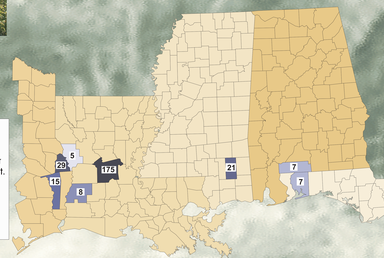
Sound management of longleaf pine plantations

requires prediction of stand growth and development. This is needed to determine timber yield as well as stand characteristics that are reflected in the productivity of understory communities and the suitability of stands for wildlife. The only growth and yield model for planted longleaf pine considers only unthinned stands of no greater than 40 years old (Lohrey and Bailey 1977). Goelz and Leduc (2001) provide an empirical yield table for longleaf pine plantations. This paper summarizes a growth and yield model for longleaf pine plantations within the Gulf Coast States that is currently being developed that will be applicable to thinned and unthinned plantations up to at least 65 years old.

Above: One of our study sites in 1957, a few years after planting.
Below: The same site in 2000.

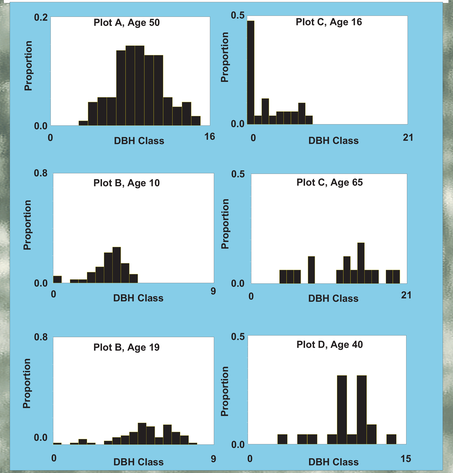
The Forest Service's laboratory at Pineville, LA

has been conducting research on the growth and development of longleaf pine plantations for over 50 years. We have seven long-term studies, including over 250 permanent plots, scattered within the Gulf Coastal Plain. **See map to right.** The plots represent ranges of site, age, initial spacing, and thinning regimes. These plots have all been measured for twenty years or more, and include plantations currently over 65 years old. This data set is being used to create a growth and yield model that will predict stand characteristics for longleaf pine plantations.



Longleaf pine often has irregular diameter distributions

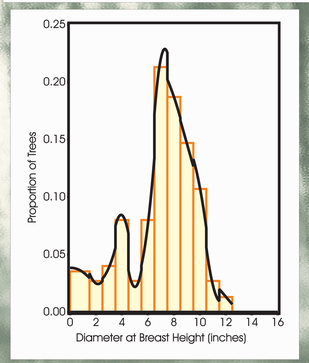
(Figure below, Goelz and Leduc 2002). There are several causes for these irregular diameter distributions. Length of time in the grass stage varies among individuals in a stand; effectively, multiple cohorts comprise a stand. This may create diameter distributions that are multi-modal; if unimodal, the diameter distribution may be strongly skewed. Longleaf pine can persist in inferior crown positions for many years. These small trees create a diameter distribution with a long left-hand tail; such diameter distributions are not well-represented by most parametric diameter distributions. Regular prescribed fire can cause mortality that affects diameter distributions. These characteristics obviate the use of classical diameter distribution modeling methodology.

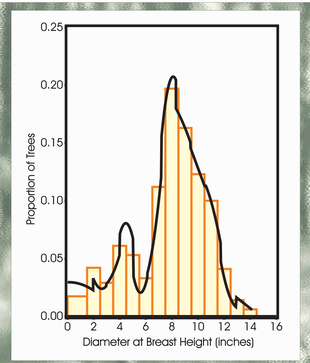


Our model for longleaf pine is structured differently

from standard diameter distribution models used for southern pines, but the output is still a stand and stock table similar to existing diameter distribution models. Thus, our novel model structure is transparent to the user. Rather than a simple histogram, the diameter distribution within each class will be defined by a simple quadratic polynomial. A histogram assumes a uniform (flat) distribution within each class; this differs by having a curved (quadratic) distribution within each class. This is an important distinction as the uniform distribution produces a bias in standard stand table projection procedures (Goelz 2002). The diameter distribution is segmented. The distribution will thus be continuous within each class, but discontinuous at the boundary of each class (See figure on left, below).

