Crop Canopy Reflectance Sensors Approaches in Sugarcane

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Abstract. Crop canopy reflectance sensors are a useful approach to identify the crop development variability within fields and, among their many uses, variable rate on-the-go application of nitrogen (N) deserves mention. However, there is a lack of studies about the suitability of canopy sensors in sugarcane fields. To test this suitability, Precision Agriculture Lab. (LAP/ESALQ/ USP) has conducting studies since 2007. In this paper, partially results from three canopy sensors were addressed. The relationship between canopy sensor readings and N rates and crop samples were performed in sugarcane fields. The canopy sensors have the potential to guide the N application as well as give valuable information to support sampling schemes and delineation of management zones.

Resumo. Sensores de refletância do dossel são ferramentas úteis para identificar a variabilidade no desenvolvimento das culturas e, entre seus múltiplos usos, a aplicação em tempo real de nitrogênio (N) em taxas variáveis merece destaque. Entretanto, há escassez de estudos sobre a eficiência desses sensores na cultura da cana-de-açúcar. Para verificar isso, o Laboratório de Agricultura de Precisão (LAP/ESALQ/ USP) tem conduzido estudos desde 2007. No presente trabalho, será abordado parte dos resultados de pesquisas com três sensores de dossel. Buscou-se verificar a relação dos sensores de dossel com doses de N e com dados de amostragem de plantas em lavouras de cana-de-açúcar. Os sensores mostraram potencial em direcionar a aplicação de N. Além disso, podem fornecer informações úteis no auxílio à amostragens localizadas e delimitação de zonas de manejo.

Introduction

Crop canopy reflectance sensors have been widely documented as useful tools to identify the crop development variability within fields [Samborski et al. 2009]. This approach is based upon the fact that the amount of green tissues alters differently the intensity of reflectance of the spectral wavebands, being possible a reliable estimation of biomass and chlorophyll amount in the crop [Blackmer et al. 1996].

Among of the many uses of canopy sensors, variable rate application of nitrogen (N) on-the-go is the most important. This approach is based on the relationships between in-season measurements of biomass and the final yield as well as the chlorophyll amount and the N content in the plant. The efficiency of this approach has been well documented in wheat and maize [Raun et al. 2002; Teal et al. 2006; Berntsen et al. 2006; Kitchen et al. 2010; Ferguson et al. 2011; Solie et al. 2012].

However, there are few studies addressing the suitability of the canopy sensor in sugarcane fields [Singh et al. 2006]. In this context, canopy sensors have been studied in sugarcane by the Precision Agriculture Lab., University of São Paulo, Brazil, since 2007 and results of the technology for sugarcane are promising [Molin et al. 2010; Amaral and Molin 2011; Portz et al. 2011; Amaral et al. 2012]. The objective of the present paper is show the suitability of canopy sensors in sugarcane fields, addressing their uses and potentials.

Materials and Methods

Five crop canopy reflectance sensors have being studied by Precision Agriculture Lab. (USP), but only three will have partially results showed in this paper. The canopy sensors presented here are the N-Sensor (N-Sensor^{TM} ALS, Yara International ASA, Duelmen, Germany) and two CropCircle models, ACS-210 and ACS-430 (Holland Scientific, Lincoln, NE, USA). These sensors have different operational and measurement concepts, but, regardless the device, the main goal is allowing the variable rate application of N on-the-go based. However, it was first necessary to test canopy sensor relationships with plant parameters and their capability in identifying sugarcane N nutrition, which was the main objective of this paper. Due to the differences, they will be treated separately and called the American (CropCircle devices) and European (N-Sensor device) canopy sensors.

The American canopy sensors uses two wavebands to calculate the normalized difference vegetation index (NDVI). The ACS-210 emits modulated light and captures its reflectance in the visible (amber, 590 nm) and near infrared (NIR, 880 nm), while the ACS-430 works with red-edge (730 nm) and NIR (780 nm) wavebands, calculating $NDVI_{amber}$ and $NDVI_{red\text{-}edge}$, respectively. These sensors works in nadir view (perpendicular to the soil) with a footprint around 0.5 m, measuring one row at a time. Experiments with ACS-210 were conducted in plots with N rates (0, 50, 100, 150 and 200 kg/ha of N) in different growth conditions (soil and season). Moreover, above ground biomass samples in four fields were correlated with ACS-430 readings.

The European sensor uses an optimized vegetation index based on red-edge (730 nm) and NIR (760 nm). The system measures two oblique ellipses (left and right of the vehicle) of approximately 3.0 m each. Experiments were conducted on eight commercial fields and the sensor readings were compared to the crop parameters (sampled data).

