Longleaf Pine – Growth and Yields and Mean Annual Increments in Planted Stands from the Western Gulf Region, South Carolina and Georgia Long-term Studies

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Background and Introduction

Mean annual increment (MAI) estimates of wood growth and yields in longleaf pine (*Pinus palustris*) stands are valuable tools for rotation age determinations and financial decisions. MAI is often expressed in terms of tons/acre/year of wood+bark growth, either to a merchantable top (for pines to a 3 inch top for pulpwod and to a 6, 8, or 10 inch top for chip-n-saw, sawtimber, or poles) or as total tons (to the top of the tree stems). MAI is pine species specific and will vary due to soils, land use history, trees per acre, forest management intensity, and other factors. Accurate estimations of when (age or age range) maximum MAI is realized is also valuable in decision-making for pine species. For this paper we used the volume and weight equations for longleaf pine by Baldwin and Saucier (1983) on growth data from several longleaf studies in the SE US.

Longleaf pine, due in part to its period in the grass stage (no height growth) that may be from 2 to 20 years depending on soils, site, genetics, and management factors, achieves its maximum MAI later than loblolly and slash pine assuming they are grown on soils and land use history conducive to growing all three species. Studies in the last 30 – 40 years on loblolly and slash pine growth over time tends to reach a maximum MAI at age 15- (slash pine at high planting densities, intensive management, and good soils) to 25-years (loblolly and slash pine with modest levels of management, moderate planting densities, on low fertility soils). Longleaf pine’s maximum MAI tends to occur earlier on better soils/sites with better management and later on poorer soils/sites and lower levels of management (Figure 1).

Longleaf Plantation wood+bark Growth and MAI Values

Planted Western Gulf Region Studies

Work done by Geolz and Leduc (2001) with long-term data on unthinned longleaf plantations in the Gulf Coastal Plain (Alabama, Mississippi, Louisiana, east Texas) indicate that wood maximum mean annual increment occurs at age 30-years on the best sites (site index; SI25 > 60 feet) at 5.5 tons/acre/year, at age 35-years on moderately productive sites (SI25= 50-60 feet) at 4.4 tons/acre/year and on poor sites (SI25<50 feet) at age 55 – 60-years at 1.85 tons/ac/year.

The low number or trees per acre (TPA) in the SI<50 feet longleaf plantation plots (326 TPA at age 15-years, 158 TPA at age 25-years and 120 TPA at age 40-years, Table 1) contributed to low tons/acre wood production and tons/acre/year production rate (Table 1). The SI=50-60 feet and SI>60 feet TPAs were much higher than the low SI (<50 feet) at 510 and 815/acre at age 15-years, 565 and 591 TPA at age 25-years and 363 and 384 TPA at age 40-years, respectively (Table 1). The 510 and 815 TPA at age...
15-years for the moderate and high SI sites are much higher than the average surviving TPAs (354/acre) on the most recent Conservation Reserve Program CP36 plantings (1999 – 2006) on former old-field sites in Georgia summarized by Dickens and others (2017) with an average planting density of 500 TPA, an average basal area of 100 square feet/acre, and an average MAI of 3.9 tons/acre/year through age 15-years.

Figure 1. Planted longleaf pine plantation mean annual increments (MAIs) by Site Index (base age 25-years) in the Gulf Coastal Plain.
South Carolina, Cut-over, Low Fertility, Well to Excessively Well Drained Sandy Soils Sites

Four planted longleaf long-term studies were installed in South Carolina on low fertility, well to excessively well drained sandy soils (Alpin, Lakeland; Lamellic and Typic Quartzpsamments and Blanton; Grossarenic Paleudults) where depth to a restrictive layer (to slow down water and nutrient movement through the soil profile) was 50 to over 80 inches. Longleaf pine growth, yields (G&Y), and MAIs on these sites were on the low end of the G&Y and MAI spectrum. Nonetheless, knowledge of G&Y and MAIs on these poor sites (where loblolly and slash pine will often not grow to merchantability in a reasonable amount of time) can be useful in estimating longleaf wood growth over time.

