EVALUATING GROWTH ASSUMPTIONS USING DIAMETER OR RADIAL INCREMENTS IN NATURAL EVEN-AGED LONGLEAF PINE

John C. Gilbert, Ralph S. Meldahl, Jyoti N.Rayamajhi, and John S. Kush[1]

Abstract—When using increment cores to predict future growth, one often assumes future growth is identical to past growth for individual trees. Once this assumption is accepted, a decision has to be made between which growth estimate should be used, constant diameter growth or constant basal area growth. Often, the assumption of constant diameter growth is used due to the ease of calculations. To determine which assumption is appropriate for natural even-aged stands of longleaf pine, permanent plot data from the U.S. Forest Service Regional Longleaf Pine Growth Study (RLGS) can be analyzed. Data from the RLGS cover a range of age classes, basal area classes, and site indices across the Gulf States. Plots have been measured every 5 years since the establishment of the study in 1964. Results show constant basal area growth to be the more valid assumption for natural even-aged longleaf pine.

INTRODUCTION

When using increment cores (past radial growth) to predict future growth, one often assumes future growth is identical to past growth for individual trees (i.e., growth is constant over a given time period). Once this assumption is accepted, a decision has to be made between which growth estimate should be used, constant diameter growth or constant basal area growth. Often the assumption of constant diameter growth is used due to the ease of calculations. However, this may not always be the most valid approach. Clutter and others (1983) stated their southern pine data does not follow the assumption of constant diameter growth, but the assumption of constant basal area growth has not been proven invalid. To determine which assumption is appropriate for natural even-aged stands of longleaf pine, permanent plot data from the U.S. Forest Service Regional Longleaf Pine Growth Study (RLGS) were analyzed. Data from the RLGS cover a range of age classes, basal area classes, and site indices across the Gulf States. Plots have been measured every 5 years since the establishment of the study in 1964.

DATASET DESCRIPTION

In 1964, Dr. Robert M. Farrar, Jr., with the USDA Forest Service established the Regional Longleaf Pine Growth Study (RLGS) in the Gulf States (Farrar 1978). The original objective of the study was to obtain a database for the development of growth and yield predictions for naturally regenerated, even-aged longleaf pine stands. Plots were installed to cover a range of ages, densities, and site qualities. The study accounts for change in growth over time by adding a new set of plots in the youngest age class every 10 years. The study currently consists of 292 1/5-acre and 13 1/10-acre permanent measurement plots located in central and southern AL, southern MS, southwest GA, northern FL, and the sandhills of NC. At the time of establishment, plots are assigned a target basal area class of 30, 60, 90, 120, or 150 square feet per acre. They are left unthinned to grow into that class if they are initially below the target basal area. Plot selection was based upon a rectangular distribution of cells formed by: 5 age classes from 20 to 100 years, 4 site quality classes ranging from 50 to 80 feet at 50 years, 5 density classes ranging from 30 to 150 square feet per acre, and plots left unthinned to examine the dynamics of dense stands. In subsequent re-measurements, a plot is thinned back to the previously assigned target if the plot basal area has grown 7.5 square feet per acre beyond the target basal area. The thinnings are generally of low intensity and are done from below. Net measurement plots are surrounded by a similar and like-treated half-chain wide isolation strip. Plots are inventoried and treated as needed, every 5 years (Kush and others 1987, 1998).

METHODS

The RLGS dataset was divided into measurement series of ten years, which provided sets of past, current, and future observed diameters for each plot and tree. Predicted future diameters were calculated using both assumptions (See eq. 1, 2, and 3). To evaluate which assumption provided the best estimate of growth, model validation was performed for the predictions for both methods over the classes of basal area, site index, and age. The validation process used bias and accuracy criteria from Burk (1986). Equations 4 and 5 are for bias and accuracy, respectively. The models were also compared using percent mean difference (Buford 1991). Equation 6 is for percent mean difference.

