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The Influence of Hardwood Interspecific Competition on Stand Structure and Dynamics for Loblolly Pine Plantations

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ABSTRACT : The purpose of this study is to investigate the effects of hardwood competitions in stand structure and dynamics by applying prediction models for unthinned loblolly pine (*Pinus taeda L.*) plantations. A parameter recovery procedure for the Weibull distribution function based on four percentile equations was applied to develop diameter distribution prediction models. Four percentiles of the cumulative diameter distribution prediction equations were predicted as a function of quadratic mean diameter plus competing hardwood trees per hectare variables. According to the results of this study, it was found that as the amount of competing hardwood trees increased, diameter distributions in terms of stand structure dynamics tended to be more skewed to the right. Therefore, the influence of non-planted hardwood trees interspecific competition on planted loblolly pines showed negative effects on the stand structure and dynamics.

Key words: Interspecific competition, *Pinus taeda,* Stand structure and dynamics, Weibull distribution

INTRODUCTION

The competing vegetation management in forestry has increased in recent years in response to several reports of the impact of hardwood competitions on the yield of pine plantations. Because forest managers often require information concerning the effects of removing non-planted hardwood trees on the growth yield of pine plantations (Knowe 1992).

Especially, diameter class and volume distribution information is important to make decision on the type and timing of management strategies for the planted loblolly pines which are the most economically important timber producing species in the southern United States.

Adverse effects of hardwood competition on the growth of planted loblolly pine have been documented by many studies (Haywood and Tiarks 1990, Glover and Zutter 1993, Fortson *et al.* 1996). They found strong negative effects of competing hardwood competition and competing vegetation on the growth of planted pine trees.

Two stand-level loblolly pine simulation models have been developed using the relationship between pine volume and percent of hardwood basal area (Burkhart and Sprinz 1984, Smith and Hafley 1987). Smith and Hafley(1987)'s simulator that account for the hardwood basal area in the models which were based on a bivariate distribution of height and diameter in which the minimum and modal height and diameter were adjusted for hardwood basal area.

There were several different methods for estimating the three parameters of the Weibull distribution (Clutter *et al.* 1983). The parameter recovery technique employed in this study was presented by Brooks *et al.* (1992). This parameter recovery procedure utilizes the expected value of the minimum observation from a sample size n from the Weibull distribution, four percentiles, and the second moment of the Weibull distribution to estimate the a, b, and c parameters.

The objective of this study involved an investigation of the impacts of hardwood competitions on stand structure and dynamics prediction models in unthinned loblolly pine plantations. A model for percentiles of the diameter distribution and quadratic mean diameter prediction equations were developed to account for the effects of hardwood competition defined by the ratio of non-planted hardwood trees to total trees per hectare stand level.

MATERIALS AND METHODS

Study area

Long-term data from East Texas Pine Plantation Research Project (ETPPRP) permanent research plots located in loblolly

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Table 1. Observed summary statistics for loblolly pine stand data sets (n=1,597)

	Mean	Std Dev.	Min.	Max.
AGE	11	5.2	1	27
SI	21.0	4.6	5.5	35.7
TPH	1,154	368	215	2,476
HT	11.1	5.5	0.6	30.5
DQMEAN	12.2	6.4	0	28.4
PBA	15.9	11.2	0.1	44.2
HDB	1.8	2.5	0	23.6
RHDT	0.1	0.1	0	0.9

Note: AGE= plantation age (years), SI= site index (meters), TPH= total trees per hectare, HT= average height of ten tallest trees (meters), DQMEAN= quadratic mean diameter (cm), PBA= loblolly pine basal area per hectare (m^2), HDB= hardwood tree basal area per hectare (m^2), RHDT= ratio of hardwood trees to total trees per hectare.

pine plantations across east Texas were analyzed in this study. The ETPPRP study area covers 22 counties across east Texas. Generally, the counties are located within the rectangle from 30° - 35° north latitude and 93° - 96°west longitude.

