TEMPORAL BEHAVIOR OF NDVI MEASURED WITH AN ACTIVE OPTICAL SENSOR FOR DIFFERENT VARIETIES OF SUGARCANE

COMPORTAMENTO TEMPORAL DO NDVI MENSURADO COM SENSOR ÓPTICO ATIVO PARA DIFERENTES VARIEDADES DE CANA-DE-AÇÚCAR

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ABSTRACT

Active optical sensors are a new approach for site specific nitrogen management on real time and they have been successfully used on grain crops. This work consisted in evaluating the behavior of the Normalized Difference Vegetation Index (NDVI) using a commercial active optical sensor on 28 sugarcane varieties, as well as analyzing the temporal behavior of this index for each variety throughout the initial 150 days of their productive cycle. The NDVI data was collected with 90, 120 and 150 days after planting (DAP). A descriptive statistical analysis of the data was performed and a Tukey test was applied to contrast the NDVI means. Results indicated that the varieties interfere in the NDVI readings and, in general, the readings with 90 DAP were different from those with 120 and 150 DAP, tending to stabilize along time for each variety.

Keywords: Precision Agriculture, NDVI, Remote Sensing.

RESUMO

Sensores óticos ativos são uma nova opção para o manejo da aplicação localizada de nitrogênio em tempo real e têm sido empregados com sucesso em culturas de grãos. Este trabalho consistiu em avaliar o comportamento do NDVI (Normalized Difference Vegetation Index) obtido com um sensor ótico ativo comercial, em 28 variedades de cana-de-açúcar, assim como analisar o comportamento temporal deste índice para as diferentes variedades ao longo dos primeiros 150 dias de seu ciclo. Os dados do NDVI foram coletados longo dos primeiros 150 dias de seu ciclo.

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Os dados do NDVI foram coletados aos 90, 120 e 150 dias após o plantio (DAP). Realizou-se análise estatística descritiva dos dados e teste de Tukey para contrastar as médias do NDVI. Os resultados indicaram que as variedades interferem nas leituras do NDVI, assim como, de forma geral, as leituras aos 90 DAP foram diferentes das realizadas aos 120 e 150 DAP, tendendo a se estabilizar ao longo do tempo para cada variedade.

Palavras-chaves: Agricultura de Precisão, NDVI, Sensoriamento Remoto.

INTRODUCTION

The sugarcane sector has great economical, social and environmental importance to Brazil. Sugarcane milling in the 2005/2006 harvest was 431.4 million tons, which represents an increase of 3.8%, or an addition of 15.7 million tons over the total produced in 2004/2005 harvest season. This resulted in the production of 26.7 million tons of sugar and 17 billion liters of alcohol (DIEESE, 2007).

Precision agriculture is applicable if spatial variability exists, that has recently been indicated on yield maps (JOHNSON & RICHARD JR, 2005; MAGALHÃES & CERRI, 2007; MOLIN et al., 2005). Remote sensing has become more useful after being associated with precision agriculture, resulting on improvements on the development of the acquisition capacity, processing and interpretation of ground, aerial and satellite data (McNAIRN et al., 2001). NOVO (1989) shows the main advantages of remote sensing and the importance of multi-spectral capacity of sensor systems to generate products in different spectral bands. Spectral indices such as the Normalized Difference Vegetation Index (NDVI) have been developed to obtain, in an indirect way, information from crops, such as photosynthetic efficiency, yield estimate and profit potential (RAUN et al., 2001).

Concerns with the development and test of new varieties has been constant, seeking to increase yield, obtain better resistance to plagues and diseases and a better adaptation to weather variations, soil types, crop techniques or management. Most of the research to test the discrimination of sugarcane varieties with orbital remote sensing has used multi-spectral data, such as in JOAQUIM (1998) and FORTES (2003).

INAMASU et al., (2006) tested an active optical sensor on sugarcane. The sensor measures directly the NDVI and was not able to detect differences in potassium levels applied, but readings increased according to treatments of nitrogen levels. These types of sensors, which produce their own light, have been considered for the recommendation of nitrogen fertilization in real time, especially for grain crops. However, when considering it for being used on sugar cane, reflection has to be done on the influence of the varieties in the NDVI obtained with such sensors and the calibration of the sensors for different scenarios that exist in Brazil. Another factor is the temporal variability of the NDVI, considering the growth and possible moment of nitrogen application for sugarcane. With this motivation the present work was conducted, which consisted in evaluating the NDVI behavior of 28 sugarcane varieties to verify their influence in the readings obtained with an active optical sensor, and to analyze the temporal behavior of this index for those varieties.