MAIs on these cut-over, poor sites ranged from 2 to 3+ tons/acre/year. We noticed in our plots that lower topographical positions and concave landforms had much better MAIs then upper topographical positions and convex landforms. When planning a cruise or inventory in longleaf pine stands that have these topographic and landform shapes install inventory plots in all these topographic positions and landform shapes to accurately estimate longleaf pine wood growth, yields and MAIs.

Sand Hills State Forest Planted Longleaf Pine Long-term Study

The Sand Hills State Forest (Chesterfield County, SC) 1963 planted longleaf stand (at a 6x6 feet spacing, a common planting spacing in the 1960’s) was a cut-over site on a deep, excessively well drained soil with low fertility (4 or less lbs/ac of available-phosphorus). The stand was thinned at age 21-years, removing 8 tons/ac (leaving 20 tons/ac with pre-thin basal area (BA) of 90 square feet/acre and post-thin BA of 64 square feet/acre) and at age 31-years removing 20.5 tons/acre (leaving 43 tons/acre with a pre-thin BA of 100 square feet/acre and a post-thin BA of 60 square feet/acre). This
The study area was chosen due to the level topography and relatively homogeneous longleaf tree sizes and stems/acre. Based on this study area and no fertilization this longleaf stand produced 28 tons/acre merchantable wood though age 21-years for a MAI of 1.33 tons/acre/year (Figure 3 and 4). Merchantable wood yield through age 31-years was 71.5 tons/acre or a MAI of 2.3 tons/acre/year. Merchantable wood growth and yield after the second thinning (age 32- to age 42-years) was 22.5 tons/acre and a MAI of 2.25 tons/acre/year (Figures 3 and 4).

**Yemassee, South Carolina Planted, Unthinned Longleaf Long-term Studies**

Three planted, unthinned longleaf pine studies were installed in Yemassee, South Carolina to determine the benefit of NPK fertilization on tree and stand growth and pine straw production. The three sites were low fertility (soil available-P <6-10 lbs/acre), well to excessively well drained sandy soils (Grossarenic Paleudults and Typic Quartzipsamments; SI25=45-55 feet). Once paired plots (no fertilizer or NPK) were installed in each stand, baseline measurements of diameter (dbh = diameter at breast height = 4.5 feet above groundline), total height and trees/plot (therefore trees/acre) were taken. These baseline measurements prior to a first thinning allowed us to have wood growth and yields and MAIs for each stand. Table 1 is the baseline data for the three planted (6x10 feet original planting spacing = 726 TPA) longleaf stands. Longleaf pine wood growth and yields were 65 tons/acre and a MAI of 3.1 tons/acre/year through age 21-years for stand #12, 38 tons/acre and a MAI of 2.1 tons/acre/year through age 18-years for stand #16 and 53 tons/acre and a MAI of 2.5 tons/acre/year through age 21-years for stand #2 (Table 1).

![Figure 3. MAI from the Sand Hill State Forest, South Carolina study area. A cut-over, mechanically prepared, low fertility, deep, excessively drained sand (Alpin soil series), 1963 planted longleaf (6x6 feet spacing), thinned @ age 20- and 32-years.](image-url)
Figure 4. Wood growth over time from the Sand Hill State Forest, South Carolina study area. A cut-over, mechanically prepared, low fertility, deep, excessively drained sand (Alpin soil series), 1963 planted longleaf (6x6 feet spacing), thinned @ age 20- and 32-years.

Table 1. Planted, unthinned longleaf stands on low fertility, well to excessively well drained sandy soils with growth parameters for the three stands.

<table>
<thead>
<tr>
<th>Longleaf study areas</th>
<th>Mean TPA (range)</th>
<th>Mean dbh (in) (range)</th>
<th>Mean ht (ft) (range)</th>
<th>BA/ac (ft²) (range)</th>
<th>MAI (tons/ac/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stand #12 21-yrs old</td>
<td>550 (450-600)</td>
<td>5.7 (5.3-6.0)</td>
<td>40 (38-42)</td>
<td>100 (90-105)</td>
<td>3.1</td>
</tr>
<tr>
<td>Stand #16 18-yrs old</td>
<td>450 (410-510)</td>
<td>5.2 (4.6-5.8)</td>
<td>41 (37-46)</td>
<td>65 (53-86)</td>
<td>2.1</td>
</tr>
<tr>
<td>Stand #2 21-yrs old</td>
<td>470 (420-520)</td>
<td>5.4 (5.2-5.7)</td>
<td>44 (42-47)</td>
<td>77 (61-92)</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Planted stands in 1994-96; this is an example of SI estimates not always accurate in estimating MAIs → look at hts vs MAIs (mean hts shown here not co-, dom hts)
Old-field planted, unthinned Longleaf Stands in Screven and Tift Counties, Georgia