Each plot consists of two adjacent subplots separated by a 18.3-meter buffer. Within a subplot, for this study, the life of each planted loblolly pine tree had been tracked for 12 years. In addition, the numbers of non-planted hardwood trees within two embedded 0.002314 hectare circular plots (radius = 2.7 meters) in each subplot were tracked for twelve years.

A total of 1,597 observations from loblolly pine plantations were utilized for model fitting. Average age of loblolly pine was almost 11 years. Average site index of loblolly pine was about 21 meters (base age: 25 years, Lee 1998). The average number of trees per hectare was 1,154. The summary statistics of the observed variables are depicted in Table 1 for loblolly pine plantations.

Model development

Prediction of diameter distribution percentile equations The Weibull parameter recovery method was applied in this study that required use of the 0th, 25th, 50th, and 95th diameter percentiles. The 0th(D_0), 25th(D_{25}), 50th(D_{50}), and 95th(D_{95}) percentiles were obtained for each plot by using a FORTRAN program. Separate regression equations for the percentiles were developed for the planted loblolly pines. The basic model for percentile prediction equations was:

$$(D\,i) = f(DQMEAN, AGE, RHDT\ RIGHT) \qquad (1)$$

where:

$D\,i$ =0th, 25th, 50th, and 95th percentiles of diameter distribution.

Weibull parameter recovery methods The Weibull distribution parameter recovery procedure developed by Da Silva (1986) and subsequently utilized by Brooks *et al.* (1992), first determines the predicted location parameter 'a' using the predicted values for D0 and D50, and an initial assumption that the shape parameter 'c' is 3.0.

Assuming that c=3, the location parameter, 'a', was obtained by using the minimum (D_o) and median (D_{50}) diameters and sample size (n):

$$\hat{a} = (n^{1/3} D_0 - D_{50})/(n^{1/3} - 1),\ \text{if a<0.0 then a=0} \qquad (2)$$

The shape parameter was estimated by using the estimate for the location parameter and D_{95} and D_{25}:

and the scale parameter, 'b', was obtained by solving the second

$$\hat{c} = 2.343088/\ln\left[\frac{D_{95} - \hat{a}}{D_{25} - \hat{a}}\right], \qquad (3)$$

moment of the Weibull distribution for the positive root with the estimates for 'a', 'c', and D_q^2

$$\hat{b} = -\frac{\hat{a}\Gamma_1}{\Gamma_2} + \sqrt{\left(\frac{\hat{a}}{\Gamma_2}\right)(\Gamma_1^2 - \Gamma_2) + \frac{D_q^2}{\Gamma_2}}, \qquad (4)$$

where:

Γ = the gamma function,

$\Gamma_1 = \Gamma(1+1/c)$,

$\Gamma_2 = \Gamma(1+2/c)$,

D_q = quadratic mean diameter.

Weibull cumulative function for the stand table calculations The Weibull function has been widely used to model diameter distributions since the early applications by Bailey and Dell (1973):

$$F(X) = 1 - \exp\left[-\left(\frac{X - a}{b}\right)^c\right], \qquad (5)$$

$$(a \leq X < \infty),\ 0\ \text{otherwise}.$$

The location parameter 'a' which gives the minimum value of the distribution (minimum diameter values is ≥ 0), and the scale parameter 'b' which is related to the range of the diameter distribution, and the shape parameter 'c' which determines the skewness of the distribution. Subtracting the cumulative distribution up to the lower limit of the class from the upper limits gives the proportion of trees in that class (Avery and Burkhart 1994).

$$P_i = (1 - \exp\left[-\left(\frac{U_i - a}{b}\right)^c\right]) - (1 - \exp\left[-\left(\frac{U_{(i-1)} - a}{b}\right)^c\right]), \quad 6)$$

where:

P_i = proportion of trees in diameter class i,

U_i = upper limit of diameter class i.

