Advances In Modeling Silvicultural Treatments In Loblolly Pine Stands[1]

Marilyn A. Buford[2]

Abstract.--Accurate prediction of stand growth and yield requires a thorough understanding of the effects that various silvicultural treatments have on stand structure and development. Tree improvement, thinning, site preparation and fertilization have been shown to change the shape and/or level of growth curves. Therefore, modeling success can be best achieved where emphasis is placed on the effect of those treatments on the basic relationships underlying stand growth and development and validation against long-term data.

Many silviculturalists are interested in treatments or combinations of treatments that increase production efficiency. Efficiency is improved if there is a reduction in production cost per unit of a desired quality. For a forest crop, that reduction can be measured directly in dollars. Costs associated with a silvicultural regime include the operational costs of cultural treatments, costs of installing studies to document treatment effects, costs of waiting for operational or research results, and costs of taking a wrong action. These costs make mathematical models of stand growth necessary tools for projecting probable treatment effects and resulting yields. To be useful for extrapolation, a model must reflect observed or quantified behavior of stands over the long term. This paper briefly outlines loblolly pine (*Pinus taeda* L.) stand behavior and reviews several recent advances in modeling silvicultural treatments in loblolly pine stands.

BEHAVIOR OF LOBLOLLY PINE STANDS

Much of what is known about the development of loblolly pine stands is derived from long-term observations in density-control studies installed at very early ages in natural stands and from planted spacing studies. Examination of long-term results provides much information about the effects of height growth, initial density, and the interaction of these factors in stand development.

The following are observations from loblolly pine stands of the same initial density:

a. Stands on poor sites contain more trees per acre than stands on better sites at the same age (Figure 1);

b. At the same mean height of dominant trees, stands on better sites contain more trees per acre than stands on poorer sites (Figure 2); and

c. Better sites can support higher basal areas than poorer sites.

Given the same site quality, basal areas and volumes produced from stands of different initial densities converge, cross over, and decline (Figure 3).

Mean annual increments of both volume and basal area culminate earlier on better sites than on poor sites and at higher initial densities than at lower initial densities. These observations and trends are apparent in the compiled information from long-term density studies (Balmer *et al.* 1975, Harms and Lloyd 1981, Gilmore and Gregory 1974, Arnold 1978, Arnold 1981, Sprinz *et al.* 1979, Hafley *et al.* 1981, Buford and Hafley 1985, Harms and Langdon 1976).

TREATMENTS

Silvicultural treatments have three classes of goals: 1) manipulating the tree directly by genetic improvement, 2) improving the competitive environment by thinning or weed control and 3) improving the chemical and physical environment by site preparation or fertilization. Advances in modeling these treatments rest on determining their effect on relationships basic to stand development.

Tree Improvement

Using long-term, block-planted genetic studies to investigate the effects of tree improvement on loblolly pine stand dynamics, Buford (1986) and Buford and Burkhart (1985) found that: 1) for seed sources and families, the shape of the height-age curve is dictated by the site, but the level of the height-age curve is dictated by the seed source or family (Fig. 4); 2) for seed sources and families, the shape of the height-diameter relationship at a given age is determined by the site and initial density, while the level of the height-diameter relationship is determined by the seed source or family and is directly related to the dominant height of the seed source or family at that age; and 3) if silvicultural treatments are the same and are equally successful, variances of height and diameter in stands originating from selected genotypes are not different from those in genetically unimproved stands. The implications for modeling growth of stands originating from selected genotypes are: 1) genetic improvement of trees affects the rate at which stands develop, but does not fundamentally alter the pattern of stand development from that of unimproved stands; 2) changes in genetic material on a given site will likely affect the level, but not the shape, of basic associations such as the height-age and height-diameter rela-

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[2]Research Forester, USDA Forest Service, 2730 Savannah Highway, Charleston, SC 29407.

tionships; and 3) correctly characterizing the height-age profile is crucial. In general, growth of genetically improved loblolly pine can be modeled by altering the height-age curve in current growth and yield models to reflect differences in the level, or site index, attained by different sources or families (Buford and Burkhart 1986). At present, there is a major effort to identify key hypotheses about dynamics of stands of genetically improved stock and to determine the most efficient experimental means to test those hypotheses (Nance et al. 1986).

Thinning

Several diameter distribution models have been developed which include a thinning component. Thinning is accomplished by truncating the diameter distribution or by removing certain proportions of stems from specified diameter classes. Height is predicted from a height-diameter equation and is not among the thinning criteria. Examples of this type of model are given by Matney and Sullivan (1982) and Cao et al. (1982).