After adjusting for mortality, the limits of each diameter class will be projected into the future by using an individual tree diameter growth equation. At this point, each diameter class is potentially of varying width, but will possess the same number of trees per acre (the curved line segments on the figure on right, below; note that the diameter classes are no longer one inch wide—as larger trees have more growth than smaller trees, the range of each diameter class has increased). Then, by using appropriate limits of integration, we will reconstitute fixed one-inch diameter classes (The histogram of the figure on right, below). Although this might seem somewhat involved, it is completely transparent to the user who will perceive a familiar stand and stock table as output.





Site index is a critical component

of the model, as site quality is one of the main driving variables for forest growth and yield. We present preliminary site index curves in the figure to the right (Goelz [in prep]). The equation is a modification of McDill and Amateis (1992). The curves happen to be very similar to the site curves presented in the classical miscellaneous publication No. 50 (USDA 1929). Like miscellaneous publication 50, these curves are based on a grass stage of 5 years and a base age of 50 years. Although the curves seem to be diverging across the range of age from 15 to 70 years, the asymptote is a constant plus site index; thus at extreme ages, the curves will be parallel and equidistant.

Our data, although extensive, is not ideal. We have several studies that include repeated measurements to age 65, however none of these older studies have measurements before age 16, and all of them are based on bare root seedlings. This dataset provides good information on long-term growth, but provides no information on length of the grass stage. In our modeling, we can estimate grass stage length as a parameter, but it is poorly estimated with this data. We chose 5 years as a compromise estimate for grass stage length when using bare root seedlings. We have one newer study established with container stock that has measurements between 4 and 22 years age, however we cannot estimate site index as measurements are not near base age. For plantations established with container stock, the length of the grass stage is specified as 2 years. In application, a user can specify the expected grass stage from one to seven years, or accept the default of five years for bare root plantations and two years for plantations established from container stock.

There is more to a forest than the trees.

As longleaf pine is typically planted in an ecosystem restoration context, an appropriate model should consider more than simply timber growth (Goelz 2001). Thus we will consider elements that are not typically incorporated into standard growth and yield models. Some of these issues are illustrated by pictures to the right. Critical issues include: (1) estimation of non-timber variables; (2) incorporation of (prescribed) fire effects;
(3) extrapolability to ages that exceed the data.
Independently-derived non-timber and fire components will be incorporated into the implementation of the model. These supplemental components are not measured in our database. However, we intend to incorporate results of other experiments that describe the relationship between stand structure and fire regime on understory community characteristics and pinestraw as well as the effects of fire on longleaf pine mortality and growth (for example, Haywood et al 2001, Haywood and Grelen 2000, Boyer 1987, Boyer and Fahnestock 1966). The user of the model can decide to switch on these supplemental effects or not, depending on their interest.

Extrapolability will be considered in model formulation (Goelz 2001). It is a critical component of model formulation because, in an ecosystem restoration context, a land manager will be interested in simulations that exceed the 65 year old plantations in our database. Goelz (2001) explores several methods to consider extrapolability. The figure to the lower right indicates the stability of a model parameter as the oldest data is first deleted, then added back in model estimation. If the parameters are little affected by the truncation of the oldest data, it is reasonable to assume that the model will also perform adequately when extrapolated to older ages.

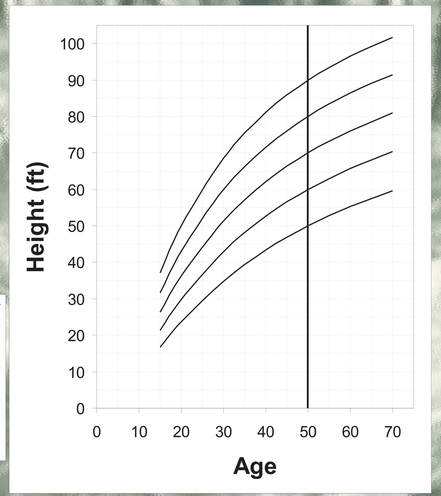
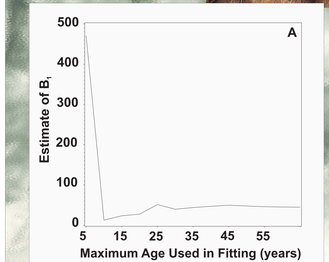


Photo credits: J.D. Haywood and FWS



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A Model for the Growth and Development of Longleaf Pine Plantations

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