This equation was used for calculating diameter class frequencies with all Weibull diameter distribution models.

RESULTS AND DISCUSSION

Diameter percentile prediction equations

The components of stand structure prediction system are equations to estimate certain diameter percentiles and quadratic mean diameter. A total of 1,597 observations from loblolly pine plantations were utilized for model fitting. Separate regression equations for the minimum dbh (D_0) on the plot and 25th, 50th, and 95th percentiles were developed for loblolly pines based on the model selection criteria. The prediction equations for the 0th, 25th, 50th and 95th percentiles plus quadratic mean diameter (DQMEAN) are presented in equations (7) to (11). The R^2 variation explained by these equations ranged from 74.1% for equation (7) to 99.2% for equation (9).

· Estimating D_0 as:

$$D_0 = -1.051820 + 0.493539 * DQMEAN + 0.018329 * AGE - 0.144216 * RHDT$$

$$(R^2 = 0.741 \quad RMSE=0.655) \quad (7)$$

· Estimating D_{25} as:

$$D_{25} = -0.303698 + 0.971203 * DQMEAN - 0.041617 * AGE - 0.079231 * RHDT$$

$$(R^2 = 0.980 \quad RMSE=0.268) \quad (8)$$

· Estimating D_{50} as:

$$\ln D_{50} = -0.144548 + 1.076485 * \ln(DQMEAN)$$

$$(R^2 = 0.992 \quad RMSE=0.057) \quad (9)$$

· Estimating D_{95} as:

$$D_{95} = 0.362488 + 1.158622 * DQMEAN + 0.055616 * AGE + 0.002634 * RHDT$$

$$(R^2 = 0.983 \quad RMSE=0.366) \quad (10)$$

Quadratic mean diameter (DQMEAN) is the most important independent variable in predicting percentile-based diameter prediction equations.

· Estimating DQMEAN as:

$$DQMEAN = \exp\left(3.80475 - 25.57333\left(\frac{1}{HT}\right) + 0.36536\ 1n(AGE) - 0.26880\ 1n(AGE * TPA) - 0.26467 * RHDT\right)$$

$$(R^2 = 0.961 \quad RMSE=0.085) \quad (11)$$

If site index (SI) is unknown, but plantation age and stand height are known, then we could estimate site index in the following equation, as discussed in details by Lee (1998), Lee and Hong (1999):

$$SI = H\left[\frac{0.90714}{1-\exp(-0.09507 * AGE)}\right]^{1.69236} \quad (12)$$

Equation (12) can be algebraically manipulated to predict stand height from the site index prediction equation.

Illustrations of non-planted hardwood competitions on planted loblolly pine stand structure dynamics

To illustrate the use of this system, we can consider a set of representative scenarios: there were 500 planted trees per a plot size (0.4047 ha) and site index value was 21 meter. As required, RHDT were set at 0%, 25%, 50%, 75%, and 90%, and plantation age were set at 10, 15, 20, 25, and 30 years old for planted loblolly pines. Within these wide-range scenarios, it was possible to investigate the influence of hardwood competition on expected stand level diameter distributions. The solution of above scenarios gives the following illustrations of the influence of hardwood competitions on stand structure and dynamics in Figure 1.

In general, it was found that as the amount of non-planted hardwood trees increased, diameter distributions tended to be more skewed to the right. Therefore, the effects of non-planted hardwood trees interspecific competition on planted loblolly pines showed negative effects on the diameter distribution prediction values for planted loblolly pines. Interspecific competition between the planted loblolly pines and hardwood trees for growth apparently results in planted pines with smaller diameters. It could be concluded that loblolly pine plantation yields will be enhanced not only in magnitude but also in tree diameter size, if the number of hardwood trees per hectare is reduced or eliminated.