Assumed Future Diameter Estimates

Constant diameter growth

(1) Future Diameter = Current Diameter + (Current Diameter – Past Diameter)

Constant basal area (BA) growth

(2) Future BA = Current BA + (Current BA – Past BA)

(3) Future Diameter = $\sqrt{\frac{FutureBA}{0.005454}}$

Validation Equations

(4) Bias = $\frac{\sum(predicted - observed)}{n}$

[1]Research Associate and Associate Professor Emeritus, School of Forestry and Wildlife Sciences, Auburn University, AL; Statistician, Fishers, IN; and Research Fellow, School of Forestry and Wildlife Sciences, Auburn University, AL, 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.

(5) Accuracy = $\frac{\sum|predicted - observed|}{n}$

(Snee 1977, Burk 1986)

(6) Percent Mean Difference =

$$\left[\frac{1}{n}\sum\left(\frac{observed - predicted}{observed}\right)\right]\times 100$$

(Buford 1991)

RESULTS AND DISCUSSION

Models were evaluated using the bias and accuracy criteria from Burk (1986). Tables 1 through 3 show constant diameter and constant basal area growth bias and accuracy values for the ranges of basal areas, site indices, and ages, respectively. Figures 1 through 3 are graphical versions of constant diameter and constant basal area growth bias values for the ranges of basal areas, site indices, and ages, respectively. The constant basal area growth estimates performed significantly better at low basal areas and young ages than constant diameter growth estimates for natural even-aged stands of longleaf pine. Looking at bias and accuracy across all classes in table 4 also shows that growth estimates using the assumption of constant basal area growth were better than the estimates using the assumption of constant diameter growth.

Models were also compared using percent mean difference (Buford 1991). These results were similar to those using Burk's criteria. Table 5 shows constant diameter and basal area growth percent mean difference by ranges of basal areas, site indices, and ages. Figure 4 is a graphical version of the percent mean difference for both models across basal area classes. Again, the constant basal area growth estimates performed significantly better at low basal areas and young ages than constant diameter growth estimates.

Table 1—Constant diameter and basal area growth bias and accuracy by basal area classes for trees from the RLGS dataset

Basal Area (*square feet/acre*)	N	CD_Bias	CD_Accuracy	CBA_Bias	CBA_Accuracy
30	3635	0.13	0.25	-0.03	0.22
60	9656	0.15	0.24	0.03	0.18
90	18344	0.12	0.19	0.06	0.16
120	22562	0.12	0.18	0.07	0.16
150	10506	0.13	0.20	0.09	0.17

CD_ prefix = Constant Diameter Growth; CBA_ prefix = Constant Basal Area Growth.

Table 2—Constant diameter and basal area growth bias and accuracy by site indices for trees from the RLGS dataset

Site Index (*feet*)	N	CD_Bias	CD_Accuracy	CBA_Bias	CBA_Accuracy
50	10306	0.05	0.15	0.02	0.14
60	13324	0.12	0.20	0.04	0.17
70	24624	0.18	0.23	0.09	0.18
80	16449	0.10	0.19	0.05	0.16

CD_ prefix = Constant Diameter Growth; CBA_ prefix = Constant Basal Area Growth.

Table 3—Constant diameter and basal area growth bias and accuracy by age classes for trees from the RLGS dataset

Age (*years*)	N	CD_Bias	CD_Accuracy	CBA_Bias	CBA_Accuracy
20	28623	0.21	0.26	0.10	0.19
40	20177	0.09	0.16	0.05	0.15
60	9572	0.03	0.15	0.01	0.14
80	4975	0.02	0.15	0.00	0.15
100	1356	0.00	0.16	-0.01	0.16

CD_ prefix = Constant Diameter Growth; CBA_ prefix = Constant Basal Area Growth.

