COMPARING DIAMETER GROWTH OF STANDS PRIOR TO CANOPY CLOSURE TO DIAMETER GROWTH OF STANDS AFTER CANOPY CLOSURE

Thomas J. Dean, D. Andrew Scott, Ray A. Newbold[1]

Abstract—Three models are compared for their ability to account for differences in diameter growth associated with different stages of stand development. Data for the comparisons were collected in young loblolly pine plantations treated variously at time of planting for the first 10 years since establishment. Neither the growth-growing stock model nor the accelerated development model accounted for differences in average diameter growth resulting from fertilization or herbaceous weed control. A morphological model based on coordinated development between crown size and stem size, however, appeared to successfully account for treatment differences in diameter increment.

INTRODUCTION

Diameter growth declines with advanced stages of development, making analyses of treatments causing wide disparities of growth difficult to interpret after a number of growing seasons. This situation is analogous to comparing mortality among stands grown on different site qualities: stands on better sites seem to have poorer survival than stands on poorer sites due to earlier self-thinning. Fertilization at time of planting and early release are known to hasten canopy closure relative to untreated counterparts (Will and others 2006). Since diameter growth slows after canopy closure, diameter growth of the treated stands can be slower than the untreated stands. Without some sort of normalization, growth comparisons among stands in different stages of development become tenuous if not meaningless.

Three models exist that could provide some basis for normalizing growth comparisons among stands in different stages of development. The objective of this study is to investigate the potential of these models to account for differences in rate of development on growth comparisons with data collected from young loblolly pine plantations subjected to early fertilization and weed control.

THE MODELS

Growth—Growing Stock Relations

One of the first hypothesized relations between stand growth and growing stock introduced into the English forestry literature was proposed by Langsaeter (1941). While the true nature of the curve relating total growth to growing stock is controversial (e.g., Zeide 2001), average tree growth is thought to be unrelated to stand density before the canopy closes: after canopy closure, it declines steadily. Long (1985) used relative density as a surrogate for growing stock allowing him to map stages of development on the hypothetical curve relating growth with growing stock (fig. 1). According to this model, differences in relative density will account for differences in diameter growth across stages of development.

Accelerated Development

Miller (1981) stated that in the absence of a permanent change in site nutrition, a stand's response to fertilizer could be treated as a simple reduction in rotation length. This has become known as the accelerated development hypothesis (Jokela and others 1989). According to this hypothesis, after a brief increase, tree growth will return to the curve characteristic of the site and advanced developmental stage (fig. 2). Miller (1981) proposed that tree size equated to developmental stage; consequently, diameter growth of treated and untreated trees should converge at some common tree dimension.

Tree Morphology

Crown dimensions and tree size have long been known to be correlated (Larson 1963). The interrelationship between leaf area, height to the median of leaf area, and stem diameter often agrees with what would be expected if the stem behaved as a beam uniformly bending from drag of wind moving through the crown (Dean and others 2002) (fig. 3a). A corollary of this relationship is that diameter increment of the average-sized tree can be predicted from the combined changes in the quantity of leaf area and height to its median (fig. 3b). According to this model, crown size and position will account for differences in diameter growth across stages of development.

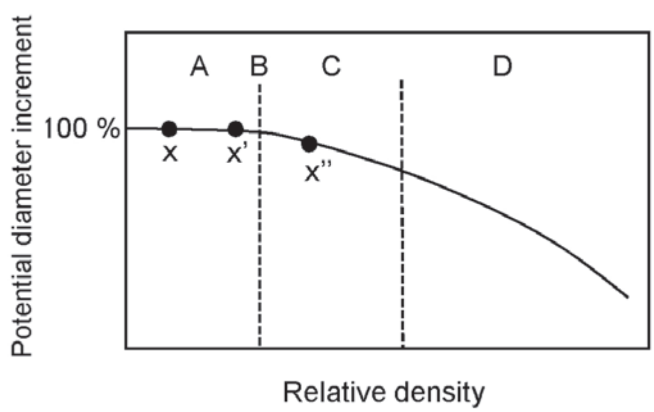

Figure 1—Growth-growing stock model for potential diameter growth as a functions of relative density and stage of stand development (A=open-grown; B=canopy closure; C=full-site; occupancy; D=self-thinning). x is a hypothetical stand at time t=0. x' and x" are stand x at t=1 if the stand were untreated or treated, respectively.