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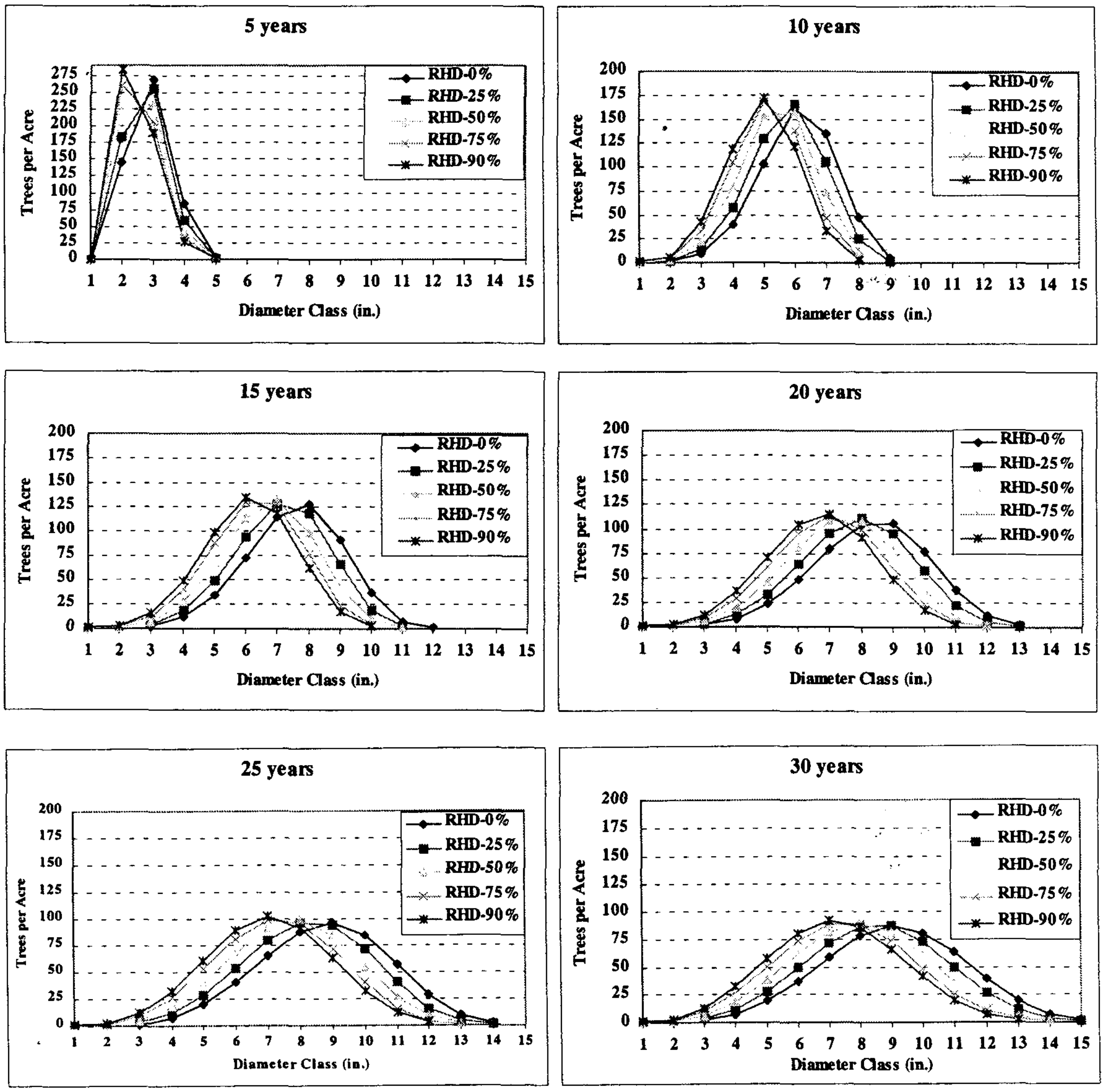

Fig. 1. The influence of hardwood interspecific competition on stand structure and dynamics for loblolly pine plantations.

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