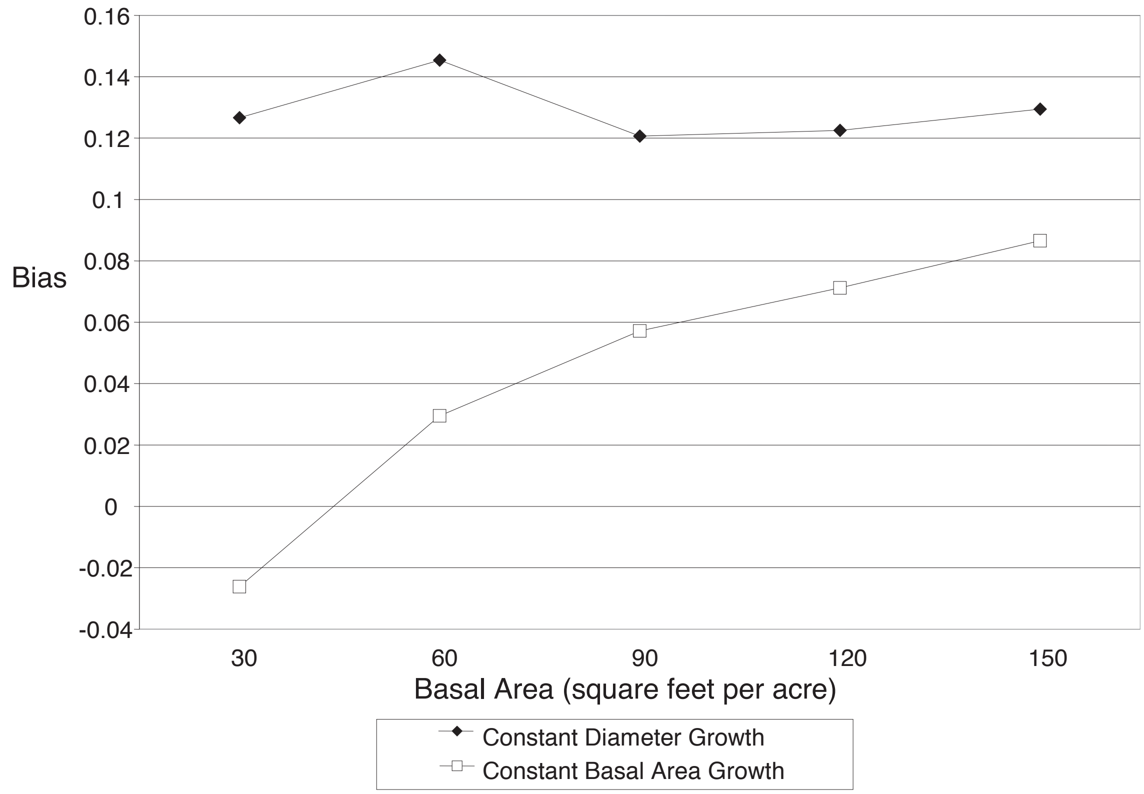

Figure 1—Constant diameter and basal area growth bias by basal area classes for trees from the RLGS dataset.

