USING AN ACTIVE CROP SENSOR TO DETECT VARIABILITY OF NITROGEN SUPPLY ON SUGAR CANE FIELDS

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ABSTRACT

Nitrogen management has been intensively studied on several crops and recently associated with variable rate application on-the-go based on crop sensors. On sugar cane those studies are yet scarce and as a biofuel crop the energy input matters, looking for a high positive energy balance production and low carbon emission on the whole production system. This paper shows the first results obtained using a nitrogen and biomass sensor (N-Sensor^{TM} ALS, Yara International ASA) aiming to indicate nitrogen application demands on commercial sugar cane fields. Eight commercial fields located in one Sugar Mill in the state of São Paulo, Brazil, varying from 15 to 25 hectares, are being monitored. Conditions vary from sandy to heavy soils and the previous harvesting occurred in May and October 2009, including first, second and third ratoon stages. Each field is being scanned with the sensor three times in the season (20, 40, and 60 cm of stem height), followed by tissue sampling for biomass and nitrogen uptake on ten spots inside the area, guided by the different values shown by the sensor. The results up to now show high correlation between the sensor values and sugar cane biomass and nitrogen uptake, giving support to the potential use of this data to elaborate algorithms to manage variable rate application of nitrogen for sugar cane.

Key words: sugar cane, nitrogen management, N-Sensor.

INTRODUCTION

Sugar cane is the most important crop for sugar and ethanol production in tropical climates and Brazil is the first producer followed by India (FAO, 2007) The cultivated area with sugarcane in Brazil is steeply increasing; the production doubled from 2001/02 (293 million tons), to 2008/09 (569 million tons) (UNICA, 2010), strongly influenced by ethanol production due to the introduction of the flex fuel car engines on the local market (ANFAVEA, 2010). Currently sugar cane production is the second local energy source, responding for 16.4% of the whole energy used due to ethanol and biomass electricity (Ben, 2009).

The sugar-ethanol industry in São Paulo state, which produces 60% of the domestic sugarcane of Brazil, is open to precision agriculture technologies focusing on managerial improvements, higher yields, lower costs, minimize environmental impacts and bring improvements in sugar cane quality, suggests a recent research which also says that 96% of the sector want to expand the use of precision agriculture practices (Silva et al., 2010).

In the sugar cane production system, especially in humid areas, nitrogen (N) availability in the soil is the most important factor limiting plant growth, development and yield. According to Vitti et al. (2007) nitrogen fertilization using doses up to 175 kg ha^{-1} result on increase of productivity on the second ratoon stage resulting on benefits to the third ratoon. In other hand N fertilization can account for a significant part of total production expenses. Therefore, the rational management of such high-cost input can have a great impact on the profitability of the crop production. In addition, the potential of environmental impacts has to be considered, since nitrogen application rates exciding the crop requirements may contribute to increase levels of nitrate in the soil, increasing the risk of nitrate leaching from agricultural lands to surface and ground waters (Carpenter et al., 1998, Verburg et al., 1998 and Muchovej, 2004); nitrate can also be lost to the atmosphere by the process of denitrification (Xen et al., 2002).

Crops N fertilization prescription have always been a challenge, because of the difficulty to predict the amount of nitrogen mineralized from the soil organic matter during the growing season and the high nitrate mobility in the soil profile. In addition, large spatial variability in nitrate content and N supply capability of the soil and N status of plants may exist in the field.

The determination of appropriate N rates to be applied to crops is of crucial interest for yield formation. Moreover, fertilizer rate is one of the major tools available to manipulate crops to produce high yields. On the other hand, the amount of N naturally supplied by the mineral soils normally is not enough to reach the crop yield potential and, therefore soil N must be supplemented with fertilizer to sustain sugar cane production (Rice et al., 2002).

Presently, the application of N fertilizers on sugarcane is done without taking into account soil and crop spatial variability, having fertilizers applied over the field in a uniform rate based on the average needs of the crops. Nevertheless many fields consist of more than one soil type with different N supply and crop yield potentials, requiring distinct fertilizer management for economical and ecological reasonable yields. In consequence of the uniform N management, some parts of the field may be under or over fertilized.

