A Generational Change in Site Index for Naturally Established Longleaf Pine on a South Alabama Coastal Plain Site

William D. Boyer, *USDA Forest Service, Southern Research Station (retired), 520 DeVall Dr., Auburn, AL 36849-5418.*

ABSTRACT: *Research on longleaf pine (*Pinus palustris *Mill.) has been carried out for over 50 yr on a coastal plain site in south Alabama. Studies have included the original second-growth stands and also naturally established third-growth stands. Site index data revealed that estimated site index values for third growth generally exceeded those for second growth. Age 50 site index in 16 study compartments with second growth near index age averaged 66ft. Estimated site index for third-growth stands recorded in 17 different compartments averaged 81 ft. Nine the 16 compartments with second-growth stands now include third growth about 40 yr in age. This provided an opportunity to make a direct comparison of generational site index differences within the same compartments. Site index for second growth averaged 65 ft (range 61 to 70 ft), while third growth averaged 83 ft (range 77 to 87 ft). Reasons for this large increase in apparent site quality are unknown, but since soils are the same, some climate changes may be suspect. South. J. Appl. For. 25(2):88–92.*

Key Words: Longleaf pine, *Pinus palustris* Mill., site index change, natural stands, second-growth stands, third-growth stands, south Alabama.

The ecology and management of longleaf pine (*Pinus palustris* Mill.) has been the principal goal of research for over 50 yr on the Escambia Experimental Forest[1] in south Alabama. All merchantable longleaf pine on land now occupied by the Experimental Forest was cut during the period from 1900 to 1919. When the Experimental Forest was established in 1947, it was occupied by relatively low density, naturally established, second-growth longleafpine stands, most averaging between 35 and 45 yr of age. About 82% of the area was typed as upland longleaf pine, and the remainder as slash pine (*P. elliottii* Engelm.) hardwood stream bottoms. At the time of establishment, the Experimental Forest was divided into 40 ac compartments, some of which became management units for early studies.

Research studies have included maturing second-growth stands and also naturally established third growth originating in 1947 and later years. Age 50 site index for longleaf pine stands, obtained in conjunction with research studies over the years, indicated that third-growth stands seemed to have consistently higher site index values than second-growth stands.

This possibility became apparent when reviewing results of two early studies with extensive site index data from 16 compartments obtained when second-growth longleaf pine stands averaged 55 yr in age. Site index among these compartments averaged 66.5 ft in one study and 66.4 ft in the other. Recent estimates of site index for third-growth stands, obtained from studies in 17 compartments, averaged 8 1.3 ft. All of these 33 compartments are intermixed, covering a similar range of soil-site conditions.

Nine of the 16 compartments in the two early studies include third-growth stands about 40 yr old. This provided an opportunity to make direct comparisons of site index values between second- and third-growth stands within the same compartments. A study to obtain site index values for these third-growth stands was carried out in the spring of 1998. The information derived from this study, plus the two earlier studies, is reported here.

Methods

Second-Growth Study 1

A study of management systems was initiated in 1948, with twelve 40 ac compartments assigned to even-aged and 12 to uneven-aged management. Stand development within the 12 uneven-aged management compartments was moni-

[1] Maintained by the USDA Forest Service Southern Research Station, in cooperation with the T.R. Miller Mill Company.

NOTE: W.D. Boyer can be reached at (334) 8268700; Fax: (334) 821-0037; E-mail: boyer@forestry.auburn.edu. Manuscript received January 24, 2000, accepted August 31, 2000. This article was written by a U.S. government employee and is therefore in the public domain.

tored through 100% inventories on a 5 yr remeasurement schedule. Measurements were begun in three compartments the first year and three more in each succeeding year over a 4 yr period. Four other compartments were similarly monitored. Some improvement cutting was done, as needed, following the periodic inventories.

As apart of this study, a cruise of all 16 compartments was conducted in 1963 to provide data on site index, age, and stand basal area within each compartment. Each compartment was divided into 16 square 2.5 ac units. Nine sample points were systematically located within each unit.

At each sample point, the nearest *dominant* longleaf pine was selected as a sample tree. Ring count at breast height (4.5 ft), diameter at breast height (dbh), and total height were recorded. Basal area at each sample point was determined with a 10 factor wedge prism. Dbh was measured to nearest 0.1. in. and height to the nearest foot. Sample tree age was recorded as ring count plus 7 yr. From this cruise, average basal area, age, and site index were determined for each compartment and each 2.5 ac unit within the compartment. Longleaf pine site index estimates, using age and total height of sample trees, were derived from Misc. Publ. 50 (USDA Forest Service 1976). Only longleaf pine uplands were included in this cruise. For the 12 compartments as a whole, 92% of the area was in the upland longleaf pine type.