MATERIAL AND METHODS

The experiment was conducted in a Red-Yellow Oxisol (environment D, Copersucar classification) in the region of Assis, SP, at 22º 39' 40'' S and 50º 25' 12'' W coordinates. The experiment used a randomized block design with 28 treatments (varieties - CT963206, CT951390, RB867515, CT931595, CT943410, RB985823, RB986955, CT963024, CT963335, SP91-1049, CT961234, CT963334, CT951086, CT951209, RB985840, CT961014, RB985814, RB986952, CT951373, RB985846, SP83-2847, CT963346, RB72454, RB855536, RB985829, RB985844, IACSP97-3402 and CT961226) and three replications. Each plot had 5 rows of 8 m, spaced 1.40 m. Only the three central rows were used for measurement of NDVI. The area of the experiment was planted at the end of March, 2006 and the fertilizer applied was a formula 09-23-27 at a 530 kg ha-1 rate.

Due to the soil water stress in the beginning of the productive cycle sugarcane showed low vegetative growth until 90 days after planting (DAP); because of that, data collection began from this point. The readings were conducted at 90, 120 and 150 DAP, using a portable active optical sensor (GreenSeeker Red Hand HeldTM, NTech Industries, Inc., Ukiah, CA), that uses light emitting diodes (LEDs) that emit light at 660 (± 10 nm, red) and 770 nm (± 15 nm, near infrared), then captures reflectance from the targets by a photodiode detector and calculates the NDVI. The readings were made, on average, about one meter from the target, as recommended by the manufacturer. Readings after 150 DAP were not made due to the limitation of positioning the sensor above the crop.

The data were submitted to a descriptive statistical analysis and the Tukey test with a 5% level of probability was applied to contrast the NDVI means from the varieties and to compare the NDVI behavior along the three readings, for each of the varieties.

The influence of varieties to the NDVI readings can be observed by the NDVI means obtained from the sensor and by the difference on its coefficient of variation (CV), and its changes along the readings. The NDVI mean for each time of reading was 0.329 with 90 DAP, 0.459 with 120 DAP and 0.501 with 150 DAP. The increment to NDVI measured with the sensor occurred due to the increase of green mass. Considering the NDVI means from each variety (Figure 1), it was noticed the tendency of an increase along the readings, with exception to varieties CT963206, RB867515, CT931595, for which the readings decreased after 120 DAP.

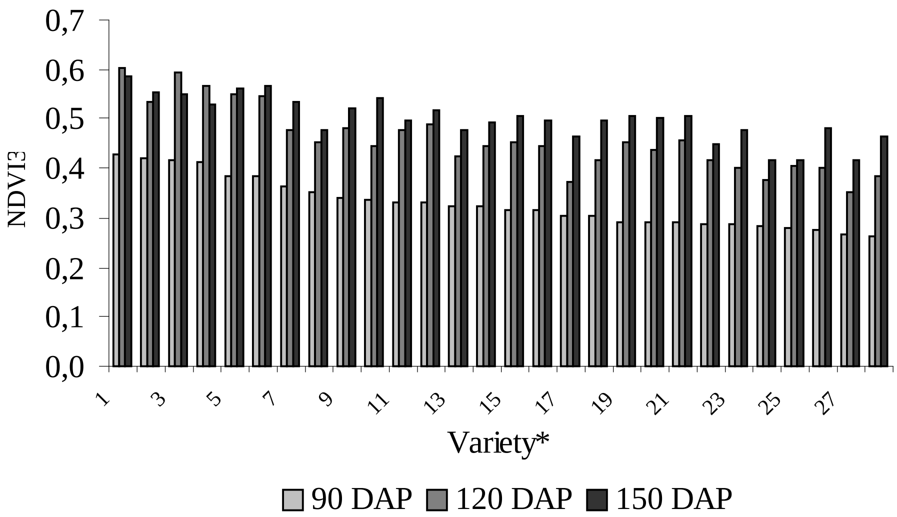

Figure 1 - NDVI means from each variety for the three readings

* 1-CT963206, 2-CT951390, 3-RB867515, 4-CT931595, 5-CT943410, 6-RB985823, 7-RB986955, 8-CT963024, 9-CT963335, 10-SP91-1049, 11-CT961234, 12-CT963334, 13-CT951086, 14-CT951209, 15-RB985840, 16-CT961014, 17-RB985814, 18-RB986952, 19-CT951373, 20-RB985846, 21-SP83-2847, 22-CT963346, 23-RB72454, 24-RB855536,25-RB985829, 26-RB985844, 27-IACSP97-3402, 28-CT961226.

In relation to the NDVI behavior of each variety (Table 1), it is noticed that with 90 and 150 DAP there was a low mean variability in the NDVI readings, when compared to 120 DAP, among varieties. However, in all readings, at least two varieties were significantly different, indicating that the sugarcane variety interferes in the NDVI value obtained by the sensor. Therefore, it indicates that it is necessary to calibrate the active sensors in the areas where they are going to be used, because different varieties may have distinct reflectance behavior for the same number of DAP.