[1]Professor, Louisiana State University Agricultural Center, Baton Rouge, LA; Research Soil Scientist, U.S. Forest Service, Southern Research Station, Pineville, LA; Professor (retired), Louisiana Tech University, Ruston, LA, respectively.

Citation for proceedings: Stanturf, John A., ed. 2010. Proceedings of the 14th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-121. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 614 p.

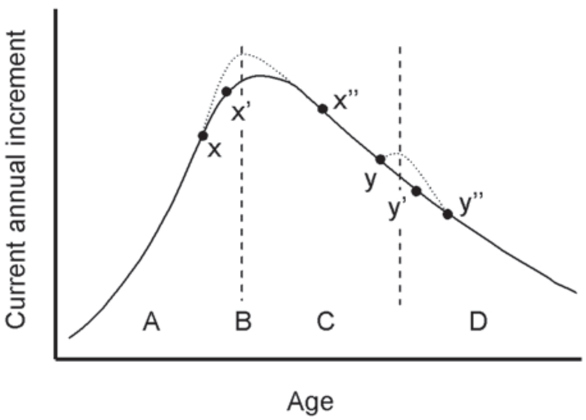

Figure 2—Miller's accelerated development hypothesis for the chronology of current annual increment (CAI) in relation to stage of development. Stages as in figure 1. Points illustrate effect of treatment on CAI (c.f., fig. 1).

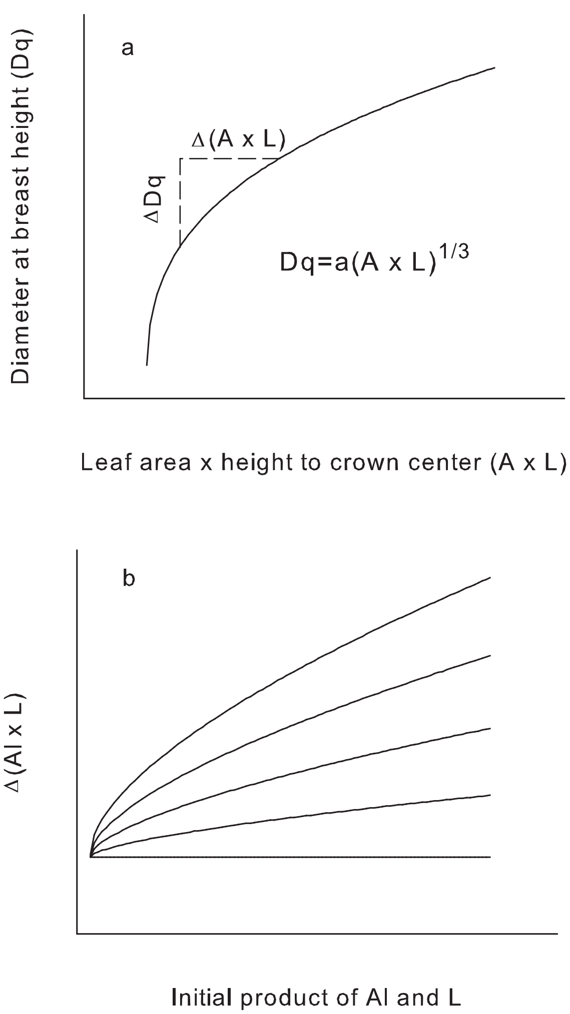

Figure 3—Tree morphology model. Relation between quadratic mean diameter (Dq) and mean product of leaf area (A) and distance to crown center (L) (a) and isolines of constant increment in Dq as a function of the mean change in (ΔAxL) and initial (AxL).