The sensors are active, which means they emit light and measure the reflected light from the canopy. The ambient light interference is eliminated by the high frequency of light emission (about 40,000 Hz) and intercalary reception. The reflectance information measured by CropCircle devices is processed in a specific dataloger, while the information by N-Sensor is processed in a specific software installed in a generic computer. When the sensors are connected to a GNSS (Global Navegation Satellite System), the readings are averaged to represent the GNSS collect data frequency. All the present study data were collected in 1 Hz. The georeferenced data was processed in a GIS (geographic information system), resulting in canopy sensor maps.

Specific calibration functions were derived, and the capacity of sensor measurements to predict the actual crop biomass and N-uptake was defined. All the canopy sensor measurements were taken when plant stalk height was approximately 0.5 m, as recommended by Amaral et al. (2012) and Portz et al. (2012).

Results and discussion

The American canopy sensor ($NDVI_{amber}$) proved to be an efficient tool to identify N sugarcane nutrition. This sensor was able to differentiate N rates when sugarcane responded to the N applied (Figure 1). In addition, the American canopy sensor NDVI had a high correlation to sugarcane yield, with readings done approximately nine months before harvesting.

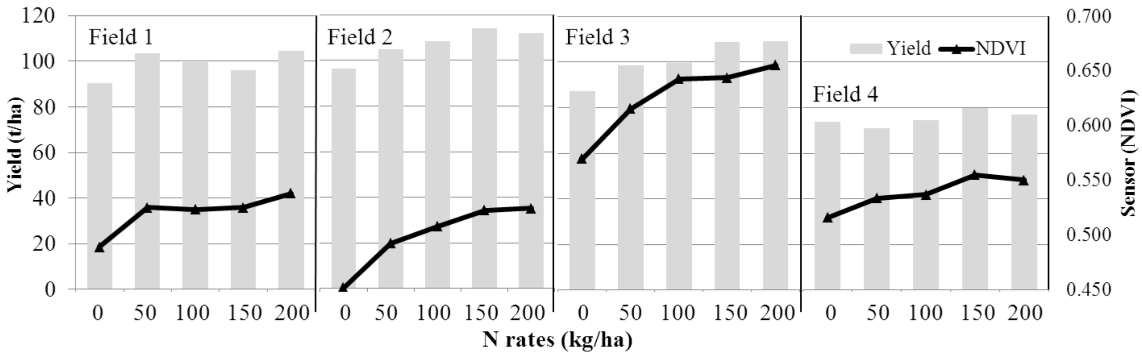

Figure 1. Yield and American canopy sensor readings ($NDVI_{amber}$) obtained with treatments (N rates) in four plot experiments

Using the American ($NDVI_{red\text{-}edge}$) and the European canopy sensors it was possible to determine accurate relationships of crop biomass and, consequently, nitrogen uptake during the initial crop growing period, correlating field samples to the predicted sensor values for the same variables (Figure 2). Sugarcane biomass and nitrogen uptake were detected by the sensor and the relationship between sensor predicted and measured values were close to the 1:1 line for the entire data set taken from average 0.5 m stalk height (0.2 to 0.7 m).