Field plot data for this cruise could not be located. Information reported here was obtained from an unpublished final report[2] that included data for all 16 compartments.

Second-Growth Study 2

This study was superimposed on Study 1. Field work was carried out in 1964. The objective was to evaluate the relationship between site index of second-growth longleaf pine and several soil and physiographic factors. Details on the design and conduct of this study were obtained from an unpublished report.[3] All field plot data were located.

Within each 2.5 ac unit of the first study were nine sample points, each 99 ft apart and forming a 198 ft square grid. One out of the possible four 99 ft square grids was randomly selected as a sample plot provided soils were relatively uniform. Otherwise, one of the remaining three plots was selected where soil conditions were more uniform. The dormant tree nearest each plot corner was selected as a sample tree. Measurements were taken as described for Study 1. Site index for each plot was the average for the four sample trees. Data were obtained for a total of 136 plots in the 16 compartments.

Third-Growth Study

Uneven-aged management in the 12 compartments assigned this method was changed to progressive strip shelterwood. Strips 165 or 219 ft wide were clearcut along the edges of three compartments (74, 103, 107) in January 1959; three more (75, 81, 125) in January 1960; and the final three (83, 102, 115) in February 1961. Three compartments (103, 81, 102) also had an additional parallel strip cut through the compartment center. Longleaf seedlings, originating mainly from a good seed crop in 1958, were released on clearcut strips.

Studies monitoring the survival and growth of longleaf seedlings were established on edge strips in five of the nine compartments, including the three compartments cut in 1960 and two (102, 115) cut in 1961. Prior to logging, longleaf seedlings were marked and monitored in clearcut strips and within the adjacent forest. One study recorded logging damage, and results were published (Boyer 1964). Another study followed seedling response to release from all overtopping competition compared to similar unreleased seedlings. Due to study requirements, removal of competing woody vegetation on the five study strips was complete. Seedlings were measured annually through December 1965, when most dominant seedlings, 7 yr from seed, were in active height growth (Figure 1).

Clearcut strips in all nine compartments provided an opportunity to obtain estimates of site index for third-growth longleaf pine within the same units that already had values for second growth. None of these third-growth stands have been cut. Plots were established in all clearcut strips, including nine strips on compartment edges plus three through compartment centers for a total of 12. Sample points were established along the centerline of each strip. The 12 strips had a total of 78 plots. The 6 compartments with edge strips only had 6 or 7 plots; the 3 compartments with both edge and center strips had 10 or 14 plots. All plots within a compartment were combined to provide data for that unit.

At each sample point, four quadrants were established, and the dominant or codominant tree nearest the sample point in each quadrant was selected as a sample tree. This provided four trees per plot. Diameter and total height of each sample tree were recorded. Stand basal area at each sample point was obtained with a 10 ft^2/ac wedge prism. Edge strips in the five compartments in the seedling release study were comprised almost entirely of even-aged third-growth longleaf pine. On these strips, one or two of

Figure 1. Longleaf pineseedlings in aclearcutstrip in compartment 81.6 yr after overstory removal.

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[2] USDA Forest Service, Southern Forest Experiment Station, "Management Systems" Final Progress Report by T.C. Croker, Jr., dated October 13, 1964.

[3] USDA Forest Service, Southern Forest Experiment Station, "Factors affecting site index of some second-growth longleaf pine stands in south Alabama," Establishment and Final Progress Report by Phillip J. Craul, dated December 3, 1964.

the sample trees in each plot were randomly selected and cored for a ring count. Sample trees not cored were assumed to be the same age as cored trees on that plot. The average height and diameter of trees selected for ring counts were compared to the average for all unselected trees on each strip to see that both groups were representative of the population on that strip. Logging on the seven remaining strips removed only merchantable trees, so some sample trees could be residuals from the second-growth stand. For this reason, ring counts were obtained for all four sample trees on each plot.

Height and age (ring count at 4.5 ft plus 7 yr) were used to estimate site index for each sample tree. Site index values were obtained using equations developed from site index curves in Misc. Publ. 50 (Farrar 1973) rather than scaling directly from the curves as in the earlier studies. Sample trees with an indicated age over 51 yr were excluded from site index evaluations. This age was selected so that trees originating from or after a heavy seed crop in 1947 (the earliest seed crop providing for third-growth stands on the Experimental Forest) could be included. Most regeneration came from the 1958 seed crop, which was released from the parent overstory within 2 yr of establishment. Only 3 of 43 trees selected for ring count on the 5 study strips exceeded 5 1 yr in estimated age and were excluded. On the remaining 7 strips, a total of 44 out of 184 sample trees exceeded 51 yr in estimated age and were excluded. All plots had one or more sample trees.