METHODS

Data from two experimental loblolly plantations were used for this study. The plantations are part of the Cooperative Research in Sustainable Silviculture and Soil Productivity, a partnership between forest industry, universities, and state and Federal agencies. The plantations selected for this analysis were established near Fred, TX and Bryceland, LA. The objectives and goals of the cooperative and details of these plantations are described in Carter and others (2006). These two plantations were selected because trees responded well to early cultural treatments of fertilization and herbaceous weed control (Dean 2001) and closed canopy sooner than the untreated trees.

Each site was blocked according to drainage or topography. Twenty-four, 0.074-ha plots were distributed uniformly between three blocks at Fred and four blocks at Bryceland and assigned factorial treatments at random. A standard pair of harvesting disturbances comprised one factor at each location (hand-felled, boles only removed and machine felled, whole-tree removed). Two other treatment factors at the Fred site were bedding (bedded and not bedded) and fertilization (or not). At Bryceland only one other factor was combined with harvesting: none, herbaceous weed control, and broadcast burning.

The Fred and Bryceland sites were planted in 1996 and 1997, respectively, and have been measured annually since. Annual quadratic mean diameter was calculated for each plot from the average basal area per tree. Annual diameter increment is the successive change in quadratic mean diameter. Relative density is calculated as the value of stand density index as a fraction of the maximum stand density index for loblolly pine noted by Reineke (1933). Stand density index is calculated with the equation $SDI=TPH(Dq/25)^{1.6}$, where TPH = trees/ha. Relative density is relative to a maximum SDI of 1110 for loblolly pine. Individual tree leaf area (A) was calculated with the equation $A = (0.0676+0.0463\ I)\ (dbh^{2.201}) /(H^{0.135})$, where I=1 if fertilized, 0 otherwise; dbh=diameter at 1.37 m (cm); and H=total tree height (m). The height to median leaf area was assumed to be the midpoint of the live crown. The probability of making of Type I error was limited to 0.10.

RESULTS AND DISCUSSION

Quadratic Mean Diameter

Both fertilization at time of planting at the Fred site and herbaceous weed control at the Bryceland site significantly increased Dq though the magnitude of the effect is much larger with fertilization than with herbaceous weed control (fig. 4). The effect of herbaceous weed control at age 8 years was not statistically significant (P=0.12). Annual increment in Dq decreased with age regardless of treatment (fig. 5). Fertilization significantly increased Dq increment between ages 3 and 5 years; herbaceous weed control increased Dq increment only at ages 3 and 4 years.

Growth—Growing Stock Relations

Relative density did not account for the comparatively large effect of fertilization on relative differences in Dq

