VALIDATION OF A RAPID NON-DESTRUCTIVE LEAF AREA INDEX MEASURING DEVICE IN SUGARCANE

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Abstract

A rapid non-destructive leaf area index (LAI) measuring device (SUNSCAN Canopy Analysis System) was validated on four sugarcane cultivars grown in two 12-month crop cycles. The device predicted LAI with reasonable accuracy (RMSE=0.46; R^2=0.90; n=54; mean relative error 59%). There were no differences in LAI prediction between the selected cultivars (NCo376, N19, N24 and N26) despite exhibiting consistently different leaf angles. There was, however, some bias in the prediction. Nevertheless, the regression equation provides a suitable calibration of the device for the South African cultivars measured in this study.

Introduction

The accurate measurement of leaf area index (LAI) of a crop typically requires destructive or laborious leaf counting and measuring techniques, both of which require significant time and large quantities of the crop to be sampled. This sampling limitation places significant restrictions in analyses of crop growth. One such example that requires accurate LAI measurement is the determination of the extinction coefficient of Beer's law equation of light interception. The extinction coefficient is known to vary due to solar angle and leaf angle. While solar angle is very predictable little is known about the effect of the variance of leaf angle in sugarcane. Some sugarcane cultivars are known for their early prostrate growth habit (e.g. N14) while others are known for their dominant vertical leaf orientation (e.g. NCo376). Thus, the use of light interception to measure LAI requires knowledge about leaf angles. In recent years non-destructive methods that involve the measurement of the penetration of light through canopies have been developed (Lang et al., 1985; Campbell, 1986; Goudriaan, 1988).

This paper reports the performance of the LAI prediction model of the SUNSCAN Canopy Analysis System that utilises non-destructive light interception, leaf angle and solar angle measurements. An accurate and rapid LAI measuring system will help progress toward better modelling of the growth and yield of different cultivars of sugarcane.

Methods

An experiment was established at Pongola (lat. 27° 24' 56" S., long. 31° 35' 37" E., WGS84 datum) to examine cultivar and seasonal effects on sugarcane growth and biomass partitioning. Leaf area index (crop leaf area per unit land area) measurements were made on three contrasting cultivars in two 12-month cycles (Commencing March and April, 2000). The March cycle included cultivars NCo376, N26 and N19 and the April cycle NCo376, N26 and N24. A Delta-T® SUNSCAN Photosynthetically Active Radiation (PAR) meter (with a beam fraction sensor) was used to predict LAI. The system comprises the two light sensors and a hand-held computer (Psion® *Workabout*). Leaf area index predictions were made with the SUNSCAN device within 1.5 hours of solar noon to achieve representative daily measures of interception. Leaf area was also measured with an electronic planimeter on 10 stalks immediately next to where the SUNSCAN readings and stalk population counts were made. Mean leaf angles were determined by the method of Wang and Jarvis (1988) that determines an Ellipsoidal Leaf Angle Distribution Parameter (*ELADP*):

$$ELADP = \frac{\pi}{2}\left(\frac{N_h}{N_v}\right) \qquad \ldots(1)$$

Where, N_h is the number of horizontal and N_v is the number of vertical leaves, less than or greater than 45 degrees, respectively from the horizon.

Results and Discussion

The LAI model prediction was reasonably accurate (RMSE=0.46; R^2=0.90; n=54; mean relative error 59%), particularly at the very low end of the scale (Fig. 1). There were no differences in LAI prediction between the selected cultivars despite exhibiting consistently different leaf angles (Fig. 2). These differences were evident between cultivars and sampling times. There was, however, some tendency toward bias in the prediction of LAI (slope = 0.61), such that LAI was slightly overestimated at very low LAI and underestimated at LAI greater than unity. Further testing is, therefore, warranted to determine if this is a systematic feature of the LAI model. Nevertheless, the regression equation in Fig. 1 provides a suitable calibration of the LAI model to the South African sugarcane cultivars measured in this study.