Based on that, site specific crop management approaches have been designed to optimize crops production by managing crop and soil, taking into account the variability inside each field. Map and sensor-based approaches are the basic methods of implementing site-specific management of variable rate application of crop inputs. However, mapping approach based on grid soil-plant sampling, map generation and variable-rate application in the field for the required spatial resolution for site specific N fertilization will not be economical, considering the spatial N soil variability that can exist over very short distances in the field (Solie et al., 1999).

Moreover, sensor based methods using reflectance measurements have been used in order to estimate the N status of plants. They use data acquired on real time by the sensor to control site specific field operations while the machine is moving, collecting data about the current plant growth in a high spatial resolution, enabling the detection of N needs in real time, transforming those needs in a fertilizer rate to be applied few seconds after the sensor measured. However, a crop specific agronomic algorithm is necessary to convert the sensor readings in a fertilizer rate behind it.

In this sense, variable N management based on reflectance sensor is one of the most promising practices of precision agriculture to optimize nitrogen-use efficiency and decrease environmental impact of agriculture on the sugarcane crop production.

According to Jasper (2006) apud Reuch (2005) the N-sensor ALS uses an optimum waveband selection (730nm and 760 nm) for determining the nitrogen uptake from crops by active remote sensing, being superior to “classical” reflectance ratios, with one waveband in the visible and one waveband in the near infrared region of the spectrum. In particular, the resulting relationship seemed to be largely independent of growth stage and variety, and showed less saturation at high N uptake levels.

According to Singh (2006), there is no information available in literature for the use of this sensor by sugar cane growers, and it needs to be tested and validated for sugar cane cropping systems. This paper shows the first results obtained using the N-Sensor aiming to indicate nitrogen application demands on commercial sugar cane fields.

MATERIALS AND METHODS

During the 2009 growing season eight fields of commercial sugar cane were evaluate. They are all from 15 to 25 hectares and located around the São Martinho Sugar Mill (21°19’11”S, 48°07’23”O), in the state of São Paulo, Brazil. Conditions vary from sandy to heavy soils, and the previous harvesting occurred from the beginning of the season (May, 2009) corresponding to the dry time of the year, to late season (October, 2009), wet time of the year, including first, second and third ratoon stages. Results from two of those fields, having different conditions, but about the same size, were chosen to be presented in this paper. The first field, was planted with the CTC 9 variety, monitored during the second ratton stage, and harvested on the dry season over a clay soil. The second field was planted with the SP 80–3280 variety, monitored at the third ratton stage and harvested on the wet season over a sandy soil (Figure1).

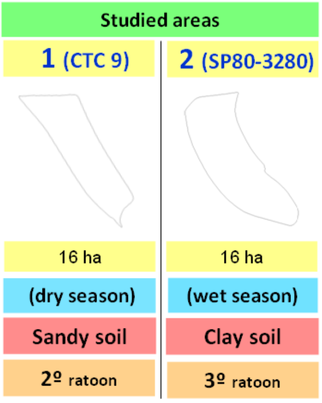

Figure 1. Sugar cane fields being showed on this paper

After harvest and before sugarcane started budding, each field had soil sampled in one hectare grid looking to investigate the natural variability of the areas, aiming to solve possible future questions related to variability showed by the sensor measurements.

After harvest, all fields have been fertilized with a uniform dose of 100 kg ha^{-1} of nitrogen using ammonium nitrate at 30% as N source, spread over the sugarcane rows surface.

The sugar cane fields were scanned using the N-Sensor$^{\text{TM}}$ ALS (Yara International ASA) that comprises a transmitter with a xenon flashlight, providing multi-spectral light (650 – 1100 nm) of high intensity, and a receiver with two photodiodes and interference filters with 730 and 760 nm centre wavelength and a half band width of 10 nm in front of them (Jasper, 2009).

N-content and N-uptake on the biomass based the method to obtain the data to correlate real N-uptake from the crop to the estimated N-uptake derived from the sensor readings (Link, 2005).