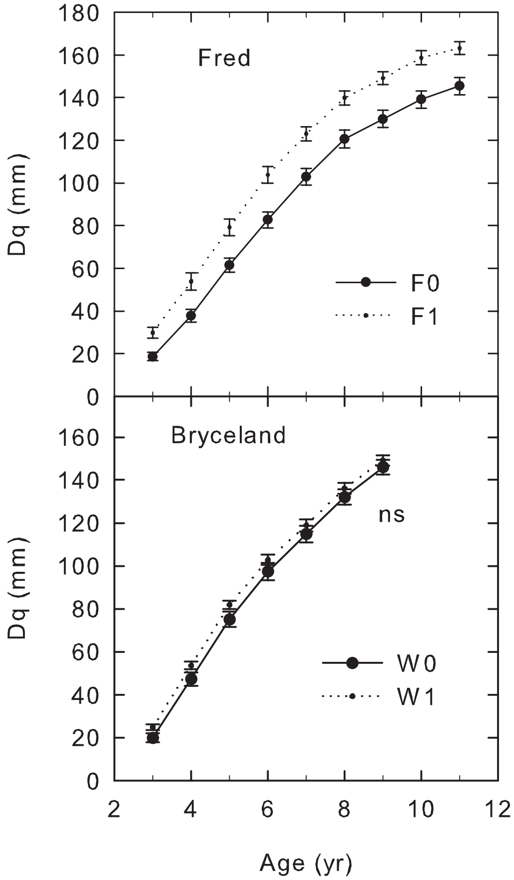

Figure 4—Effects of fertilization at time of planting (Fred) and herbaceous weed control (Bryceland) on chronology of quadratic mean diameter (Dq).

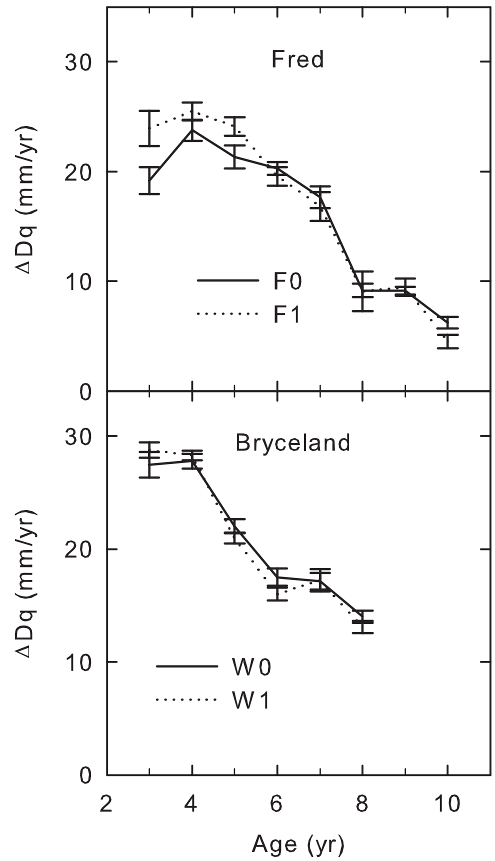

Figure 5—Effect of fertilization (Fred) and herbaceous weed control (Bryceland) on annual increment in Dq. Error bars are plus and minus one standard error.

increment (fig. 6). In other words, fertilization increased site occupancy without the expected commensurate reduction in relative increment in Dq. Relative density accounted for the small effect of herbaceous weed control on relative annual increment of Dq, especially at the young ages where herbaceous weed control significantly increased both diameter increment and SDI.

Accelerated Development

According to the accelerated development model, treatment effects, especially fertilization, should dissipate, returning growth to a value commensurate with its advanced stage of development. Miller (1981) implies that size manifests tree development, but offers no guidance on how to define size. Data from these plantations do not support this model, however. For a common initial value of leaf area per tree, fertilized trees exhibited greater diameter increment than unfertilized trees (fig. 7). At no time during this study did diameter increment of fertilized trees match the diameter increment of the unfertilized trees.

Tree Morphology

The morphological relationships between leaf area, its vertical distribution, and stem diameter appear to account for both the presence and absence of treatment effects on the annual increment of Dq in these loblolly pine trees (fig. 8). According to this model, larger annual increases in crown dimensions are required to produce the same diameter increment as the initial crown size is larger. The need to have larger increments in crown size to maintain constant values of diameter increment as the crown enlarges seems to account for the loss of significant fertilization effects on Dq after age 5 at the Fred site. This also seems to account for the lack of an effect of herbaceous weed control on Dq increment. While trees receiving early herbaceous weed control at the Bryceland site had larger crowns, the increment in crown size was only sufficient to maintain Dq increment at values similar to that observed with the unreleased trees.