Results

Second-Growth Study 1

For the 16 compartments in this study, average site index was 66.5 ft with a range from 61 to 76 ft and standard deviation of 3.8 ft. Average age was 54.8 yr with a range from 44 to 63 yr. Basal area was recorded at the beginning of final 5 yr remeasurement period for each compartment, which ranged from 1954 to 1959. Average basal area was 33.7 ft^2/ac with a range from 19 to 59 ft^2/ac.

Second-Growth Study 2

This study had fewer sample trees per 2.5 ac unit than the first study and thus represented a smaller sample. The purpose was to ensure relatively uniform soil conditions within a plot in order to determine the relationship between identified soil types and longleaf pine site index. A total of nine soil types were represented in this study. Variation of site index within soil types was so great, that means for each type differed significantly only between the two extremes (Craul 1968).

Average site index for all 16 compartments was 66.4 ft, with range of 61 to 78 ft and standard deviation of 4.2 ft. Average age was 54.9 yr, with a range of 46 to 63 yr. Average basal area was 50.5 ft^2/ac with a range from 34 to 80 ft^2/ac.

Site index and age of second growth sample trees in the first two studies were nearly identical, which was expected since the second study was a subsample of the first. However, stand basal area differed, averaging 34 ft^2/ac in the first and 50 ft^2/ac in the second study. All plots in the second study were randomly selected from those included in the first except when soil-site conditions were not uniform. Then a different plot was selected. Within the 16 compartments, the coefficient of variation in basal area for the second study averaged 22%, suggesting more uniform stand conditions than in the first study, where coefficient of variation in stand density averaged 62%. The stand density difference between the two studies did not affect estimated site index or age. Other studies also suggest that site index (or height growth) in natural longleaf pine stands is relatively unaffected by stand density (McClurkin 1953, Sparks et al. 1980).

Only 9 of the 16 compartments covered in these two studies contained third-growth stands. Second-growth data for these 9 compartments, from Study 2 where field data were available, differs little from the average for all 16 compartments. Average site index for the 9 compartments was 65.5 ft, with a standard deviation of 3.2 ft. Average age was 55.3 yr, dominant sample tree height 67.7 ft, and basal area 50.6 ft^2/ac. (Table 1).

Third-Growth Study

Estimated site index for third-growth stands averaged 83.1 ft, with a standard deviation of 2.9 ft. Average age was 40.1 yr, dominant-codominant sample tree height 73.5 ft, and basal area 69.4 ft^2/ac. (Table 2).

Three of the nine compartments with third-growth stands had strips cut through the center as well as along the edge. Estimated average site index for all plots in each center strip differed from that in the edge strip of the same compartment by an average of 1.4 ft, suggesting that both edge and center strips were sampling similar populations.

Table 1. Plot and tree variables for dominant longleaf pines providing site index values for second-growth stands in south Alabama.

Compartment	Plots (no.)	Basal area (ft^2/ac)	Age (yr)	Tree height (ft)	Site Index (ft age 50)
74	8	44.9	60.8	72.5	67.9
75	8	53.9	63.4	72.4	65.8
81	5	58.5	59.4	74.1	68.7
83	9	46.7	55.3	69.9	66.9
102	7	50.3	50.6	65.9	65.9
103	8	34.5	55.8	64.4	61.6
107	9	80.3	46.0	67.3	70.1
115	11	41.2	55.0	64.2	61.8
125	9	45.3	51.1	58.8	60.6
Mean		50.6	55.3	67.7	65.5
SD		12.38	5.16	4.68	3.22

Table 2. Plot and tree variables for dominant and codominant longleaf pines providing site index values for third-growth stands in south Alabama.

Compartment	Plots (no.)	Basal area (ft^2/ac)	Age (yr)	Tree height (ft)	Site Index (ft age 50)
74	7	55.7	41.5	72.7	81.2
75*	7	81.7	38.8	75.0	84.8
81*	10	88.0	39.6	74.3	84.2
83*	6	61.7	39.2	76.8	87.2
102	14	55.7	40.3	71.1	80.6
103	14	53.6	40.8	68.9	77.1
107	6	58.3	40.0	74.7	84.6
115*	7	81.4	40.7	73.1	82.6
125*	7	88.6	39.7	75.2	85.8
Mean		69.4	40.1	73.5	83.1
SD		14.21	0.80	2.26	2.91

* Compartments with seedling survival and growth studies.