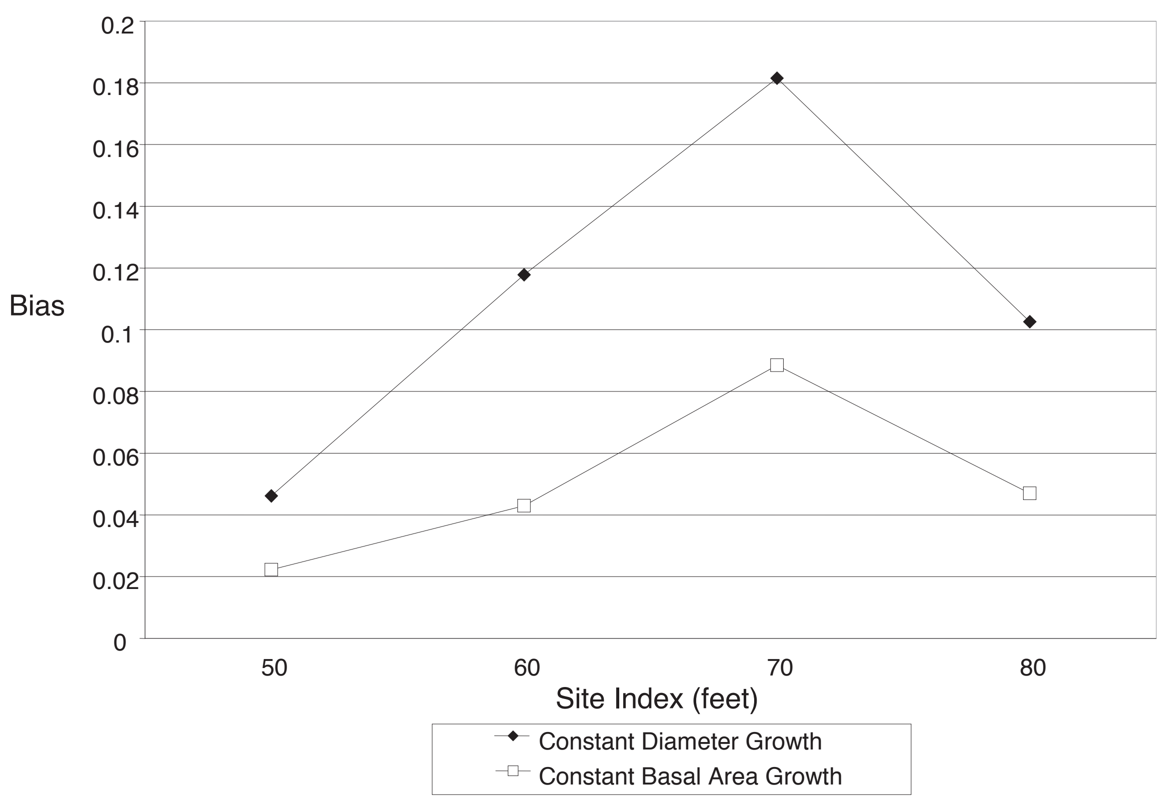

Figure 2—Constant diameter and basal area growth bias by site indices for trees from the RLGS dataset.

