SOIL FERTILITY ASSESSMENT IN THE 3-PG MODEL USING SITE INDEX IN THE SOUTHEASTERN UNITED STATES

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Soil fertility is one of the most important, yet least understood aspects of forest ecosystems. Study of soil fertility in forest ecosystems is complicated by the complex relationship between soil properties and stand productivity and immense variability in properties and characteristics of soils within relatively small geographic areas. Furthermore, the deep rooting systems of trees, which are capable of exploring soil throughout the soil profile, complicates the relationship between soil properties and stand productivity (Landsberg and others 2003, Dye and others 2004). Due to these complexities, soil fertility in forest ecosystems is measured by indirect approaches namely phytocentric and geocentric. The phytocentric approach uses tree based metrics to estimate soil fertility, while the geocentric approach uses the physical site characteristics as a relative indicator of soil fertility.

Site quality determines the potential productivity of forest ecosystem and site quality to a large extent is a function of the physical, chemical, and biological properties of soil as modified by anthropogenic factors (Augusto and others 2002). Many traditional growth and yield models and process-based models require some quantitative information about site quality / soil fertility to predict growth, yield, and physiological outputs of crop species. Site index is a realized measure of site quality and is widely used in many traditional growth and yield models as a driver of productivity (Burkhart and Tomé 2012). Similarly, several geocentric approaches using soil physical properties, topographic features, and climatic characteristics have attempted to quantify site quality/soil fertility (Carmean 1975, Fontes and others 2003, Hagglund 1981, Sampson and others 2008).

Quantification of soil fertility in forested ecosystems has important implications for modeling forest productivity. Knowledge of soil fertility is equally important for making fertilizer decisions and estimating fertilizer response. A key question arising from previous research is how can site index, a widely used indicator of site quality in forested ecosystem, be used as a potential tool for soil fertility estimation. Specifically, site index is a realized measure of site quality that is affected by not just soil fertility but a variety of edaphic and climatic factors including soil moisture and temperature. However, previous studies on loblolly pine have suggested that soil moisture is not a strong determinant of productivity in the southeastern US as this region receives fairly well distributed rainfall through out the year and annual precipitation exceeds potential evapotranspiration.

The 3-PG model (Physiological Principles Predicting Growth) has been parameterized and tested on many commercially important species throughout the globe (Almeida and others 2004, Stape and others 2004, Landsberg and others 2001, Bryars and others 2013, Rodŕiguez and others 2002, Coops and others 2005, Landsberg and Sands 2011). Past results with the 3-PG model have shown that 3-PG can be used to predict productivity with a limited number of input variables and unique parameter sets for each species.

3-PG is a monthly time-step process-based model. It requires 40 species-specific parameters. Additionally, 3-PG requires three sets of input variables: climatic data, stand initialization data, and site-specific data. Climatic data includes monthly averages of maximum temperature, minimum temperature, vapor pressure deficit, and radiation. Stand initialization data consists of initial stocking and initial biomass of seedlings. Site-specific data includes available soil water, soil textural class, and fertility rating. The 3-PG model has four biological sub-models to model C assimilation, C allocation, stand dynamics, and evapotranspiration. Biomass pools and stand density are the primary outputs from 3-PG. Fertility rating is a site-specific variable in 3-PG that describes soil nutrient status on a scale of 0 to 1. FR is an important variable in 3-PG that affects leaf area index and hence absorbed photosynthetically active radiation (APAR), canopy light use efficiency, and canopy conductance.

We developed a method to predict the soil fertility rating in the model 3-PG for loblolly pine plantations based on the relationship between stand productivity and site index. Then FR was used in 3-PG to predict loblolly pine yield and mortality on 21 sites across the southeastern

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Citation for proceedings: Schweitzer, Callie J.; Clatterbuck, Wayne K.; Oswalt, Christopher M., eds. 2016. Proceedings of the 18th biennial southern silvicultural research conference. e–Gen. Tech. Rep. SRS–212. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 614 p.

United States. When observed yield and stem number were compared against the simulated values, 89 percent of the variation in yield and 89 percent of the variation in stand density were explained by simulated values. The USDA NRCS SSURGO dataset contains site index values for loblolly pine for the major soil series in most of the counties in the southeastern US. We observed good correlation between site index reported in SSURGO database and site index values observed in field inventory across major soil series in the southeastern US. When site index values from SSURGO dataset were used to derive FR values to predict loblolly pine productivity at a regional scale, the 3-PG model provided realistic outputs of loblolly pine productivity.

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