Each field has been scanned with the sensor three times in the 2009 season (20, 40, and 60 cm of average stem height) (Figure 2). The sensor was mounted behind the cabin of a high clearance vehicle (Jacto Uniport NPK Canavieiro) providing 1.4 m of free space under the axes over the crop. The vehicle was the choice to carry the sensor as it is a self-propelled machine specially design to apply solid granulated fertilizer (uniform or variable rate) over the sugar cane rows, capable to fertilize 9 rows per swat (13.5 m), which is compatible with the sensor swat, running at 18 km h^{-1}, resulting in a high productivity machine for the sugarcane sector.

The vehicle with the mounted sensor connected to a GPS receiver, drove the whole fields spaced by teen rows (Figure 3). After scanned, the sensor data from the field were downloaded to a GIS software (SSToolbox$^{®}$), and cleaned, cutting off data points outside field boundaries and discrepant points close to the boundaries, where the sensor was scanning surface outside the field. After that the data points were interpolated by kriging, establishing five classes on teen meter cells (Figure 3).

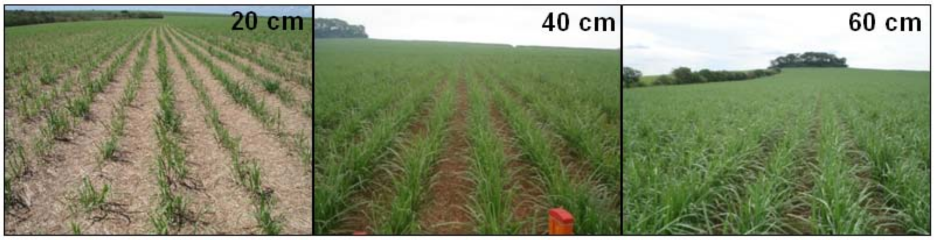

Figure 2: Sugar cane field status at the scanned times.

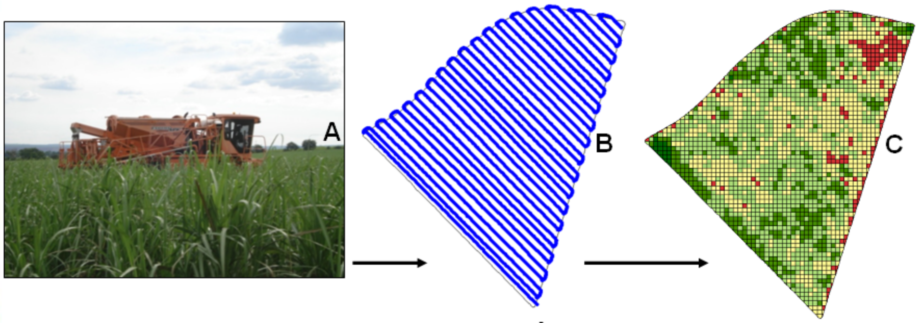

Figure 3: Scanning (A), sensor trajectory (B), interpolated map (C).

Two sample points were located in the middle of representative areas of each class, summarizing ten points per field in each scanning time (Figure 4), consisting of four sugarcane rows (4 x 1.5 m) by five meters long. On each sampling points, located in the middle of a ten meter cell, the number of stems were counted, the average high of the stems estimated and destructive plant samples of the above ground biomass were taken by cutting 1.5 m subplot on three rows, summarizing 4.5 m. Biomass samples were weighed in the field, samples were chopped in the laboratory and sub-samples were dried to estimate aboveground dry matter production, its total N content analyzed (Kjeldahl method), and the N uptake calculated.

Sensor readings of the respective sample plots were related to these crop parameters, specific calibration functions were derived, and the capacity of N-Sensor measurements to predict the actual crop biomass and N uptake was investigated.

