to up to 42% of the longleaf seed crop (Wahlenberg 1946), they do not molest the seedlings, and this much predation must have been tolerable, since birds were a natural part of the landscape in which longleaf pine flourished. Wakeley (1954) considered hogs by far the most serious threat to longleaf: "Where there are many hogs it is foolhardy to plant longleaf pine without fencing.... To this species hogs are infinitely more destructive than fire."

There are several hog and fire exclusion studies to back up this assertion, two of which reported complete failure of longleaf regeneration on tracts where feral hogs were present. Two experimental tracts at Urania, Louisiana, after five years of protection against hogs, contained an average of 6,440 longleaf saplings per acre, as compared with an average of only 8 per acre on two similar unprotected tracts (Mattoon 1922). In an area with free-ranging hogs in Georgetown County, South Carolina, hogs were fenced out of 32 1/10 acre plots. After two growing seasons the fenced areas contained 500 fire-resistant seedlings (those with root collar diameters of 1/2 inch or larger) per acre, while unfenced areas again contained only 8 per acre (Lipscomb 1989). The hogs largely ignored small first-year seedlings but focused on those large enough to have accumulated starchy content. Density of hogs was not controlled but was estimated to be about 3 to 6 animals on the 60 ac study area, or 10 to 20 acres per hog. This is comparable to the hog densities of 10.2 acres per hog reported above, on open range in colonial North Carolina, which, we have suggested may represent carrying capacity.

Ashe (1894b) and Mohr (1896) both commented on the palatability of longleaf pine seedling roots in the 1/2 to 2 inch diameter range. Wakeley (1954) reported hog consumption of 200-1,000 longleaf seedlings per day, at rates of up to six per minute. Hopkins (1947a, 1947b, 1947c) after observing hogs rooting up hundreds of seedlings a day, analyzed the root starch content and found them to be as nutritious as corn. Little wonder then that hogs would home in on longleaf seedlings, which, in the grass stage, are highly conspicuous and vulnerable for three to seven years. With 10,000 to 40,000 hogs on open range in every settled county in the longleaf region (U.S. Censuses of Agriculture 1840-1900), all that would be required to eliminate reproduction would be for a drove of hogs to happen upon a regenerating plot once every three or four years to largely eliminate the species from the landscape.

Hogs on open range were completely dependent on natural forage, none being provided by their owners (Beverley 1705). If carrying capacity had been reached, survival would be tenuous and occasional disasters could be expected when mast crops or other wild foods failed. A curious example occurred in Illinois when hogs starved in winter after passenger pigeons unexpectedly descended in a local area and ate all the fall mast of acorns, beechnuts, and chestnuts (Bakeless 1961). This raises the question about the reverse situation, that saturation of the landscape with hogs contributed to the extinction of the passenger pigeon. Their summer breeding range extended only as far south as Virginia but from late September to early November the flocks migrated to the winter range from South Carolina to Florida (Bent 1932 [1963]). This coincided with longleaf seed fall, and it has been observed that related birds like mourning doves and quail have crops "crammed" with longleaf seeds during this time (Wahlenburg 1946). In the South, memory of the passenger pigeon persists only in place names like "Passager Swamp" in Isle of Wight County, VA.

The end of open range

The effects of hogs on longleaf pine were not noticed until the massive wave of logging that followed the Civil War physically removed the forest. Most of the timber cut in the period 1870-1900 was still virgin forest (Mohr 1896), where the effects of hogs were inconspicuous as long as the trees stood. Note that longleaf had indeed been extirpated from much of the northern range a hundred years before, but the process had taken 200 years, while decimation of the forest using steam logging technology occurred almost overnight. This precipitated an immediate shortage of lumber for fencing (Hale 1883), and forced landowners to look at the problem of livestock on open range. For the first three centuries, crops had been fenced in to protect them from livestock which had free run of the land. Even if a farmer had little stock of his own, he had no choice but to fence his crops against the animals of his neighbors. As more land came into agriculture, demands for fencing increased until the timber shortage made it apparent that it would more economical to fence in the livestock rather than the crops.