An individual tree model treats the stand as an aggregrate of separate trees, each having specific characteristics. Such a model for loblolly pine stands was presented by Daniels and Burkhart (1975). In this model, thinning was accomplished by removing individuals meeting specified criteria from the diameter distribution. Although the individual heights are known, height was not used in thinning decisions. In the models discussed above, stand parameters are not functions of initial density or spacing, but of the number of surviving trees at any given time.

A model for thinned stands mathematically derived from a model for unthinned stands was presented by Hafley and Buford (1985). The stand is modeled as a bivariate distribution of heights and diameters with stand characteristics predicted from age, initial density, and dominant height. The model shows the convergence of basal area and volume observed in long term density studies. Thinning was accomplished by manipulating the bivariate distribution so that thinning decisions are based on height and diameter. The model was validated using data from long-term thinning studies. It closely predicted height and diameter distributions for 25 years after thinning under various regimes (Smith and Hafley 1986). Key decisions made in developing this model were that the growth of all stand characteristics, including height, is affected by initial density, that height growth effects the growth of other stand characteristics and, therefore, that height should be considered in thinning decisions.

Fertilization and Site Preparation

Recent results from the Lower Atlantic Coastal Plain indicate that both bedding and phosphorus fertilization alter the shape and level of the height growth curve on a given site. Results at ages 10 and 15 from a study in South Carolina (McKee and Wilhite 1986, Buford and McKee 1986) and at age 13 from a study in North Carolina (Gent et al. 1986) consistently show differences of 10 feet or more in average height (at ages 10, 15 and 13) between bedded plus phosphorus and control treatments. Differences in the shape of the height-age profiles are more pronounced among treatments on the wetter sites (McKee and Wilhite 1986). Indications are that progress can be made in modeling these treatments by quantifying the effects of changes in the soil chemical and physical properties on the height growth profile.

CONCLUSIONS

This paper has presented a compilation of observations on loblolly pine stand development. Advances in modeling silvicultural treatments such as tree improvement and thinning have been made where emphasis has been placed on the effect of the treatment on basic relationships underlying stand growth and development. Progress in yield projection will continue if the emphasis in model building is placed on understanding changes in the underlying relationships of stand dynamics and validating the resulting models against long-term data.

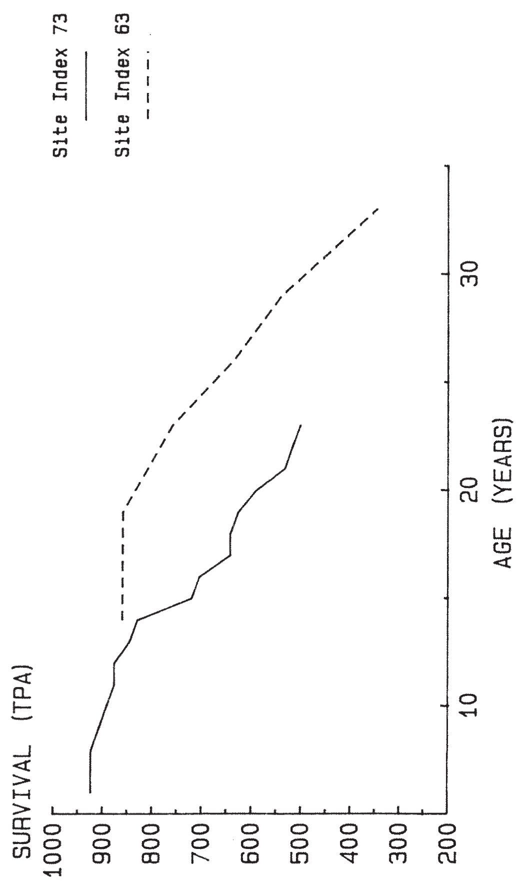

Figure 1.--Given the same initial density, stands on poorer sites contain more trees per acre than stands on better sites at the same age.