Long-term study areas were established in January-February 2004 on two former old-fields with moderate fertility in planted (December 1986 @ 605 TPA) longleaf stands to address the value of a single or split NPK fertilizer application. These two study areas are in Screven and Tift County, Georgia. Three (Tift County) or four replications (Screven County) of control (no fertilizer), single dose NPK, or $\frac{1}{2} + \frac{1}{2}$ split dose 3 years apart NPK) plots were installed in each stand at age 17-years. Diameters (dbh; diameter at breast height; 4.5 feet above groundline), total height and height to a fork, ramicorn branch, stem canker, or other defect were noted on each tagged and numbered tree in each plot. All living trees were remeasured at age 21-years. The single and first of the split NPK treatments were applied in March 2004. The second of the split NPK application occurred in those plots on February 2007 (age 20-years). Wood growth and yield and MAIs reported here are at age 17- and 21-years prior to thinning at each site (Table 2 and 3). The wood and pine straw gains from the single and split application of NPK was not enough to justify the cost of fertilization on both cases based on data through age 27-years (after the first thinning at both sites). Therefore this paper will focus on the control (no fertilizer) wood growth and yields and MAIs.

Wood yields at the Screven County, Georgia site were 112 tons/acre at age 17-years and 145 tons/acre at age 21-years (Table 2) for the control (no fertilizer) plot longleaf pines. This equates to 6.6 tons/acre/year MAI at age 17-years and 6.9 tons/acre/year at age 21-years.

Wood yields at the Tift County, Georgia site were 99 tons/acre at age 17-years and 133 tons/acre at age 21-years (Table 2) for the control (no fertilizer) plot longleaf pines. This equates to 5.8 tons/acre/year MAI at age 17-years and 6.4 tons/acre/year at age 21-years.

These two old-field planted longleaf stands in Georgia tons/acre wood+bark estimates are based on volume and weight equations developed in slower growing, higher stocked stands, most likely with less forking and ramicorn branching than found in these two fast growing stands so the tons/acre yield estimates may be high. Conservatively and until we have new volume and weight equations for longleaf pine grown on old-field sites (working on this as of 2018 with a cooperative agreement with the Natural Resources Conservation Service; NRCS), these tons/acre estimates may be 10-20% high. These same volume and weight equations were used for the slower growing, lower fertility, poorer soils on cut-over sites in South Carolina, most likely are giving us better planted longleaf tons/acre wood+bark growth and yield and MAI estimates.
Table 2. Screven County, Georgia old-field planted, unthinned longleaf (moderate fertility, with low hardwoods/acre at age 17- and 21-years; basal area/acre, tons/acre wood+bark production and MAI estimates.

### Longleaf pine growth parameters through age 21-years-old Screven Co site
(SI=70' base age 25-yrs, 60% seeding/acre planted; 320 TPA surviving at age 21-yrs, with 54% stem defect) Bonaeno and Blanton soil series

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Basal area/acre (ft²) age 17-yrs</th>
<th>Basal area/acre (ft²) age 21-yrs</th>
<th>Tot tons/ac age 17-yrs</th>
<th>Tot tons/ac age 21-yrs</th>
<th>MAI (tons/ac/yr)</th>
<th>MAI (tons/ac/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>121</td>
<td>135 (+14)</td>
<td>112</td>
<td>145</td>
<td>6.6</td>
<td>6.9</td>
</tr>
<tr>
<td>½+ 1/2 NPK</td>
<td>113</td>
<td>125 (+12)</td>
<td>102</td>
<td>138</td>
<td>6.0</td>
<td>6.6</td>
</tr>
<tr>
<td>Full NPK</td>
<td>120</td>
<td>136 (+16)</td>
<td>96</td>
<td>143</td>
<td>5.6</td>
<td>6.8</td>
</tr>
</tbody>
</table>

MAI estimates may be 10-20% high due to excessive forking and volume and weight eqns used; conservative MAI through the first 20- to 25-yrs may be 5-6 tons/ac/yr on these old-field sites.