ACKNOWLEDGMENTS

Funding for this project from Challenge Cost-Share awards from U.S. Forest Service Southern Research Station with matching funds provided by Temple-Inland Forest Products, Inc, International Paper Co., Weyerhaeuser Co., and Roy O. Martin Timber Company all of whom participated with LSU Agricultural Center and Louisiana Tech University in Cooperative Research in Sustainable Silviculture and Soil Productivity.

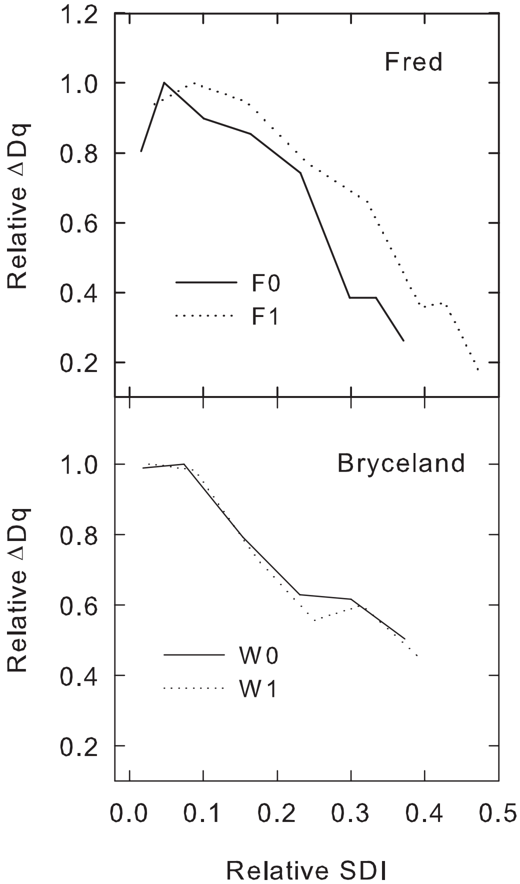

Figure 6—Effect of fertilization (Fred) and herbaceous weed control (Bryceland) on annual increment in quadratic mean diameter (Dq) relative to the maximum as a function of stand density index (SDI) relative to the maximum value for loblolly pine (450).

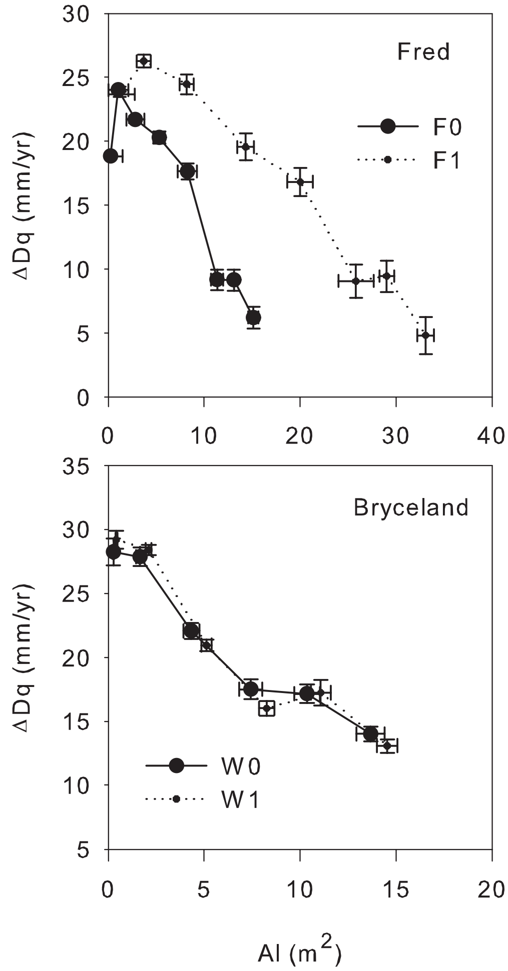

Figure 7—Effect of fertilization (Fred) and herbaceous weed control (Bryceland) on annual increment in mean quadratic diameters (ΔDq) and leaf area per tree (Al) at the beginning of the growing season. Vertical and horizontal bars are standard errors of the means.