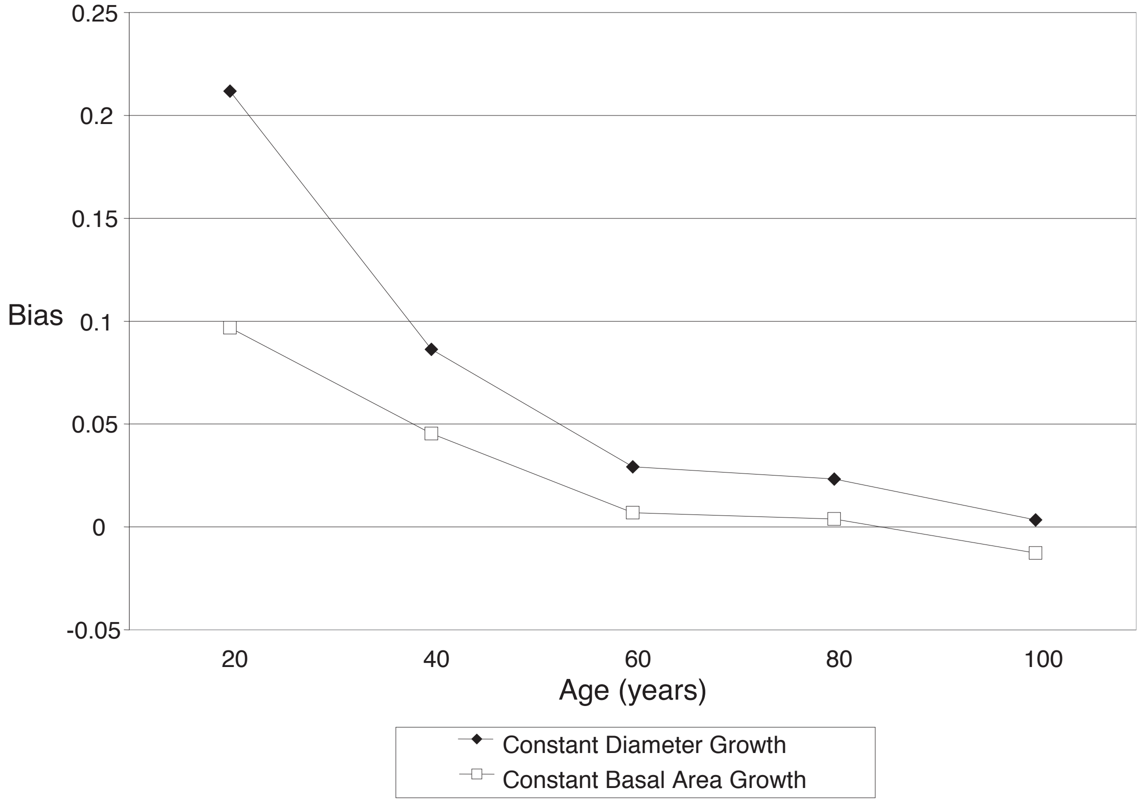

Figure 3—Constant diameter and basal area growth bias by age classes for trees from the RLGS dataset.

Table 4—Constant diameter and basal area growth bias and accuracy over all classes for trees from the RLGS dataset

N	CD_Bias	CD_Accuracy	CBA_Bias	CBA_Accuracy
64703	0.13	0.20	0.06	0.17

CD_ prefix = Constant Diameter Growth; CBA_ prefix = Constant Basal Area Growth.

Table 5—Constant diameter and basal area growth percent mean difference by ranges of basal areas, site indices, and ages for trees from the RLGS dataset

Classification	Ranges	CD_Mean Difference (%)	CBA_Mean Difference (%)
Basal Area (square feet per acre)	30	0.61	0.31
	60	0.66	0.32
	90	0.41	0.25
	120	0.45	0.31
	150	0.49	0.35
Site Index (feet)	50	0.25	0.21
	60	0.64	0.35
	70	0.71	0.43
	80	0.18	0.13
Age (years)	20	0.97	0.57
	40	0.15	0.13
	60	0.06	0.06
	80	0.03	0.03
	100	0.02	0.02

CD_ prefix = Constant Diameter Growth; CBA_ prefix = Constant Basal Area Growth.