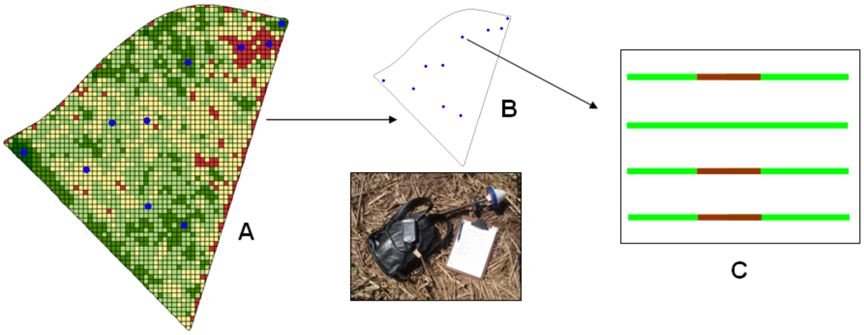

Figure 4: Map sample points (A), exported file (B), sample point (C).

RESULTS AND DISCUSSION

The first field harvested at the beginning of the dry season had the three measurements with the N-Sensor (Figure 5) conducted during the same period, coincident with the lowest temperatures of the year, slowing down the crop growth development.

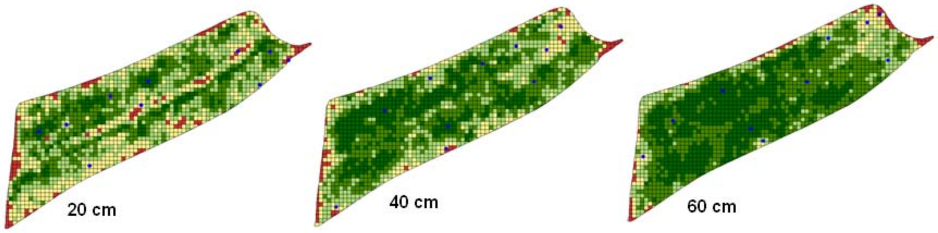

Figure 05: Dry season, sandy soil field, second ratton, at the scanned times.

The interpolated maps show the N-Sensor readings at three sugar cane growth stages indicating that sensor is capable to detect the variability inside the area. Analyzing the three maps it is possible to see significant variability of biomass and nitrogen in short distances inside the sugar cane field and also the stability of values on low and high zones inside the area among measurement times.

Using the sample values of the thirty plots from the three scanning times (20, 40 and 60 cm of stem height) against the sensor values it was possible to obtain the sensor predicted values that are show for Biomass (Figure 6) and N-uptake (Figure 7). Figure 6 shows that the sensor was capable to predict the real sugar cane biomass in a high correlation (R^2=0.9479). It also shows that the measurement at 20 cm of stem height was too early, resulting on low and concentrated values.

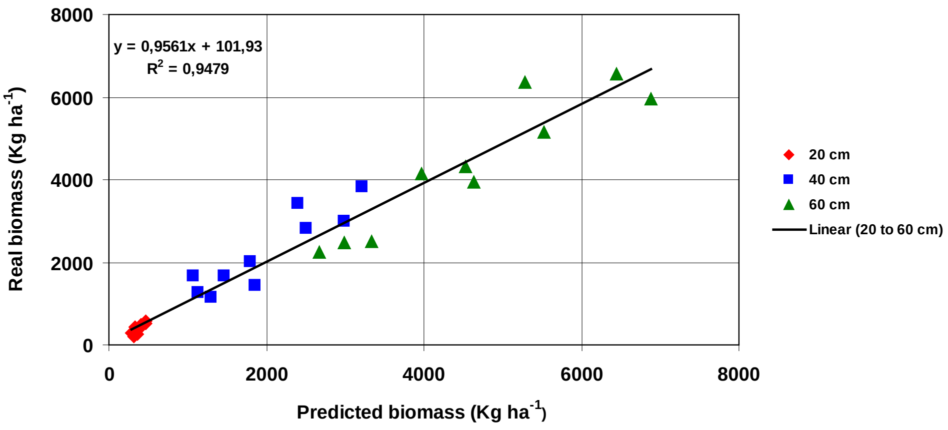

Figure 6: Sensor predicted biomass against real biomass along readings for the first field

