Stand Dynamics of Even-Aged Longleaf Pine According to Two Contemporary Growth and Yield Models: FVS-SN and FORSim-LPGS

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Introduction

Extensive areas in the Southeast are being planted with longleaf pine (*Pinus palustris*). Approximately 870 million seedlings have been planted since 1966, enough to stock 1.4 million acres, assuming a nominal spacing of 620 trees per acre (D. Gjerstad, unpublished data). The motivations for planting longleaf are varied and range from efforts to restore threatened natural ecosystems, to diversification and bet hedging on the part of timber growers. Longleaf pine has a reputation for being both more difficult to plant and slower growing than loblolly and slash pine, despite accumulating evidence to the contrary (LLA 2008). Inherent economic benefits associated with longleaf include fire tolerance, resistance to fusiform rust, high quality timber products, and pine straw. While reliable stand dynamics models exist for loblolly and slash pine, a combination of the lack of interest in managing, and availability of data on longleaf pine, have constrained the development of models for this species. The purpose of this study is to compare and contrast two available empirical models for predicting the growth and development of longleaf pine, The Southern Variant of the Forest Vegetation Simulator (FVS-SN; FVS Staff 2002) and FORSim-LPGS (FORSight Resources 2008). Because independent data with which to validate either model is lacking, knowledge of stand dynamics in conjunction with longleaf pine silvics are used to evaluate model behavior and provide a basis for the cross comparison (*sensu* Zhang et al. 1993, Leary 1997).

Methods

Brief descriptions of both models are provided in Table 1. The modeled scenarios consisted of: plantations established at 400 TPA (with 90% 1st year survival); site indices ranging from 60-80-100 ft at base age 50; development of natural stands (unmanaged), and thinning from above and below to BA=50 ft^2/ac at stand age 40. All scenarios were projected to stand age 80.

Table 1. Characteristics of the stand dynamics models.

Characteristic	FVS-SN	FORSim-LPGS
Basic framework	Individual tree, distance independent	Young stand: Whole stand prediction/projection. Old stand: Individual tree, distance independent.
Inputs	Required: location (user defined or default latitude=32.4 and longitude=86.3), stem density (user defined), site index (user defined or white oak SI=70 default and mapped), projection length (user defined or 50 yr default), product specs (pulpwood and sawlogs, user defined or default), Optional: calibration based on measured diameter and height increments, growth adjustment based on management or no management, tree lists.	Required: total stand age, site index, stem density, projection length, product merchandizing specs. Optional: choice of using prediction or projection models, BA, dominant height, stand type, years to reach breast height, whether stand was previously thinned, tree list for stands >= 20 years
Growth	Separate small (<3" dbh) and large (≥3" dbh) tree models; basal area of larger trees is used to modify dbh growth, height growth is adjusted based on relative height, live crown ratio, and shade tolerance.	Predict or project stand basal area and dominant height for stands < 20 years; project basal area of tree lists either inputted or initially generated using the Weibull pdf for stands >= 20 years; predicted total tree heights for tree list data based on dbh, age, BA, and predicted dominant height; and dominant height for stands >= 20 years is the average height of top 40% of trees in the dbh distribution
Mortality	Two types of mortality: background mortality based on proximity to species maximum dbh, and density dependent mortality initiated when SDI ≥ 0.85*SDI max (SDI max=390 for longleaf pine) and distributed based on tree location within basal area percentile.	Projected survival for stands < 20 years based on initial TPA, and starting and ending age; and projected survival for stands >= 20 years by dbh class based on dbh and predicted dbh increment. Survival adjusted for unthinned and thinned stands using a stand-level mortality model
Site quality	Site index is a function of dominant height and total age at base age 50 years	Site index is a function of dominant height and total age at base age 50 years
Volume equations	National Volume Estimator Library (form-class segmented-profile equation for USDA For Serv Region 8)	Stem-profile function for predicting multiple product volumes by crown ratio class
Adjustments (e.g., site prep effects)	Species specific growth modifier for planted stands	Inputted or predicted years to breast height adjusts predicted or projected dominant height to account for site preparation treatments

