LAI-2000 ACCURACY, PRECISION, AND APPLICATION TO VISUAL ESTIMATION OF LEAF AREA INDEX OF LOBLOLLY PINE

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Abstract—Leaf area index (LAI) is an important parameter of forest stand productivity that has been used to diagnose stand vigor and potential fertilizer response of southern pines. The LAI-2000 was tested for its ability to provide accurate and precise estimates of LAI of loblolly pine (Pinus taeda L.). To test instrument accuracy, regression was used to compare needefall estimates of LAI to those from the LAI-2000. To test instrument precision, analysis of variance was used to test sources of variation including instrument drift, overcast versus clear skies, time of day, and synchronization of above- and below-canopy sensors. A regression model was developed to calibrate visual estimates of LAI with LAI-2000 estimates and measures of height and stand basal area.

INTRODUCTION

Leaf area index (LAI) is the ratio of foliage surface area to ground surface area of a vegetative stand. It has become widely accepted as an indicator of photosynthetic capacity and level of stress of forest stands (Waring 1983). Since maximum LAI of a forest stand is limited by nutrient availability, any deviation from this value can indicate whether it will respond to fertilization, given fixed levels of other growth limiting factors, such as soil water and temperature (Vose and Allen, 1988). Thus, monitoring of LAI has potential application in prescribing of fertilizer treatments.

Techniques for estimating LAI of loblolly pine include those that utilize optical sensors, such as the LAI-2000 canopy analyzer (Li-Cor, Inc., Lincoln NB) and those that are conducted visually (Sampson and others 1996). Estimates from optical sensors are considered reasonably precise and accurate, but they require purchase of expensive equipment. Visual estimates can be reliable and inexpensive, given adequate training of observers, but they can suffer from bias. A combination of the two methods of LAI estimation may provide the desired level of accuracy, precision, and cost. This study had two objectives: 1) to quantify accuracy and precision of the LAI-2000, and 2) to calibrate visual estimates of LAI with LAI-2000 estimates and measures of height and stand basal area.

METHODS

The research was conducted in mid-rotation plantations of loblolly pine that were absent of shrubs and hardwoods. For each test of the LAI-2000, an above-canopy sensor (A) logged readings in a nearby large opening (no vegetation at greater than 15 degrees above the horizon) while a below-canopy sensor (B) was used to log readings within the study area. All LAI-2000 readings were taken with the sensor facing north at 1.4 meters above ground and a 90-degree view cap attached to the lens. In the laboratory, data from the two sensors were merged and LAI was calculated with Li-Cor software.

To test LAI-2000 accuracy, needlefall estimates of LAI were regressed against LAI-2000 estimates using measurements taken at a site near Eatonton GA (Scott 1997). Instrument precision was tested at sites near Athens GA or Phenix City AL by taking repeated measurements above the same points but under different instrument or sky conditions. These tests included comparisons of instrument drift (measurements taken in rapid progression), consecutive days with overcast versus clear skies, time of day (10:30, 11:30, or 12:30 Eastern Standard Time, EST), and levels of synchronization between A and B sensors to identical light conditions (1 percent, 5 percent, and 10 percent differences). Tests of instrument drift, time of day, and A/B sensor synchronization were repeated in March, June, and December 2000. Data from each precision test were subjected to analysis of variance with repeated measurements in time (split-plot design). A blocking factor of either individual sample points within a plot (drift study) or individual plots (time of day and synchronization studies) was included in the design. Linear regression was used to test the relationship between LAI estimates of overcast versus clear skies.

To address the second study objective, a total of 25 points were located in stands that varied in height and stand basal area. Following a period of field training, six observers estimated LAI visually above each point during early May and August 1999 using the methods of Sampson and others (1996). Approximately ten days prior to the visual estimates, LAI of each plot had been estimated with the LAI-2000. Measurements of average height and stand basal area also were taken in each plot. LAI-2000 estimates were regressed against visually estimated values, indicator variables for each observer, and stand variables. Stepwise regression with backward elimination was used to test the significance of each variable in the model.

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RESULTS

Accuracy of the LAI-2000 was high, with estimates exceeding those obtained from needlefall by only 4 percent. No significant differences were found when LAI-2000 measurements were taken in rapid succession above the same points (instrument drift). LAI-2000 readings taken on cloudy days averaged 7 percent greater than those taken on clear days. Readings taken at 10:30 EST averaged 4 percent greater than those taken at 11:30 and 12:30 EST. June readings with 1 percent synchronization between A and B sensors averaged 14 percent higher than those taken with 5 and 10 percent synchronizations; however, levels of synchronization did not affect readings taken in March and December.

For both the May and August data, a log-log regression model was found to be most suitable for calibrating visual estimates of LAI. In this model, the interaction of visually estimated LAI and stand basal area explained 55 to 68 percent of the variation in LAI-2000 estimates. Average height explained an additional 8 to 18 percent of variation. None of the indicator variables for individual observers were significant in the model, indicating an absence of bias.

CONCLUSIONS

Results of this research indicate that the LAI-2000 is a relatively accurate and precise instrument for estimating LAI of loblolly pine plantations. The instrument overestimated LAI slightly when compared to needlefall estimates. No significant drift was found in repeat measurements taken in rapid succession. On the average, the LAI-2000 gave somewhat higher readings under cloudy versus clear sky conditions. Readings were higher when taken during mid-morning versus late morning or early afternoon. Apparently bright sky conditions cause slight reductions in LAI-2000 estimates. Of all accuracy and precision tests, levels of synchronization between A and B sensors resulted in the greatest variation among readings. When synchronization between the two sensors was low (5 or 10 percent differences) during the June readings, LAI-2000 estimates were reduced in value relative to the 1-percent synchronization; however, this trend was not observed in the March and December readings. Thus, a high degree of synchronization (1- percent difference) is critical if the sensor is to detect change in LAI during the growing season.

The interaction of visually estimated LAI and stand basal area was the best single variable for predicting May or August LAI-2000 readings. This result suggests that visual estimates of LAI are influenced by stand basal area. In support of this finding, Sampson and others (1996) recommend a linear adjustment to visually estimated LAI to account for deviations in basal area from what would be considered full stocking. Average height, an indicator of age and site productivity, also was a significant variable in the regression models. The visual estimates of LAI were not influenced by potential bias from individual observers.

Our research has indicated that visual estimates of LAI can be successfully calibrated with more objective estimates obtained using needlefall collections or optical sensors. This combination of techniques can be used to provide a reliable and low cost method for estimating LAI of pine plantations.

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