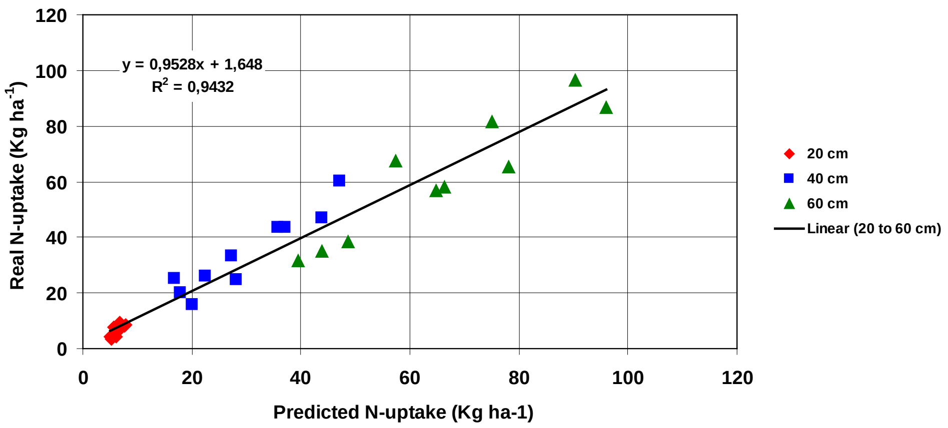

Figure 7: Sensor predicted N-uptake against real N-uptake along readings for the first field

The sensor measurements predicted the nitrogen uptake of the sugar cane crop with high accuracy (R^2=0.94) in this field (Figure 7).

The second field harvested at the beginning of the wet season had the three measurements with the N-sensor (Figure 8) conducted during the warmest time of the year, when the growing of the crop is very fast.

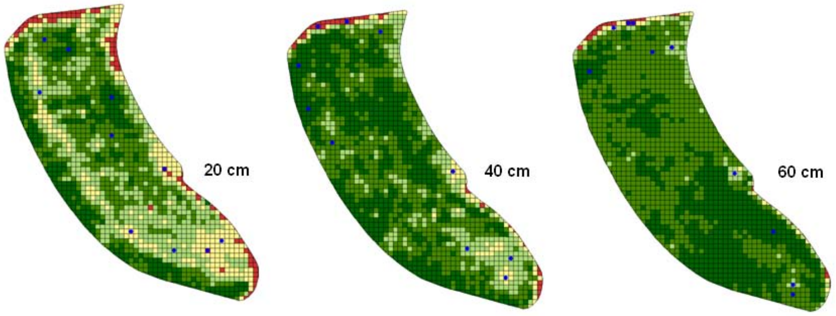

Figure 8: Wet season, clay soil field, third ratton at the three scanned times

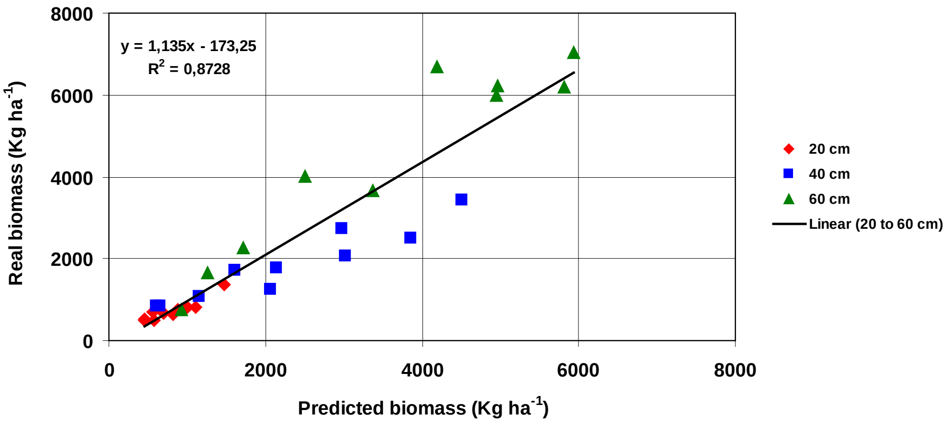

Figure 9: Sensor predicted biomass against real biomass along readings for the second field

Figure 9 shows that the sensor used was also capable to predict the real sugar cane biomass in a good correlation (R^2=0.87) in the field investigated during the wet season, but accuracy dropped during this time.