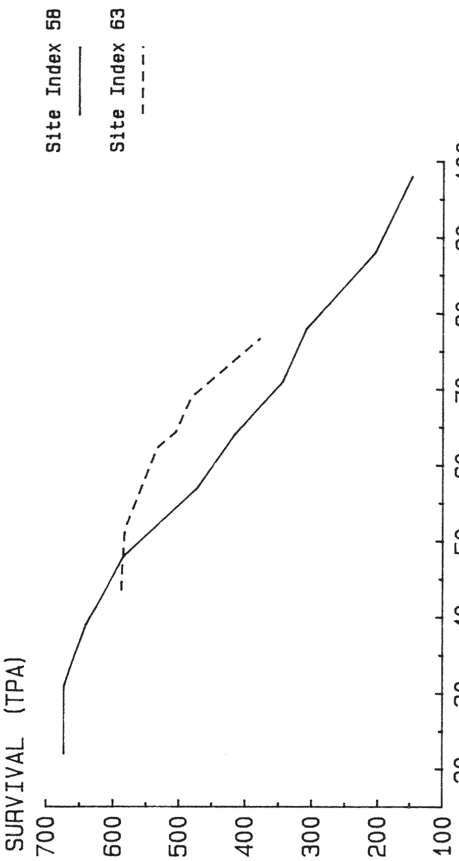

Figure 2.--Given the same initial density, stands on better sites contain more trees per acre than stands on poorer sites with the same dominant height.

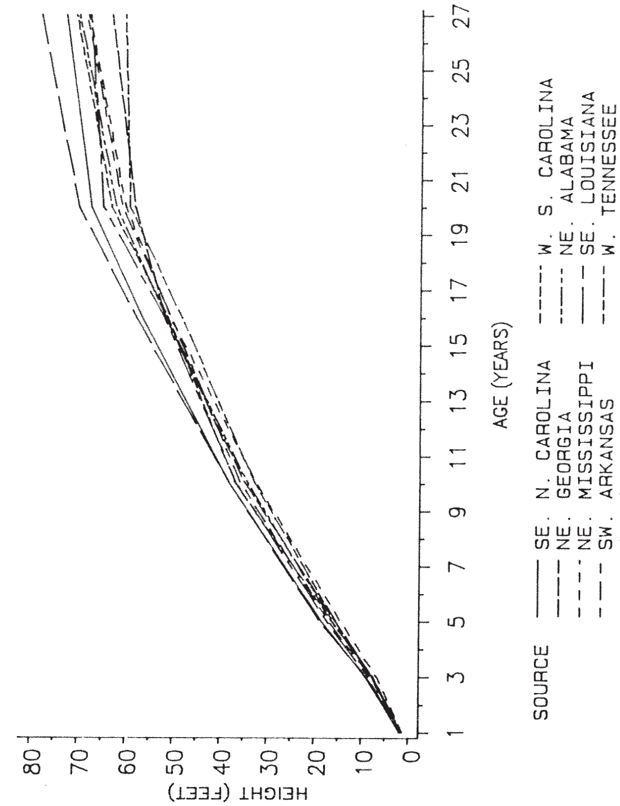

Figure 4.--Height-age profiles for sources at one location of the Southwide Pine Seed Source Study.

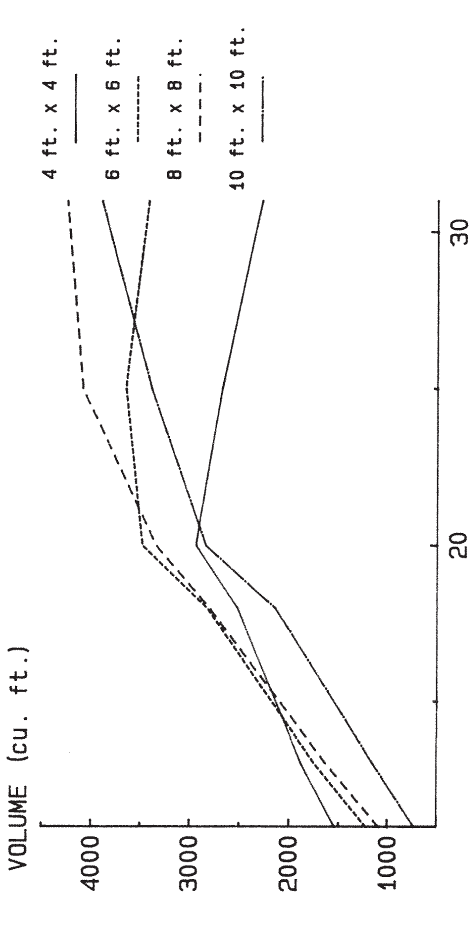

Figure 3.--Volume per acre over time for four spacings on the same site.

LITERATURE CITED

Arnold, L. E. Gross yields of rough wood products from a 25-year-old loblolly and shortleaf pine spacing study. Forestry Res. Rep. 78-7. Urbana Champaign, IL; University of Illinois Agricultural Experiment Station; 1978. 4 pp.