In response, fence laws (stock laws) were passed throughout the South, beginning in the 1870s. After the Civil War an act of the legislature in South Carolina allowed each township to determine by vote, "whether the crops or the stock shall be enclosed" (State Board of Agriculture 1883). This option may not have worked, especially along the boundaries of counties with different rules, since by 1883 a statewide law was passed "...making it incumbent upon the owners of live stock to see that they do not trespass on others. The tiller of the soil is no longer compelled to build fences to protect the fruits of his labors from the inroads of his neighbors' cattle, thus saving all cost in building and repairing fences..."(State Board of Agriculture 1883). A respondent to a timber survey, from Anson County, North Carolina commented that, "every man who owns cattle, hogs, sheep, goats or horses in Anson County is now compelled to pasture them on his own land. None are allowed to run at large on the range. This system came into effect in our county about two years ago, and so much is it esteemed already that a return to the old style of fencing the crops against the incursions of stock is next to impossible. This is regarded as the most important single step taken in this county in the last twenty years" (Hale 1883). The process took decades to become effective over the whole South and there are still areas where hogs run wild (Lipscomb 1989).

LANDSCAPE CHANGES FROM 1900 TO 1990

Fire suppression and the decline of fire as a natural determinant of vegetation

The end of open range should have been a boon to longleaf pine, but while three centuries of open range was drawing to a close, a new threat was in the making. Fire was still widespread, but by the Civil War, much of the landscape had been fragmented by agriculture, reducing the size of fire compartments. In central South Carolina there were an average of 50 acres per farm cleared and tilled (State Board of Agriculture 1883). As long as stock raising was the primary source of income, the remaining woodlands were burned by the residents to green up forage for livestock. This practice may have perpetuated longleaf pine and its associated flora of wiregrass and savanna herbs, in a landscape where roads, plowed fields and other manmade firebreaks had eliminated landscape-scale fires ignited by lightning. When cattle grazing declined in importance after the Civil War, the practice of spring burning was abandoned in major agricultural areas. Describing the resultant vegetation changes in South Carolina, one writer noted that, "the uplands were covered, as they still are, with a large growth of yellow pine [longleaf], but a deer might then have been seen, in the vistas made by their smooth stems, a distance of half a mile, where now, since the discontinuance of the spring and autumn fires, it could not be seen fifteen paces, for the thick growth of oak and hickory that has taken the land" (State Board of Agriculture 1883).

On all but the drier lands, longleaf reproduction is completely eliminated by mesophytic pine, hardwood and shrub invasion within a few years after fire exclusion (Sherrard 1903, Frost in prep). Nowhere in the South can longleaf be seen reinvading the mesophytic mixed pine-hardwood succession that has replaced it.

Modern fire laws and the state apparatus for prevention and suppression of wildfire did not come into being in most of the South until the period 1910-1930. This left a window of some 50 years, between the end of open range and the beginning of 20th century fire suppression, in which longleaf pine could reproduce. Many of the stands which did result have now been logged and most of those naturally-regenerated stands still remaining, date to the end of this window of opportunity.

Fernow (1893) was one of the first to argue for governmental involvement in forestry: "there exist some legislative provisions regarding forest fires in almost every State, but they are rarely if ever carried into execution for lack of proper machinery." Most states remedied this condition in the next 30 years, however. In 1919, Virginia passed laws creating the position of State Forester and provided for forest wardens. The act also imposed fines and a minimum penalty of a year in prison for maliciously starting a forest fire, a far cry from the days when burning was a casual act.

While early foresters were convinced that both hogs and fire were inimical to longleaf regeneration, the first real demonstration was conducted in 1903. Sherrard (1903) examined a fenced plot from which fire and hogs were excluded. Within a few years a dense stand of slash pine had established itself beneath the longleaf. Sherrard was pleased with the result. Never mind that the new forest would be composed of a new dominant species and of entirely different structure than the open longleaf forests. And curiously, neither he nor Ashe, nor Mohr ever questioned that if fire were the enemy of longleaf, why did its exclusion lead to an entirely different forest type?

Few of the early foresters cared to acknowledge the role of lightning as an ignition source. In South Carolina, Sherrard (1903) blamed all fires on humans, stating that fires were "carelessly set to improve grazing, to clear land, and to protect woods where turpentine is being gathered." Burning in this case was done after first raking pine straw away from the flammable boxes in the bases of the trees. Ashe even believed that one of the reasons longleaf pine was being replaced by loblolly was that it was more sensitive to fire: "the loblolly pine is less injured by fire because its bark is thicker and so offers more protection to the growing wood,—the bark, too, lying closer to the wood in firmly appressed layers, does not so easily take fire." "The chief agencies, then, which prevent a regrowth of long leaf pine on the high sandy lands, are the hogs and the fires..." ...the burnings of the present and future, if not soon discontinued, will mean the final extinction of the long leaf pine in this State (NC)." (Ashe 1894). Sherrard however, recognized that, "the Longleaf Pine may rightly be called a fireproof species in so far as the survival of scattered groups and patches of second growth and individuals is concerned. But extended areas under forest are impossible under present conditions." He was one of the first to call for a public campaign against fire: "the people must be educated to a sentiment against fires."