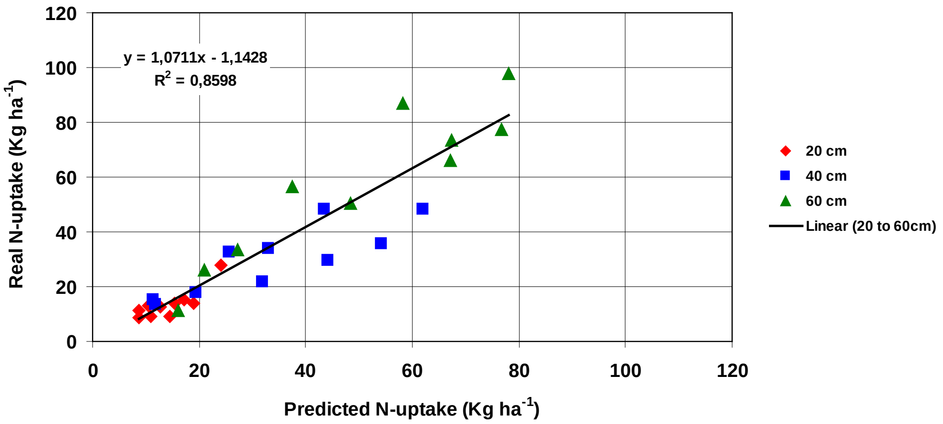

Figure 10: Sensor predicted N-uptake against real N-uptake along readings for the second field

The sensor measurements also enabled the prediction of the current nitrogen uptake of sugar cane on the wet season with a good accuracy R^2= 0.86 (Figure 10).

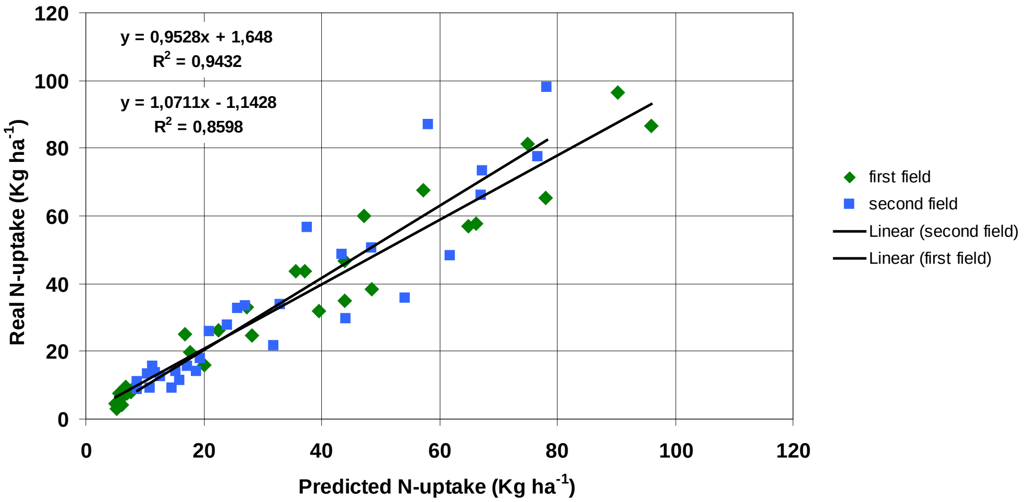

Figure 11: Sensor predicted N-uptake against real N-uptake along readings for the first and second field

It is possible to see on these two distinct fields (Figure 11), that N-uptake by the sugar cane crop could be detected by the sensor in the same scale, independent of differences on varieties, soil, season period and ratton of the sugar cane field being monitored.

CONCLUSIONS

The method implemented in this study is allowing a good amount of data and providing the proper measurements of parameters for modeling biomass and N uptake. According to the data already collected the sensor is capable to detect the variability of biomass and nitrogen supply by the soil present on commercial sugar cane fields.

The results indicate that exist variability on biomass production and N-uptake by the sugar cane on distinct varieties, soil and season period, but those differences are not affecting the detection of actual biomass and N-uptake by the sensor. The results suggest that it is possible to implement a mathematic algorithm to conduct the real time application of nitrogen on variable rate based on sensor readings.

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