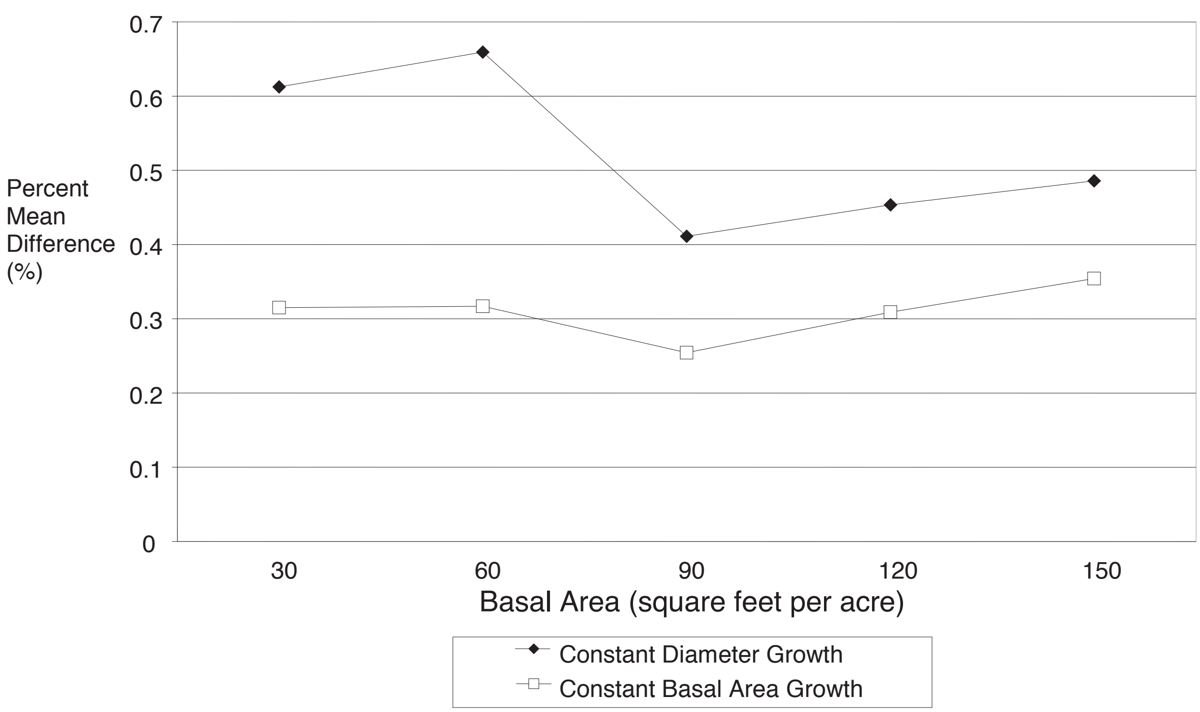

Figure 4—Constant diameter and basal area growth percent mean difference by basal area classes for trees from the RLGS dataset.

CONCLUSIONS

For natural even-aged stands of longleaf pine, growth estimates using the assumption of constant basal area growth were consistently better than the estimates using the assumption of constant diameter growth in all measurements of validation. However, the magnitude varies across the ranges of basal areas, site indices, and ages. It is up to the user to concentrate on the ranges of interest. The final choice between the two methods is greatly dependent on acceptable error, ease of calculations, and time.

ACKNOWLEDGMENTS

The authors would like to thank Robert M. Farrar, Jr. for initiating the RLGS and the U.S. Forest Service for its funding of the RLGS for these many years.

LITERATURE CITED

Buford, M.A. 1991. Performance of four yield models for predicting stand dynamics of a 30-year-old loblolly pine (*Pinus taeda* L.) spacing study. Forest Ecology and Management. 46: 23-38.

Burk, T.E. 1986. Growth and yield model validation: have you ever met one you liked? In: Allen, S; Cooney, T.C., (eds.) Data management issues in forestry: Proceedings of FORS 1986 computer symposium. Forest Resources Systems Institute, Florence, AL: 35-39.

Clutter, J.L; Fortson, J.C.; Pienaar, L.V. [and others]. 1983. Timber Management: A Quantitative Approach. Krieger Publishing Company, Malabar, FL: 333 p.

Farrar, R.M., Jr. 1978. Silvicultural implications of the growth response of naturally regenerated even-aged stands of longleaf pine (*Pinus palustris* Mill.) to varying stand age, site quality and density and certain stand structure measures. Ph.D. dissertation, University of Georgia, Athens, GA: 132 p.

Kush, J.S.; Meldahl, R.S.; Dwyer, S.P. [and others]. 1987. Naturally regenerated longleaf pine growth and yield research. In: Phillips, D.R. (comp.) Proceedings of the fourth biennial southern silvicultural research conference. Gen. Tech. Rep. SE-42. U.S. Forest Service, Southeastern Forest Experiment Station, Asheville, NC: 343-344.

Kush, J.S.; Meldahl, R.S.; McMahon, C.K. 1998. Thirty years old – The Regional Longleaf Pine Growth Study. In: Waldrop, T.A. (ed.) Proceedings of ninth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-20. U.S. Forest Service, Southern Research Station, Asheville, NC: 113-117.

Snee, R.D. 1977. Validation of regression models: methods and examples. Technometrics. 19: 415-428.