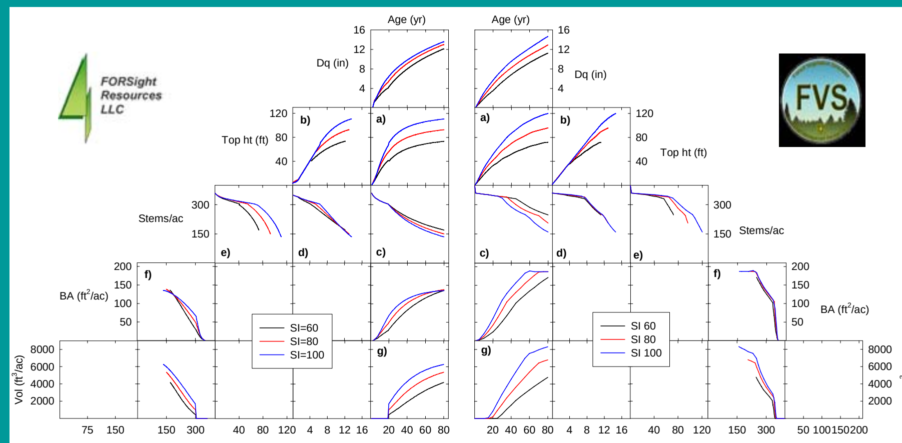

Figure 1. Comparison of law-like relationships in forest growth and yield as portrayed by LPGS (left) and FVS (right) over an 80 year projection period for planted (400 TPA, 90% 1st year survival), but otherwise unmanaged, longleaf pine. Indexed relationships include: a) height-age site class, b) height-diameter site class, c) Sukachev effect, d) Reineke's rule, e) spacing percent, f) stocking guide framework, and g) volume-age site class (after Leary 1997).

Table 2. Description of law-like relationships presented in Figure 1 and indication of model compliance with those claims.

Stand Dynamic Relationships	Evaluation Claim / Criteria	FVS-SN	FORSim-LPGS
a) Height-Age Site Class	Stand top height will be higher at a given age on higher sites	ok	ok
b) Height-Diameter Site Class	Total heights of trees of a given diameter will be greater on higher sites	ok	ok
c) Sukachev Effect	Stands on higher sites will self-thin faster than those growing on lower sites	ok	ok
d) Reineke's Rule	The relationship between Dq and stand density is independent of site with a constant slope of -1.6, and is linear on log-log scales	ok	suspect
e) Spacing Percent	Stands self-thin when the mean inter-tree spacing to top height ratio approaches 10-12%, is linear on log-log scales, and is relatively independent of site	suspect	suspect
f) Stocking Guide Framework	Stand density declines with increasing BA, and then either stabilizes or declines slightly, and independent of site quality	ok	suspect
g) Volume-Age Site Class	Site productivity is related to wood volume produced at a given age	ok	ok

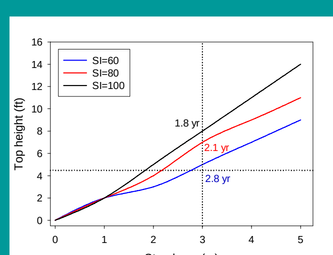

Figure 2. The time required for planted seedlings to reach 4.5 ft tall (horizontal dotted line) for various site indices according to FVS-SN. This value was set equal to 3 yr (vertical dotted line) independent of site index for the LPGS runs. Longleaf pine seedlings go through a 'grass' stage of varying length prior to commencing with height growth (or 'bolting'). The rapid response portrayed on the higher sites by FVS-SN may be overly optimistic.