The first voice to clearly distinguish the natural role of fire was Roland Harper who stated, "it can be safely asserted that there is not and never has been a long-leaf pine forest in the United States...which did not show evidences of fire, such as charred bark near the bases of the trees; and furthermore, if it were possible to prevent forest fires absolutely the long-leaf pine—our most useful tree—would soon become extinct" (Harper 1913).

If not admitted by foresters, it was well known to inhabitants of the longleaf pine region as early as the 1830s, that lightning was often responsible for fires in the turpentine orchards. On a large estate in Onslow County, North Carolina, damage to the turpentine crop was prevented by providing log cabins free of rent to poor white families, whose duties included fighting summer lightning fires. "These men are required to do three things: first, they are to guard the orchards from fire, and if a small fire occur, as it often does in the summer time by lightning striking and igniting a resinous pine tree, they and their families must extinguish it. If it gets beyond their control they are to blow horns, summoning the neighboring tenants, sending all around for help, fight the fire until it is put out..." (Gamble 1921). In other areas fire was prevented because it consumed pine straw, which in many parts of the South was sold as stable bedding and "fertilizer on the cotton fields" (Mattoon 1922).

The slow and patchy reproduction characteristic of unmanaged longleaf under conditions of frequent growing season fires was a legitimate concern. Early foresters quickly discovered, however, that exclusion of fire led to establishment of dense loblolly or slash pine understory where longleaf forests had been removed or damaged by turpentining (Sherrard 1903, Figure 16). While it must have been apparent that this kind of succession would eventually lead to replacement of longleaf, it was sufficiently good news in a landscape recently denuded of its primeval forest cover, that within a few years, fire exclusion and a program of educating the public "to a sentiment against fires" became the general forest prescription for the South.

Pine Plantation

Pine plantations scarcely existed in 1900. The earliest recorded plantations in the South were three small plots established by farmers in 1892, 1896 and 1907 (Wakeley 1935). The first large attempt at plantation by the U.S. Forest Service, 900 acres on the Choctawhatchee and Ocala National Forests in 1911, proved to be an almost complete failure. Wakeley knew of only 500 acres successfully established by 1919. Problems with technique were soon worked out, however, and Table 3 shows the extent of pine plantation in the nine states within the range of longleaf pine by 1931. By this time over 20 lumber and paper companies were involved and accounted for at least 78% of the acreage.

Figure 16. The first documented study showing the effects of exclusion of fire and hogs from longleaf pine. A dense forest of slash pine is regenerating in a fenced plot after exclusion of fire and hogs for several years. Old boxed longleaf survivors and scattered slash pine make up the canopy (Sherrard 1903). Sherrard aimed to produce a similar forest on all pine lands in the two counties being studied. Southeastern South Carolina. Photo, Sherrard 1903.

Fire was a threat to pine plantations, but establishment of increasingly large areas protected from fire in the 1930s and 1940s made it seem feasible to plant loblolly and slash pine as a commercial crop. Pine plantation was expanded by large timber corporations in the 1940s and there were 12,460,000 a (5,046,300 ha) established in the years 1965 to 1967 (Boyce 1979). Forced into more marginal lands by development pressures, timber companies found it increasingly desirable to produce pine pulpwood and sawtimber using intensive management. In the former longleaf region, there are at present about (15.3 million ac) (6.2 million ha) of pine plantation, primarily loblolly and slash pine, but also some shortleaf and a small amount of longleaf in the former longleaf pine region (Boyce 1979, Outcalt and Outcalt 1994).

Expansion of agriculture and developed land

While much mixed pine-hardwood is now converted to plantation after logging, much is also cleared and converted to cropland, the second larg-

Table 3. The first pine plantations: 1892-1931. Data are from Wakeley (1935), with exception of the acreage before 1928 in South Carolina, from Boyce (1979). A small amount of planted trees (<5%) were hardwood.