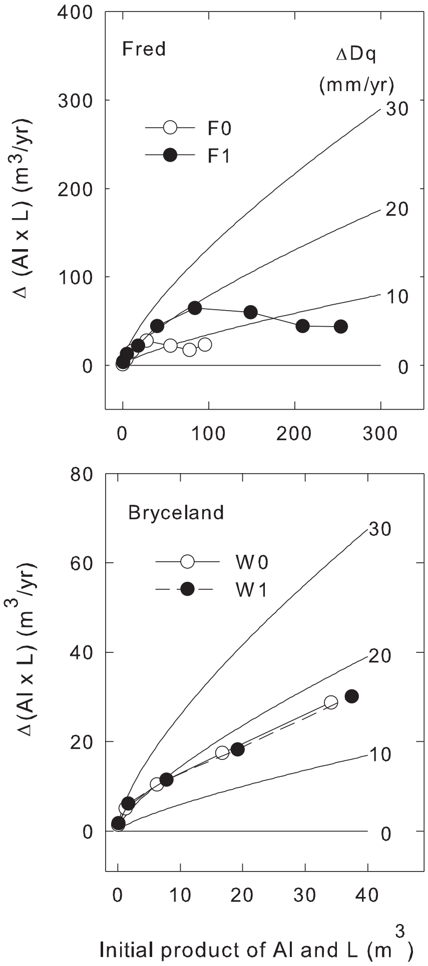

Figure 8—Isolines of annual increment in mean quadratic diameter (ΔDq) as a function of the average change in the product leaf area and distance between breast height and median leaf area and the average product of leaf area (ΔAl x L) and distance between breast height and median leaf area at the beginning of the growing season (Al x L). Plotted data are measured combinations of the (ΔAl x L) and (Al x L) of the treated and untreated plots at Fred, TX and Bryceland, LA, increasing in age from left to right.

LITERATURE CITED

Carter, M.C.; Dean, T.J.; Wang, Z. [and others]. 2006. Impacts of harvesting and postharvest treatments on soil bulk density, soil strength, and early growth of *Pinus taeda* in Gulf Coastal Plain: a long-term soil productivity affiliated study. Canadian Journal of Forest Research. 36: 601-604.

Dean, T.J. 2001. Potential effect of stand structure on belowground allocation. Forest Science. 47: 69-76.

Dean, T.J.; Roberts, S.D.; Gilmore, D.W. [and others]. 2002. An evaluation of the uniform stress hypothesis based on stem geometry in selected North American conifers. Trees Structure and Function. 16: 559-568.

Jokela, E.J.; Harding, R.B.; Nowak, C.A. 1989. Long-term effects of fertilization on stem form, growth relations, and yield estimates of slash pine. Forest Science. 35: 832-842.

Langsaeter, A. 1941. Om tynning i enaldret gran- og furuskog (About thinning in even-aged stands of spruce, fir, and pine). Meddel. F. D.Norkse Skogforsoksvesen. 8: 131-216.

Larson, P.R. 1963. Stem form development of forest trees. Forest Science Monograph 5. 42 p.

Long, J.N. 1985. A practical approach to density management. Forestry Chronicle. 61: 23-27.

Miller, Hugh G. 1981. Forest fertilization: some guiding concepts. Forestry. 54: 157-167.

Reineke, L.H. Perfecting a stand-density index for even-aged forests. Journal of Agricultural Research. 46: 627-638.

Will, R.E.; Markewitz, D.; Hendrick, R.L. [and others]. 2006. Nitrogen and phosphorus dynamics for 13-year-old loblolly pine stands receiving complete competition control and annual N fertilizer. Forest Ecology and Management. 227: 155-168.

Zeide, Boris. 2001. Thinning and growth: a full turnaround. Journal of Forestry. 99: 20-25.