The *ELADP* for the cultivars in the March crop ranged from 1.25 to 2.41 at very low LAI, indicating mean leaf angles ranged from 35 to 50 degrees, but *ELADP* increased to 2.90-5.28 range (mean leaf angles of 20 to 30 degrees) between LAI 1 and 2 (Fig. 2). NCo376 had the highest *ELADP* (mean 2.3 compared to N19 at 1.6) at low LAI but N19 achieved a higher *ELADP* (mean 4.5 compared to NCo376 at 3.3) at high LAI. Because *ELADP* variance was large it is unlikely that other cultivars with intermediate leaf angle habit will exhibit a different LAI prediction response. As the crop approaches full canopy cover *ELADP* is expected to decrease to around 1.0 to 0.5 (mean leaf angle of 60 to 70 degrees). The measurement of a leaf angle parameter complicates the measurement of LAI and as such introduces new sources of error and variance for which careful training

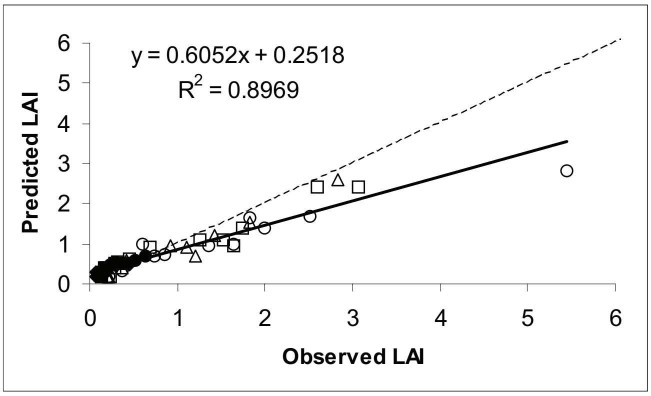

Figure 1. Comparison of observed and predicted leaf area index (LAI) of a March (NCo376 ○; N26 □ and N19 Δ) and April (NCo376 ●; N26 ■ and N24 ♦) cycle crop showing the fitted (solid) and 1:1 (dashed) line.

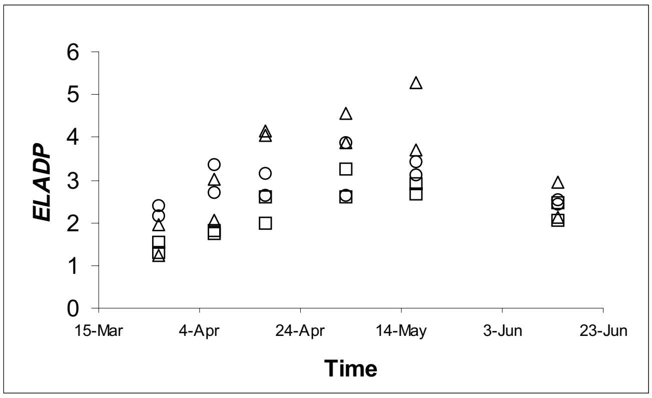

Figure 2. Changes in the Ellipsoidal Leaf Angle Distribution Parameter (*ELADP*) over time in the March cycle crop 2000 (NCo376 ○; N26 □ and N19 Δ).

and replication will be necessary. It however, does overcome significant problems of the more conventional methods. The big advance of this system is its rapid measurement time. Once the *ELADP* is determined from a count of about 100 leaves the LAI is determined in seconds.

Contemporary models of sugarcane have not been designed to simulate cultivar light interception differences with respect to LAI, rather they have mainly dealt with pheonological differences including tiller number (Inman-Bamber, 1994). More routine measurements of LAI offer improved scope to investigate ways to model different cultivars of sugarcane that are known to exhibit different leaf angles that theoretically should have different light interception characteristics. Knowledge of this should lead to more accurate models of LAI and light interception in sugarcane.

Conclusions

A rapid non-destructive LAI measuring device shows good initial performance against observed data in sugarcane. Despite a limited data set the LAI model prediction was reasonably accurate (RMSE=0.46; R^2=0.90; n=54; mean relative error 59%), particularly at the very low end of the scale. The device should be equally applicable to other cultivars with intermediate leaf angle habit. There was, however, some tendency toward bias in the prediction of LAI. Further testing is, therefore, warranted to determine if this is a systematic feature of the LAI model in the device. Nevertheless, the regression equation provides a suitable calibration of the device for the South African cultivars measured in this study.

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