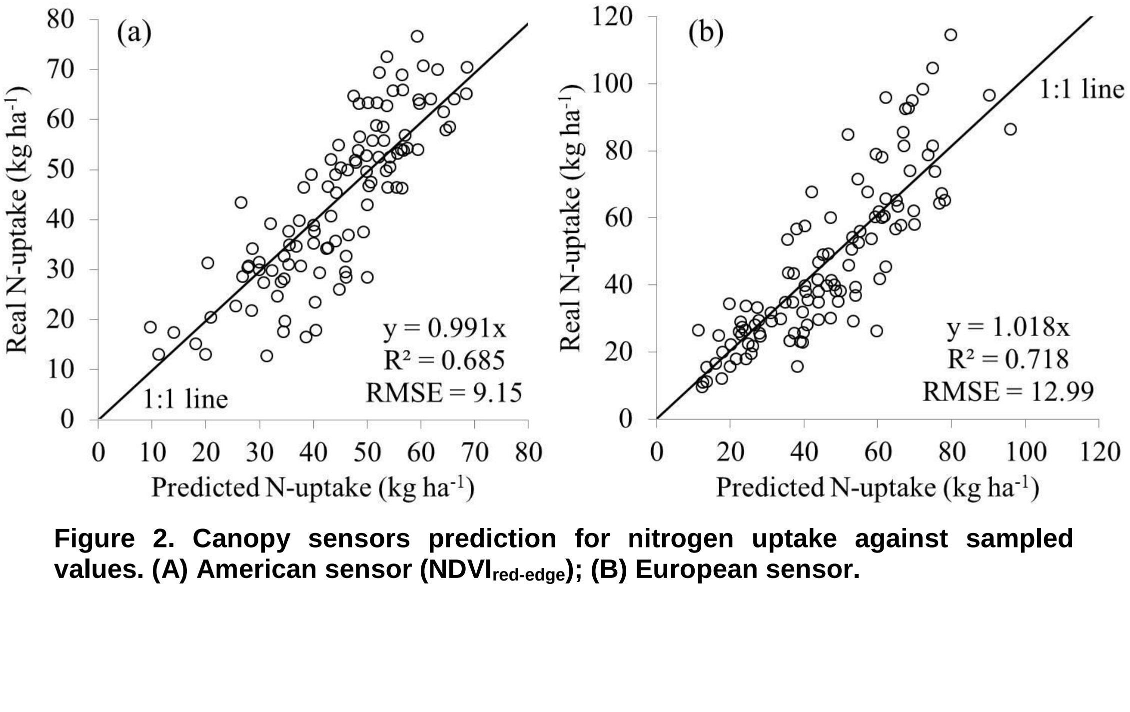

Figure 2. Canopy sensors prediction for nitrogen uptake against sampled values. (A) American sensor ($NDVI_{red\text{-}edge}$); (B) European sensor.

One way to establish variable rate application is based on N uptake required for cane production (estimation based on sensor readings). Another way to direct N application is based on fertiliser distribution models that are established to apply more N in areas with more biomass (higher sensor values), assuming that in those areas all other production factors are at satisfactory levels, which can increase the potential N response. As both sensors demonstrated a good response to sugarcane development, more studies should be conducted in order to improve the efficiency of nitrogen variable rate applications guided by canopy sensors.

Despite the guidance of top-dressing N applications, canopy sensors can obtain useful information to other approaches. As sensor readings were well correlated with biomass accumulation (Figure 2), maps generated from this data reliably matches crop variability within the fields (Figure 3), what may support sampling guidance in local investigations and the definition of management zones.

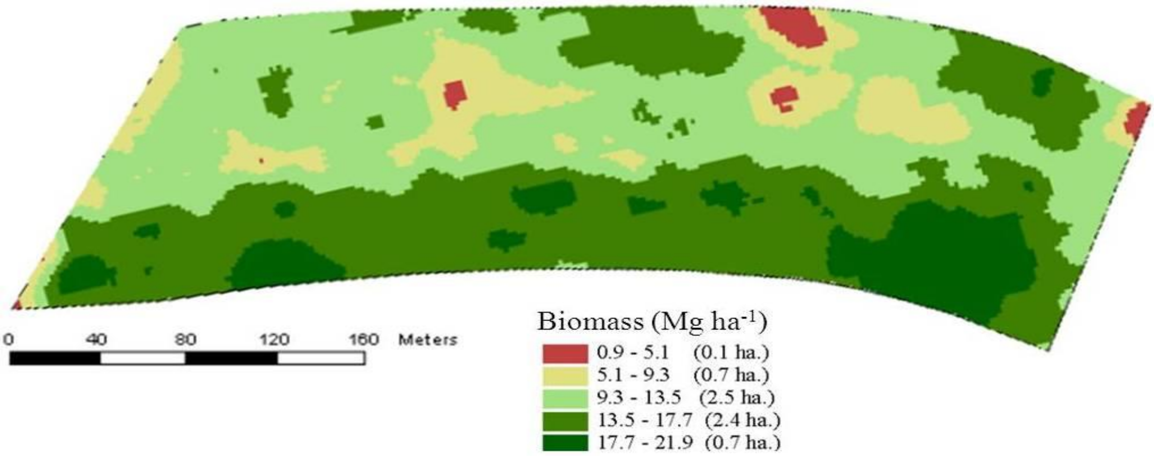

Figure 3. Interpolated map showing the biomass variability estimated by the American canopy sensor ($NDVI_{red\text{-}edge}$) within a sugarcane field (6,4 ha).

Conclusions

Crop canopy reflectance sensors are suitable tools to identify the variability in sugarcane fields. The canopy sensor approach were able to identify N response of sugarcane as well as its biomass amount and N uptake. As a result, these devices have not the exclusive potential to guide the variable rate N on-the-go application (the most valuable application), but also guide sampling schemes based on crop development and additional information to delineation of management zones.

More studies involving nitrogen variable rate application guided by canopy sensors should be conducted in order to prove the efficiency of this approach.

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