The observed general increase in site index for longleaf pine on a south Alabama Coastal Plain site is supported by the direct comparison of site index values for naturally established second- and third-growth longleaf pine within the same compartments. Estimated site index of third-growth stands exceeds that for second-growth stands by an average of 17.6 ft (Table 3).

Discussion

An average increase of 17.6 ft between generations in estimated site index for naturally established longleaf pine was entirely unexpected. The average height of 40-yr-old third-growth stands, at 73.5 ft, was already 8 ft greater than site index values for second-growth stands. Yield tables for naturally established longleaf pine (Farrar 1985) indicate that a site index increase of this size should result in a 30 to 35% increase in volume yield through age 50.

A bias does exist in the comparison of site index values for second- and third-growth longleaf pine in this study. Values for second-growth stands, according to instructions in reports and to Craul (1968), were based on dominant pines only. Third-growth estimates were based on both dominant and codominant pines. Site index values for southern pines are generally based on average heights of both dominant and codominant trees, and this procedure was followed when evaluating third-growth stands. Site index estimates may have been higher if only dominant trees had been selected.

Table 3. Site index differences between second- and third-growth longleaf pine stands within same management units in south Alabama.

	Estimated Site Index (ft age 50)		
Compartment	Second growth	Third growth	Difference
74	67.9	81.2	13.3
75	65.8	84.8	19.0
81	68.7	84.2	15.5
83	66.9	87.2	20.3
102	65.9	80.6	14.7
103	61.6	77.1	15.5
107	70.1	84.6	14.5
115	61.8	82.6	20.8
125	60.6	85.8	25.2
Mean	65.5	83.1	17.6
SD	3.22	2.91	3.69

Longleaf pine stands originating from the same 1958 seed crop have been monitored in another study that provided early estimates of site index for third-growth stands. In 1980, at stand age 21, estimated site index of dominant-codominant trees averaged 78 ft. When remeasured at age 39, estimated site index for these trees averaged 83 ft. Four feet of this 5 ft gain in estimated site index occurred between age 21 and 30, with only a 1 ft gain between age 30 and 39. This suggests that site index at index age may be little, if any, greater than present estimates.

Early growth of second-growth stands appeared normal, based on examination of both increment cores and recently cut stumps of second-growth trees on the Experimental Forest. Less than 5% of trees showed any signs of early suppression followed by later release. Early radial growth of second-growth trees, based on radius of first 25 rings, actually exceeds that of third-growth trees, probably because of higher average density of third-growth stands. Periodic fire was common throughout the development of both second- and third-growth stands represented in this study. The area now included within the Experimental Forest was open to forest grazing both before and for some time after its establishment.

Periodic fires may have had some negative impact on site index values for both second- and third-growth stands in this study. Regular burning of longleaf stands originating from the 1958 seed crop has, through age 36, resulted in a reduction of 6 ft in estimated site index compared to similar unburned stands (Boyer 2000).

While site index variations of longleaf pine within a localized area are largely determined by soil-site conditions, broad variations throughout its range seem influenced mostly by climate. One study covered a number of sample locations from south Mississippi to east Texas. Total January through June rainfall was the single variable most closely associated with site index (McClurkin 1953). Some recorded soil variables were significant only after effects of rainfall were removed.

Some changes in productivity of longleaf pine have been reported that could be related to the increase in site index. First, tree ring analysis of longleaf pines ranging from about 100 to 400 yr in age indicated an unexpected increase in radial growth beginning about 1950 and continuing to the present (West et al. 1993). This growth increase was largely attributed to some external source other than climate. Correlations of increased tree growth with temperature, precipitation, and Palmer drought severity index were too weak to explain the response. The authors suggest that the increase in atmospheric CO, may play some role. Longleaf pine seedlings have responded to increased CO, levels with increased growth (Runion et al. 1999).

Second, cone production by longleaf pine, averaged for five to nine sites throughout the Southeast, had more than doubled during the 10 yr after 1986 compared to the preceding 20 yr (Boyer 1998). An analysis of 40 yr of cone production at one site showed correlations of cone crop size with both temperature and precipitation at certain selected points over the 4 yr beginning the year before flower initiation through year of cone maturity (Pederson et al. 1999).

The large increase in longleaf pine site index has been observed at only one location, and the extent that this may be a regional phenomenon is unknown. Factors responsible for this increase are also unknown. Since soil-site conditions are the same, however, some climatic factors may be suspect.

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