Table 3. Tift County, Georgia old-field planted, unthinned longleaf (moderate fertility, with low hardwoods/acre at age 17- and 21-years; basal area/acre, tons/acre wood+bark production and MAI estimates.

### Longleaf pine growth parameters through age 21-years-old Tift Co site
(SI=70' base age 25-yrs, 60% seeding/acre planted; 335 TPA surviving at age 21-yrs with 46% stem defect) Lee field and Albany soil series

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Basal area/acre (ft²) age 17-yrs</th>
<th>Basal area/acre (ft²) age 21-yrs</th>
<th>Tot tons/ac age 17-yrs</th>
<th>Tot tons/ac age 21-yrs</th>
<th>MAI (tons/ac/yr)</th>
<th>MAI (tons/ac/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>114</td>
<td>126 (+12)</td>
<td>99</td>
<td>133</td>
<td>5.8</td>
<td>6.4</td>
</tr>
<tr>
<td>½+ 1/2 NPK</td>
<td>113</td>
<td>129 (+16)</td>
<td>97</td>
<td>137</td>
<td>5.7</td>
<td>6.5</td>
</tr>
<tr>
<td>Full NPK</td>
<td>127</td>
<td>146 (+19)</td>
<td>120</td>
<td>164</td>
<td>7.0</td>
<td>7.8</td>
</tr>
</tbody>
</table>

MAI estimates may be 10-20% high due to excessive forking and volume and weight eqns used; conservative MAI through the first 20- to 25-yrs may be 5-6 tons/ac/yr.
Summary

The wood growth and yields and MAIs from the Western Gulf long-term studies through age 50-years based on site index and TPAs though age 15-years (and later years) may be reasonable values to use for that region. Based on the Western Gulf longleaf work, a longleaf site index of greater than 60 feet (base age 25-years) maximum MAI is reached at age 30-years and is producing 5.5 tons/acre/year. Site indexes of 50 to 60 feet reach a maximum MAI at age 35-years of 4.4 tons/acre/year. Site indexes less than 50 feet reach a maximum MAI at about age 45-years and level off to 1.8 tons/acre/year. Remember though that the high SI of 60 feet or greater had 591 TPA at age 25-years and the SI of 50-60 feet than 565 TPA, while the SI less than 50 feet had 158 TPA. Surviving TPA at a given age is an important factor in the amount of wood produced per acre.

The low fertility, cut-over, well to excessively well drained deep sandy soils longleaf pine MAIs of 2 to 3 tons/acre/year estimates from 20-years into the early 40-year old stands may be reasonable G&Y and MAIs to use for most of these soil series, and land use history sites for the Sand Hill regions of NC, SC, GA, Northern FL, AL and MS.

The two old-field planted longleaf stands in Screven and Tift County, Georgia wood+bark growth and yields and MAI estimates through age 21-years, prior to a first thinning may be on the high side considering the percentage of forked and ramicorn branch stems in these two stands, the faster growth rate and the lower number of stems/acre by age 17- and 21-yrs. Lowering the tons/acre wood+bark yields and MAIs by 10-20% in Tables 2 and 3 may be prudent until we have old-field, unthinned longleaf pine volume and weight equations, which we should have in 2019-2020. For now, conservatively, old-field planted longleaf (605 planted TPA with 325 TPA surviving at age 21-years average for both sites) MAIs of 5.0 to 6.0 tons/acre/years through age 20-years prior to thinning may be reasonable estimates.

These growth and yield (wood+bark production) and MAI curves and tables should be used as rough estimates for planted longleaf stands based on soils and land use history (cut-over low fertility sites versus former ag fields, crop-land, old-field and pasture sites with moderate to high fertility and no hardwood or woody competition for the first 10-20 years). Initial planting density and surviving trees/acre are also important factors in growth, yields and MAIs on a given soil and land use history. There is no substitute for a timber cruise if an inventory of a particular longleaf pine stand is needed.

Literature Cited:

