LONGLEAF

A diameter-distribution growth and yield model and decision support system for unthinned longleaf pine plantations

USER'S GUIDE

by Curtis L. VanderSchaaf[1]

Longleaf pine plantations located on the Solon Dixon Forestry Education Center in southern Alabama (upper left), the Harrison Experimental Forest in southern Mississippi (upper right), and the Tuskegee National Forest in Alabama (bottom).

TEXAS FOREST SERVICE
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PREFACE

 I appreciate your interest in LONGLEAF,

Curtis L. VanderSchaaf

Prior to the arrival of Europeans, it is estimated there were 60 million acres of the longleaf pine (*Pinus palustris* Mill.) ecosystem (Boyer 1990). However, by 1900 most of the longleaf stands were gone due to timber harvesting, agriculture, and fire suppression. When planting was conducted on cutover sites, rather than reestablishing longleaf, faster growing and more easily regenerated loblolly (*Pinus taeda* L.) or slash pine (*Pinus elliottii* Engelm.) were planted. Many papers compared growth and yield of older generation southern yellow pine stands – most of these showed an inferiority of longleaf to the other pines (Ware and Stahelin 1948, Wakeley 1969, Ting and Chang 1985).

However, with advances in genetics, better quality seedlings, and an increase in how to transport, store, and plant longleaf seedlings (South 2006), and the fact that we now know it is essential to control non-crop tree vegetation early in the life of the stand (e.g. Nelson *et al.* 1985, Haywood 2005), longleaf plantations are a viable economic alternative when compared to loblolly or slash. This is especially true when accounting for the significantly greater number of poles found in longleaf stands (South 2006) – the Timber Mart-South 2009 4th quarter Texas Stumpage Price report stated pine sawtimber on the stump averaged $28 per ton while pine power poles averaged $58 per ton.

Around the turn of the 20th century, most acres of longleaf stands were in the southeastern counties of East Texas (Bray 1904, Foster *et al.* 1917, Boyer 1990, Schmidtling 2001), such as Jasper, Newton, and Tyler counties (Figure 1). Currently, according to the Forest Inventory and Analysis program, there are only 45,000 acres of longleaf stands (Miles 2010). Many efforts are now underway to restore longleaf to its native range in Texas, as well as the Southeast in general. As part of this restoration process, the timber decision support system entitled LONGLEAF was developed to help landowners identify what planting density to select, an optimal rotation length, how various costs and revenues will impact management decisions, whether enrolling in a carbon sequestration program can be an attractive economic alternative, and if a plantation should be managed for the commercial harvesting of pine straw.

There are a few available decision support systems for longleaf plantations that can be purchased, but costs are generally high. WinYield was a freely available and commonly used model system but it is no longer available for download. A decision support system for naturally-regenerated longleaf pine stands in the Eastern Gulf is freely available (http://fwrc.msstate.edu/software.asp). Longleaf plantations can be modeled using the Forest Vegetation Simulator (http://www.fs.fed.us/fmsc/fvs/) but this program requires a fair amount of time to become familiar with how to conduct simulations. Yield tables are also available (Lohrey and Bailey 1977) for unthinned longleaf pine plantations located in Louisiana and Texas, but all stands were established at least prior to 1960 and therefore genetic stock, seedling quality, and regeneration practices were likely inferior to those utilized more recently. There are currently no freely available comprehensive decision support systems for longleaf pine plantations.

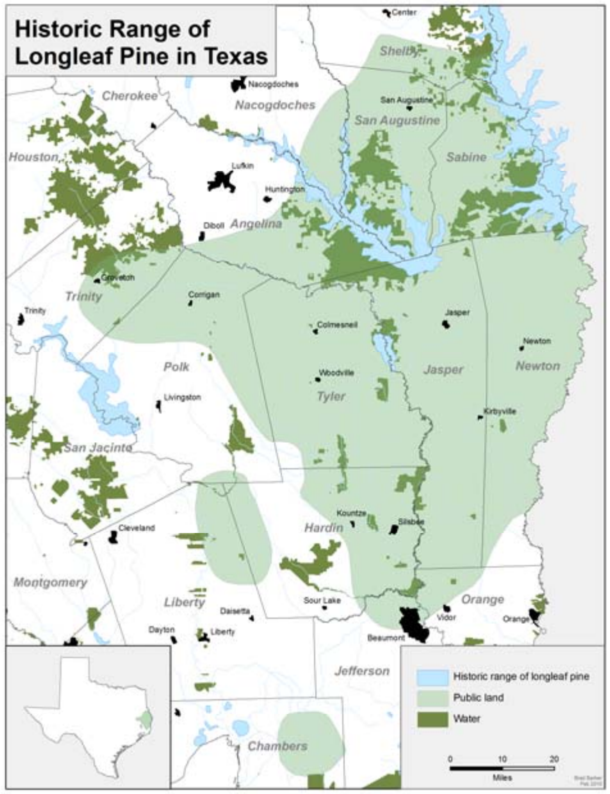

Figure 1. Historic range of longleaf pine in Texas. Adapted from Boyer (1990). Figure created by Brad L. Barber, Texas Forest Service.

<u>LONGLEAF</u>

A diameter-distribution growth and yield model system (Leduc *et al.* 2001), a refitted survival equation using the form presented in Lohrey and Bailey (1977), and a dominant height equation (Brooks and Jack 2006) were incorporated into a simulator written in Visual Basic. Data used in developing equations were obtained from long-term measurements of plantations located in Louisiana and Texas (Leduc *et al.* 2001 and the refitted survival equation), and southwest Georgia (Brooks and Jack 2006).

Dan Leduc, an Information Technology Specialist with the Restoring Longleaf Pine Ecosystems Unit in Pineville, LA, refit the survival equation presented in Lohrey and Bailey (1977) using those author's data plus more recent remeasurements and other plots:

$$TPA_2 = TPA_1\{\text{Sin}^2[\pi/2 + (1-A_1/A_2)(3.0865-0.0963[TPA_1]^{0.5}+0.0953A_1-0.00006[A_1]^2)]\}$$

Since LONGLEAF presents projections extrapolated beyond the range of the data used in model fitting, Reineke's maximum Stand Density Index (SDI) is used to constrain predicted stand development (e.g. Monserud *et al.* 2005). In the Southern Variant of the Forest Vegetation Simulator, a maximum SDI value of 390 is used for pure longleaf pine stands (Keyser 2008). Reineke (1933) reported a maximum of 400 for naturally-regenerated longleaf pine and Shaw and Long (2007) also reported a value of 400 using data obtained across the entire Southeastern US, while VanderSchaaf *et al.* (2007)

reported a maximum of 425 for naturally-regenerated longleaf stands in the Eastern Gulf region – all SDI values were calculated using an exponent of 1.6 except for VanderSchaaf *et al.* (2007) who used a value of 1.5942. The value of 425 was selected as the default value in LONGLEAF.

This simulator allows a user to determine how the stand-level variables of planting density and site quality will impact long-term yields and economic returns. Users can input revenues by one-inch diameter classes for three product classes (pulpwood, chip-n-saw, and sawtimber) and can input costs of site preparation and first-year herbaceous weed control to determine how these factors will impact the optimal rotation age. It is assumed that when entering an existing stand table (diameter distribution) all trees are out of the infamous "grass-stage." IT SHOULD BE NOTED THAT PLANTING DENSITY DOES NOT IMPACT PROJECTIONS – it is merely included for economic analysis purposes – the model is based on the existing stand table provided by the user.

Further economic sensitivity analyses can be conducted since users can change the interest rate and can vary annual revenues (e.g. hunting lease rates) and costs (e.g. management costs and property taxes). Individual total tree heights were predicted using an equation obtained from Leduc and Goelz (2009) using data from plots located throughout the Western Gulf region. Individual tree bole wood and bark weights were predicted using equations found in Baldwin and Saucier (1983) and inside-bark wood volumes were obtained by assuming each cubic foot of bole wood is equivalent to 72 pounds of bole wood and bark. Default upper-stem diameter product specifications are representative of those used in East Texas during 2008 (Mathison *et al.* 2009).

LONGLEAF is a useful tool but caution should be used because of climatic (VanderSchaaf and Prisley 2006), ecological (e.g. competing vegetation), and edaphic (soils) differences between the Atlantic Coastal Plain, Eastern Gulf, and the rest of the Western Gulf region when compared to East Texas. For example, wiregrass (*Aristida stricta*) is often found in conjunction with longleaf in more easterly areas while bluestem (*Andropogon s*pp.) is often found in conjunction with longleaf in more westerly areas such as East Texas. See Grelen and Duvall (1966) for a comprehensive description of the vegetation commonly found in the Longleaf pine-bluestem range.

Carbon sequestration

A user can also determine the economic revenues that may be received from enrolling into a carbon sequestration market (e.g. Chicago Climate Exchange - CCX). Due to the variability as to when landowners receive payment for their carbon offsets, it is assumed a carbon market will pay revenues at 3, 6, 9, 12, and 15 years after enrollment.

Enrollment is assumed to begin at the current time and must occur for a period of 15 years. There are several fees (aggregator fee, sub-aggregator fee, trading/transaction fees, and a verification fee) that a user must enter. As required by the CCX, 20% of all annual CO_2 equivalent offsets produced prior to the final payment at year 15 must be withheld in a reserve pool. Offsets in the reserve pool are used to compensate for any potential catastrophic losses (e.g. wildfires, hurricanes or tornadoes). If at the end of a landowner's contract there has not been a catastrophic event, the landowner will receive payment for the offsets that were placed into the reserve pool. For our purposes, we assume there are no catastrophic events and thus the reserved revenues at years 3, 6, 9, and 12 are returned to the landowner at year 15.

An equation found in Baldwin and Saucier (1983) was used to estimate aboveground biomass (bark and wood of the stem and branches, excludes foliage) while an equation found in Jenkins *et al.* (2003) was used to estimate belowground biomass (bark and wood of coarse roots). For more information on carbon sequestration opportunities contact the Texas Forest Service, or go to the following webpage:

http://txforestservice.tamu.edu/main/article.aspx?id=5312

Understory vegetation

An equation is included that estimates biomass of herbage (grasses, grass-likes, and forbs) as a function of overstory stand density (Grelen and Lohrey 1978). Herbage predictions can help managers determine the potential impacts of management alternatives on wildlife habitat and perhaps be helpful in determining fuel loading.

Pine straw harvesting

Due to needle length, longleaf pine straw is commonly harvested and used as mulch. These harvesting operations provide another source of revenue to landowners.

<u>Fertilization</u>

In LONGLEAF, a user can determine whether they want to annually harvest pine straw beginning at the age of 8 years. Most pine straw guides do not recommend collecting prior to this age. Although pine straw production is an excellent source of revenue, because needles contain a large amount of nitrogen, phosphorus, and potassium (plus calcium and magnesium), collection of needles may have a detrimental effect on long-term productivity of not only straw production but also wood production since these nutrients are not recycled. Thus, if annual harvesting occurs, a landowner should periodically apply fertilizers to compensate for nutrient removals, helping to maintain high needle production and good growth rates of trees. Publications recommend fertilizing every 5 to 8 years, for LONGLEAF the default frequency is every 5 years. For LONGLEAF, since needles are annually removed and to be conservative, it is assumed fertilization treatments do not increase straw yields or wood production.

<u>Control of competing vegetation</u>

Since fertilization can also increase competing vegetation and bare ground allows for easier collection of pine straw, competing vegetation may need to be periodically controlled. These operations consist of applying herbicides, mowing (or bush-hogging), or prescribed burning. The default frequency in LONGLEAF is every 3 years.
But in many cases a contractor may pay for the weed control treatment and therefore the landowner would not incur any cost; for these cases a user should enter a 0 in the **Vegetation Control Frequency (years):** input.

Since this model depicts unthinned plantations, whose overstory canopy will likely reduce or eliminate the reestablishment of competing vegetation and since annual harvesting activities will disturb reestablished competing vegetation, in some cases competing vegetation may only need to be conducted during the first year of needle collection. In these cases, a user should enter a number greater than the difference between the existing year and 35. For example, if the current stand age is 15 years and a control treatment will only be conducted at age 15, the difference between 15 and 35 is 20 and therefore a user should enter a value of 21 for the **Vegetation control frequency (years):** input.

Hence, fertilization and vegetation control are costs associated with obtaining pine straw revenues. Depending on the costs and frequency of these operations, the pine straw revenue, and site quality and stand density, harvesting pine straw may not be an economically viable alternative.

In addition to recycling nutrients, pine straw also has an important effect on soil moisture; removal can increase tree water stress on dry sites and can also increase bulk density. Additionally, pine straw helps to reduce erosion and annual harvesting may increase soil compaction. Landowners should take these factors into consideration when deciding whether or not to harvest pine straw.

<u>Pine straw collection utilization rate</u>
To be conservative, LONGLEAF has a default 80% utilization rate of the predicted straw yields. If vegetation control frequency is low, users may want to reduce the percent utilization rate to account for potential increases in competing vegetation.

<u>Sale of pine straw</u>
There are generally two ways a landowner can sell pine straw, receive revenue per harvested bale of pine straw or receive an annual payment per acre. Both methods are available in LONGLEAF.

Since pine straw yields are predicted as a function of stand density and site quality, it can be examined how different silvicultural treatments impact pine straw yields and revenues when a user selects to sell bales of pine straw. Users can enter situation specific numbers of pounds per bale and revenues received per bale.

Alternatively, a user can select to simply receive a per acre revenue from a contractor. Under this option, by default, the contractor incurs the costs of conducting fertilization and competing vegetation control treatments. Additionally, operationally, the landowner would not need to record the number of bales removed. In most situations, this is the most advantageous method of sale from a landowner’s perspective. However, in some cases the landowner may incur fertilization and vegetation control costs. The default annual contract payment in LONGLEAF is $30 per acre.

Prediction of pine straw yields

Pine straw production is predicted as a function of square feet of basal area per acre and site index at base age 50:

$$\text{Pine straw (pounds per acre)} = 4.92699 \times BA^{0.467252} \times SI_{50}^{0.992467}$$

Data used in model fitting were obtained from a table presented in Blevins et al. (2005). The table was based on pine straw production on 29 plots located in North and South Carolina.

See the East Texas Pine Straw web site for more information: http://texaspinestraw.tamu.edu/index.html

General Comments

Default costs and revenues are based on prices that could be expected in East Texas during 2009 (Texas Forest Service 2009). Due to limitations of the data used to fit models, LONGLEAF may crash because illogical diameter distribution parameters will be estimated. However, if a reasonable stand table (diameter distribution) and stand-level variables are supplied, the program should execute and reasonable projections will be obtained. Projections can be obtained up to age 35.

Future work with LONGLEAF will concentrate on allowing users to sell their trees as poles, include thinning options, and lengthen the projection period.

Acknowledgements

I thank Dan Leduc of the USDA Forest Service for refitting a survival equation and Hughes Simpson of the Texas Forest Service for providing guidance on how to calculate carbon sequestration offset returns. Several useful comments were received from Michael Chesnutt and Bill Pickens (North Carolina Division of Forest Resources), David Dickens (University of Georgia), and Dave Haywood (USDA Forest Service, Pineville, LA) on the production and harvest of pine straw. David South (Auburn University) provided several useful general comments.

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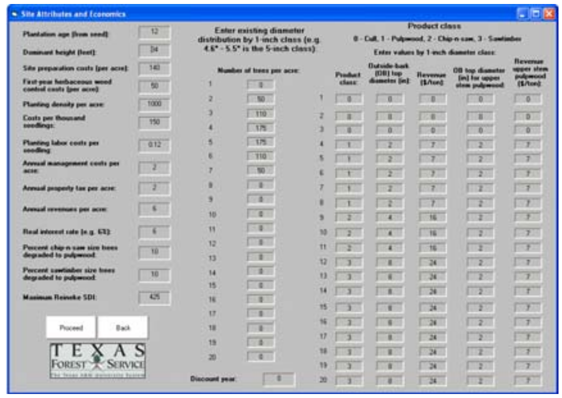
<u>GET ME GOING</u> -----

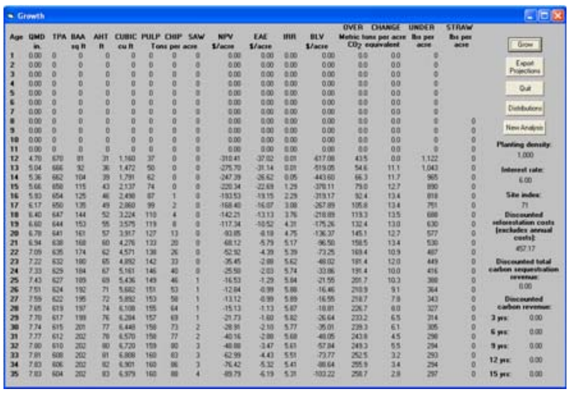
The program consists of seven pages:

Introduction

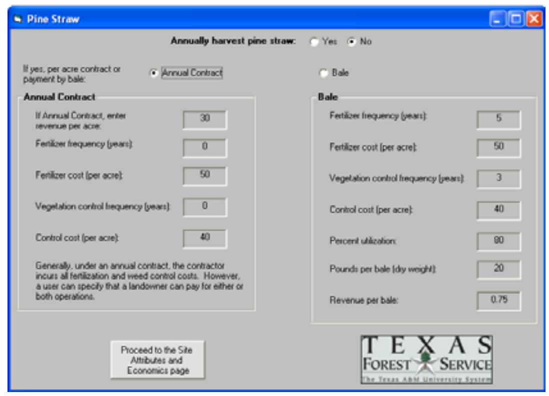
Site Attributes and Economics



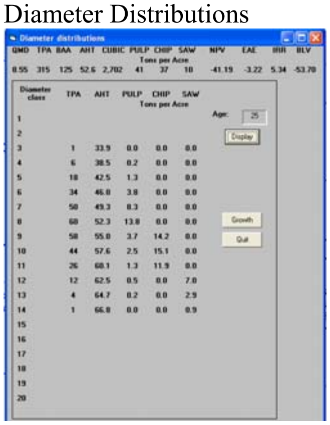
Growth



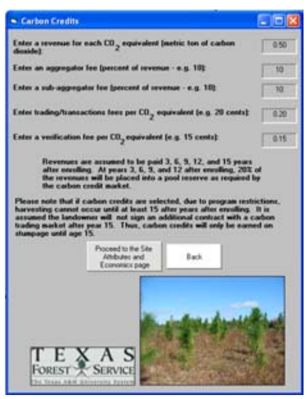
Pine Straw



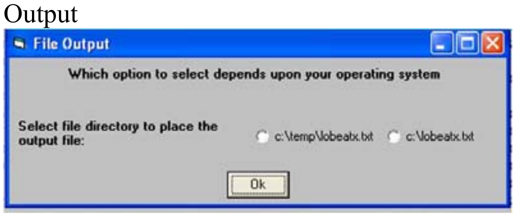
Diameter Distributions



Carbon Credits



Output



(1) Pine Straw page; if desired, a user can annually harvest pine straw. Default revenues and costs are representative of those during the year 2010. To move to the next page, click on the "**Proceed to the Site Attributes and Economics page**" button.

(2) Site Attributes and Economics page; you may change any of the preset data to suit your particular situation. Default revenues and costs are representative of those found in East Texas during the early part of 2009. For example, stumpage prices were obtained from the Texas Timber Price Trends (Texas Forest Service 2009). To move to the next page, click on the "**Proceed**" button.

Users must enter logical values for costs and revenues and a positive interest rate should be entered. The "**Discount year:**" variable allows users to vary the year to which costs and revenues are discounted. Thus, a user can discount back to the current year, another year, or back to year 0. Discounting back to year 0 may be helpful if someone wants to determine how assumed stand conditions at a certain age will impact future yields and discounted returns. If the discount year differs from 0, all regeneration costs (including first-year herbaceous weed control) are ignored and are not part of the economic analyses, however, annual management and tax costs and annual revenues are included. The exception is when calculating BLV.

If the discount year differs from 0, all regeneration costs are ignored for the current rotation but regeneration costs are included when calculating economic returns from all subsequent rotations. An alternative BLV formula is used when the discount year differs from 0 that accounts for the value of the existing stand and the delay of harvesting future stands (Straka and Bullard 1996).

A user needs to enter the planting density per acre and needs to enter the existing stand table (number of trees within diameter classes) under the heading **Enter existing diameter distribution by 1-inch class**. However, IT SHOULD BE NOTED THAT PLANTING DENSITY DOES NOT IMPACT PROJECTIONS – it is merely included for economic analysis purposes – the model is based on the existing stand table provided by the user.

(3) Carbon Credits page; if desired, a user can conduct carbon sequestration credit analyses. Default revenues and costs are representative of those during the year 2009. If a plantation is enrolled in a carbon market, harvesting cannot occur for 15 years.

(4) Growth; to display the simulated results, click on the "**Grow**" button (right side of page). You can now view the economic, volume, weight and biomass outputs. You may stop here or, if you are interested in stand structure at harvest, you may click on the "**Distributions**" button. The column headings are as follows:

Age – plantation total age, or years since planting (not from seed),
QMD - quadratic mean diameter (inches),
TPA - surviving trees per acre,
BAA - square feet of basal area per acre,
AHT - arithmetic mean height (feet),
CUBIC - total (stump to tree tip) inside bark cubic foot volume per acre,
PULP - merchantable green weight per acre (tons) for DBH classes assigned to the pulpwood product class and any upper-stem pulpwood,
CHIP - merchantable green weight per acre (tons) for DBH classes assigned to the chip-n-saw product class,

SAW - merchantable green weight per acre (tons) for DBH classes assigned to the sawtimber product class,
NPV - Net Present Value per acre (includes all stumpage revenue, annual return revenue, and if selected, carbon sequestration and/or pine straw revenues),
EAE - Equal Annual Equivalent per acre (includes all stumpage revenue, annual return revenue, and if selected, carbon sequestration and/or pine straw revenues),
IRR - Internal Rate of Return (includes all stumpage revenue, annual return revenue, and if selected, carbon sequestration and/or pine straw revenues), due to limitations in the amount of computing ability, the IRR cannot exceed 50%.
BLV – Bare Land Value, Land Expectation Value (LEV), Soil Expectation Value (SEV), or the Willingness to pay for land value (includes all stumpage revenue, annual return revenue, and if selected, carbon sequestration and/or pine straw revenues),
OVER – total amount of CO_2 equivalent sequestered (metric tons per acre) within the bark and wood of the stem, branches, and coarse roots, excludes foliage.
CHANGE – annual change (metric tons per acre) in the amount of CO_2 equivalent sequestered (metric tons per acre) within the bark and wood of the stem, branches, and coarse roots, excludes foliage.
HERBAGE – total herbage biomass (grasses, grass-likes, and forbs), pounds per acre.
STRAW – amount of pine straw production after accounting for the percent utilization rate, pounds per acre. Yields are only predicted if pine straw revenue is received from baling.

Discounted reforestation costs (excludes annual costs and pine straw fertilization and vegetation control costs) – total discounted reforestation costs that includes site preparation costs, seedling and planting costs, and first-year herbaceous weed control discounted one year at the desired interest rate.
Discounted total carbon sequestration revenue – total discounted revenues from the payment years of 3, 6, 9, 12, and 15.
Discounted carbon revenue – discounted revenues for a particular payment year. For ages 3, 6, 9, and 12, 20% of the change in the amount of CO_2 equivalent sequestered is removed from the payment at those ages, but payment is received for the 20% removed at ages 3, 6, 9, and 12 during year 15 and therefore these particular revenues are discounted 15 years.

(5) Diameter Distributions; to display a distribution for any age 10 years and older, click the "**Display**" button.

File Output

Growth and yield projections can be outputted as a comma-delimited *.txt file to a selected directory on the C:\. Users need to click on the "**Export Projections**" [**LONGLEAF.txt**] button. Depending on your operating system, you need to select a particular folder format.

The best way to view the data and to make figures is to input the text files into Microsoft Excel. The following steps should be used to enter the data into Excel:

1. Open the *.txt file,
2. Select Delimited (use all other defaults) and then click Next,
3. Select Comma as the Delimiter and click Finish.

Growth, yield, and economic projections are now in an Excel format. The values in the first row are:

Site index (base age 25), **Planting density (seedlings per acre)**, the **Interest rate,** a value of 1 is reported if entered into a carbon sequestration program and 0 otherwise, a value of 1 if pine straw is annually harvested and 0 otherwise. Stand-level variables are ordered in the *.txt file the same as they are presented in the Growth form.

To end the program, a user should click the "**Quit**" button.