	Before 1928	1928	1929	1930	1931	TOTAL
Virginia	337	47	349	316	401	1,450
North Carolina	1,525	306	544	270	468	3,113
South Carolina	3,229	—	112	481	745	4,567
Georgia	1,500	6	800	2,542	154	5,002
Florida	966	0	34	1,468	1,867	4,335
Alabama	89	50	328	266	34	767
Mississippi	—	—	—	535	594	1,129
Louisiana	19,540	9,273	10,583	6,556	2,474	49,426
Texas	—	—	—	260	—	260
						70,049

est land use category in the region. While commercial dairy operations have proliferated since 1900, total pasture probably has declined. After World War II mules and horses were retired by tractors, and surplus pasture lands went into cropland or succeeded to loblolly pine (Boyce 1980). The relative percentages of land in cropland and forest are the net result of a complexity of changes which include forest succession of abandoned cropland on small uncompetitive farms between 1940 and 1965, and clearing of new cropland from woodland by large farming operations. The 1982 Census of Agriculture reported 7,814,000 acres in pasture (6.4% of the uplands) and 25,589,000 acres in cropland (20.8% of the uplands) in the 412 counties of the former longleaf pine region (Table 1).

The logging boom of the late 19th century left in its wake cutover lands and dense, scrubby second growth, and efforts of crusading fire exclusionists guaranteed that over much of the region, the sunny, open, fire-maintained woodlands would be seen no more. For the inhabitants who lived during the first decades, seeing the forest of centuries fall around them was often a disheartening experience that transformed their world. One respondent to a timber survey in 1882 in Currituck County, North Carolina noted bitterly:

"The avaricious and insatiable saw mills, together with the desire of every man who could buy a pair of oxen and 'Carry-Log', have demolished and transported nearly all of our pine... This certainly looks like a gloomy report, but more truth than poetry" (Hale 1883).

Still, within the 3% of the landscape that still supports natural longleaf pine today, there is a remarkable galaxy of sites large and small, only one generation away from logging and turpentining, which have recovered nicely. These we may still be able to maintain, and perhaps we can restore more of Bartram's "...expansive, airy pine forests...of the great long-leaved pine...the earth covered with grass, interspersed with an infinite variety of herbaceous plants, and embellished with extensive savannas, always green..."

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Appendix I.

CHRONOLOGY OF MAJOR EVENTS IN THE DECLINE OF THE LONGLEAF PINE ECOSYSTEM:

1565-1732	Land clearing, hogs and other feral livestock introduced into the woods, small-scale naval stores production.
1714	Introduction of water-powered sawmills. Beginning of sawtimber removal from lands along waterways. By 1764 there were 40 in operation along the Cape Fear River in N.C.
1750	Feral hogs reach saturation density on open range in Virginia and northeastern North Carolina, eliminating much longleaf seedling establishment.
1815	First steamboat in the Carolinas; ten in use in South Carolina by 1826. Introduction of steam power marks the beginning of the Industrial Revolution in the South.
1833	Construction of first railroad in the U.S., between Charleston and Hamburg, South Carolina.
1834	Introduction of the copper still for distillation of turpentine. Beginning of era of massive turpentining operations.
1840	Longleaf pine largely decimated in Virginia after 200 years of small scale naval stores production as a cottage industry.
1850	Turpentine production peaks in North Carolina, begins to spread south as forests are exhausted.
1860	Feral hogs reach saturation density on open range in most of the range of longleaf pine.
1850-1870	Rapid proliferation of steam technology for logging railroads, steam skidders, steam-powered sawmills.
1865-1870	Large sales of southern lands to northern investors, particularly railroads. Sales of surplus lands by railroads to logging companies after railroad construction.
1880-1890	Beginning of standardization of railroad track sizes and linking of formerly isolated railroad lines, making overland transport of lumber practicable.
1870-1920	Massive logging, powered by steam technology. Most remaining virgin forests in the South logged.
1880-1930	Stock laws and/or fence laws passed in most of the range of longleaf pine. Last major stand regeneration occurs in many areas, in the years between the end of open range grazing and the beginning of modern fire suppression.
1920-1950	Most of the range of longleaf comes under effective fire suppression. Dense second-growth forest succession replaces diversity of savanna, woodland and open fire-maintained forests.
1920-present	Conversion of unmanaged woodlands to pine plantation.
1943	After much debate, U.S. Forest Service gives general approval to use of fire in managing woodlands. Many areas on public and private lands, however, are excluded from prescribed fire.

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