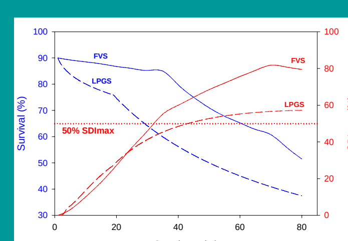

Figure 3. Inter-model comparison of self-thinning (survival %; primary Y-axis) and stocking (% of SDI max; secondary Y-axis) for longleaf pine planted at 400 TPA and SI = 80. Self-thinning progresses faster according to LPGS than FVS-SN; at stand age 40 there were 70% as many surviving stems predicted by LPGS (225 TPA) as FVS-SN (319 TPA). Site carrying capacity corresponds to approximately 60% of SDI max according to LPGS, whereas the corresponding value (roughly 80%) for FVS-SN is considerably higher.

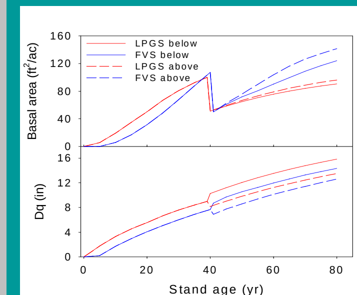

Figure 4. Simulated response to thinning from above and below at age 40 to a residual density of 50 ft^2/ac BA according to both models (400 TPA & SI=80 scenario). The expected 'chainsaw' effect is evident in the plot of average stand diameter (Dq; bottom panel), where thinning from below results in a increase and from above a decrease in Dq. Contrary to expectations, both models predict a better growth response following thinning from above, where the best trees are removed, versus thinning from below, where the best trees remain. Basal area increment (BAI) following thinning was markedly different between models (top panel), such that when averaged across treatments, predicted BAI for FVS-SN (BAI=2.2 ft^2/yr) was nearly twice as high as according to LPGS (BAI=1.1 ft^2/yr).

Results & Discussion

Both models forecast patterns of stand development that were consistent with the majority of claims embodied in the law-like relationships (Table 2). A notable difference between these models, however, was detected in relation to the prediction that diameter-based size-density relationships (d & f) operate independent of differences in site quality; here FVS-SN showed more consistency with those claims than LPGS. Interestingly, neither model agreed with a similar claim made by the height-based index of self-thinning (relationship e). Some empirical evidence suggests that self-thinning may not be entirely independent of site quality (*e.g.* Innes et al. 2005).

Also of considerable interest, and potentially useful for assessing model behavior, are the absolute values of stand parameters predicted by the models. When averaged across site index, FVS-SN forecasts stand level BAs' at ages 40 and 80 of 115 and 182 ft^2/ac, respectively, whereas the corresponding values obtained from LPGS were 99 and 137 ft^2/ac. Of greater relevance from an economic standpoint are the predicted merchantable volumes, which in the absence of management, averaged 6,625 ft^3/ac according to FVS-SN and 5,268 ft^3/ac for LPGS by stand age 80.

Conclusions

The lack of independent data with which to validate the models disallows a recommendation for using one over the other at this point, yet large differences between predictions obtained for the same scenarios underscores that need to carry out such tests. More consistent adherence to the law-like relationships presented in Figure 1 by FVS-SN than LPGS are likely the result of specific internal constraints imposed on that model (Table 1), and do not necessarily mean that the resulting predictions provide a better portrayal of reality.

References

FVS Staff. 2001. Southern (SN) Variant Overview. USDA Forest Service, Forest Management Service Center. 63 p.

FORSight Resources, LLC. 2008. FORSim Longleaf Pine Growth Simulator (LPGS) v2008.5.

Innes, J.C.; Ducey, M.J.; Gove, J.H.; Leak, W.B.; Barrett, J.P. 2005. Size-density metrics, leaf area, and productivity in eastern white pine. *Canadian Journal of Forest Research.* **35:** 2469-2478

Johnson, R. 2008. Does longleaf make dollars and $ense? The Longleaf Alliance.

Leary, R.A. 1997. Testing models of unthinned red pine plantation dynamics using a modified Bakuzis matrix of stand properties. Ecological Modeling 98: 35-46.

Zhang, L., Moore, J.A., and J.D. Newberry. 1993. A whole-stand growth and yield model for interior Douglas-fir. Western Journal of Applied Forestry 8(4): 120-125.