Arnold, L. E. Gross yields of rough wood pro ducts from a 31-year-old loblolly and shortleaf pine spacing study. Forestry Res. Rep. 81-1. Urbana-Champaign, IL; University of Illinois Agricultural Experiment Station; 1981. 4 pp.

Balmer, W. E.; Owens, E. G.; Jorgenson, J. R. Effects of various spacings on loblolly pine growth 15 years after planting. Res. Note SE-211. Asheville, NC: U. S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1975. 7 pp.

Buford, M. A. Height-diameter relationships at age 15 in loblolly pine seed sources. Forest Science 32(3):812-818; 1986.

Buford, M. A.; Burkhart, H. E. Dynamics of improved loblolly pine plantations and the implications for modeling growth of improved stands. In: Schmidtling, R. C. and M. M. Griggs, eds. Proceedings, 18th Southern Forest Tree Improvement Conference; 1985 May 21-23; Long Beach, MS. Sponsored Pub. No. 40, Southern Forest Tree Improvement Committee; 1985:170-177.

Buford, M. A.; Hafley, W. L. Probability distributions as models for mortality. Forest Science 31(2):331-341; 1985.

Buford, M. A.; McKee, W. H., Jr. Effects of site preparation, fertilization and genotype on loblolly pine growth and stand structure — results at age 15. Presented at Fourth Biennial Southern Silvicultural Research Conference; 1986 November 4-6; Atlanta, GA; 1986.

Cao, Quang V.; Burkhart, Harold E.; Lemin, Ronald C., Jr. Diameter distributions and yields of thinned loblolly pine plantations. Pub. No. FWS-1-82. Blacksburg, VA; Virginia Polytechnic Institute and State University; 1982. 62 pp.

Daniels, Richard F.; Burkhart, Harold E. Simulation of individual tree growth and stand development in managed loblolly pine plantations. Pub. No. FWS-5-75. Blacksburg, VA; Virginia Polytechnic Institute and State University; 1975. 69 pp.

Gent, J. A., Allen, H. L.; Campbell, Robert G.; Wells, C. G. Magnitude, duration tion and economic analysis of loblolly pine growth response following bedding and phosphorus fertilization. Southern Journal of Applied Forestry 10(3):124-128; 1986.

Gilmore, A. R.; Gregory, R. P. Twenty years growth of loblolly and shortleaf pine planted at various spacings in Southern Illinois. Transactions, Illinois State Academy of Science 67(1):38-46. 1974.

Hafley, W. L.; Buford, M. A. A bivariate model for growth an yield prediction tion. Forest Science 31(1):237-247. 1985.

Hafley, W. L.; Smith, W. D.; Buford, M. A. A new yield prediction model for unthinned loblolly pine plantations. Tech. Rep. No. 1, Bioeconomic Modeling Project, Southern Forest Research Center. Raleigh, NC; North Carolina State University; 1982. 65 p.

Harms, W. R.; Langdon, O. G. Development of loblolly pine in dense stands. Forest Science 22(3):331-337; 1976.

Harms, William R.; Lloyd, F. Thomas. Stand struc ture and yield relationships in a 20-year-old loblolly pine spacing study. Southern Journal of applied Forestry 5(3):162-165; 1981.

Matney, Thomas G.; Sullivan, Alfred D. Compatible stand and stock tables for thinned and unthinned loblolly pine stands. Forest Science 28(1):161-171; 1982.

McKee, W. H., Jr.; Wilhite, L. P. Loblolly pine response to bedding and fertilization varies by drainage class on lower Atlantic Coastal Plain sites. Southern Journal of Applied Forestry 19(1):16-21; 1986.

Nance, Warren L.; McCutchan, Barbara G.; Talbert, Cheryl B.; Buford, Marilyn A.; Foster, G. Sam; Sprinz, Peter. Experimental approaches for evaluating genetic effects on stand growth and yield. Presented at Workshop of the Genetics and Breeding of Southern Forest Trees Regional Information Exchange Group; 1986, June 25-26; University of Florida; Gainesville, FL; 1986. 33 pp.

Smith, W. D.; Hafley, W. L. Evaluation of a loblolly pine plantation thinning model. Southern Journal of Applied Forestry 10(1):52-63; 1986.

Sprinz, Peter; Clason, Terry; Bower, Dave. Spacing and thinning effects on the growth and development of a loblolly pine plantation. Forestry Research Report; Clason, Terry, ed. Homer, LA.: North Louisiana Hill Farm Experiment Station. 1979:1-42.