Table 1 – Comparison of the NDVI reading means for 28 sugarcane varieties at 90, 120 and 150 DAP

NDVI means								
90 DAP			120 DAP			150 DAP		
CT963206	0.429	a	CT963206	0.603	a	CT963206	0.586	a
CT951390	0.422	ab	RB867515	0.597	a	RB985823	0.568	ab
RB867515	0.415	abc	CT931595	0.565	ab	CT943410	0.562	ab
CT931595	0.413	abc	CT943410	0.549	abc	CT951390	0.556	ab
CT943410	0.385	abcd	RB985823	0.548	abc	RB867515	0.550	ab
RB985823	0.384	abcd	CT951390	0.536	abcd	SP91-1049	0.541	abc
RB986955	0.365	abcd	CT963334	0.489	abcde	RB986955	0.536	abcd
CT963024	0.350	abcd	CT963335	0.483	abcde	CT931595	0.530	abcd
CT963335	0.341	abcd	RB986955	0.476	abcde	CT963335	0.520	abcd
SP91-1049	0.336	abcd	CT961234	0.476	abcde	CT963334	0.520	abcd
CT961234	0.334	abcd	SP83-2847	0.457	bcde	SP83-2847	0.507	abcd
CT963334	0.334	abcd	CT963024	0.454	bcde	RB985840	0.505	abcd
CT951086	0.324	abcd	RB985840	0.451	bcde	CT951373	0.505	abcd
CT951209	0.322	abcd	CT951209	0.446	bcde	RB985846	0.502	abcd
RB985840	0.316	abcd	CT961014	0.445	bcde	CT961234	0.500	abcd
CT961014	0.315	abcd	SP91-1049	0.444	bcde	RB986952	0.499	abcd
RB985814	0.305	abcd	RB985846	0.436	bcde	CT961014	0.496	abcd
RB986952	0.301	abcd	CT951086	0.423	cde	CT951209	0.493	abcd
CT951373	0.293	abcd	CT963346	0.417	cde	RB985844	0.480	abcd
RB985846	0.292	abcd	RB986952	0.415	cde	CT951086	0.479	abcd
SP83-2847	0.290	abcd	RB985829	0.404	de	RB72454	0.478	abcd
CT963346	0.288	bcd	RB985844	0.401	de	CT963024	0.476	abcd
RB72454	0.287	bcd	RB72454	0.399	de	RB985814	0.467	abcd
RB855536	0.283	bcd	CT951373	0.392	e	CT961226	0.464	abcd
RB985829	0.280	cd	CT961226	0.383	e	CT963346	0.448	bcd
RB985844	0.276	cd	RB855536	0.375	e	RB855536	0.419	cd
IACSP97-3402	0.266	d	RB985814	0.374	e	IACSP97-3402	0.418	d
CT961226	0.265	d	IACSP97-3402	0.350	e	RB985829	0.415	d

* Means followed by the same letter in the row do not differ statistically by the Tukey test ($p < 0.05$).

Another characteristic observed is the change of ranking position among some varieties when considering the NDVI means. The variety CT963206 remained in first place in the three readings, but variety CT951390 went from second place at 90 DAP to sixth place at 120 DAP, and then rose to fourth place at 150 DAP. Variety CT961226 went from 28th place at 90 DAP to 25th at 120 DAP and 24th at 150 DAP.These behaviors occur due to the morphological difference of the plants and their consequent spectral response captured by the sensor as indicated by FORTES (2003). He indicated that these differences are important when using the spectral bands and vegetation indices in the variety discrimination process, which is not the objective of this work.

The CV mean was 15.9% at 90 DAP, 7.2% at 120 DAP and 13.9% at 150 DAP. These values, according to PIMENTEL-GOMES (1987), are considered medium when they are between 10 to 20%, indicating that the experiment conditions, as an open field experiment, were well controlled. Analyzing the CV values from NDVI for each variety (Figure 2), it is observed that most (67.8%) of the resulting CVs at 90 DAP were higher than at 150 DAP. This tendency was expected, since with the increase of green mass the NDVI value reaches the saturation zone (MOREIRA, 2000) reducing the reading variability. However, the highest CV values occurred in the readings at 120 DAP, which can occur due to the slow growth of the crop as a consequence of water stress. Sugarcane vegetative growth is strongly related to adequate soil moisture, favoring the root system in the process of absorbing nutrients, which is necessary for the basic structure of the plants and their development.

Considerable work is being developed with this kind of sensor for nitrogen recommendation for real time application, mainly in wheat. JOHNSON & RAUN (2003) used the concept of the N-rich strip, seeking to reduce the variation of nitrogen recommendation models in real time, once the growth stage of the crop and soil type are considered. In this way the importance of knowing the NDVI variability for different varieties stands out. The N-rich strip technique also tends to reduce this variation in the proposed model.

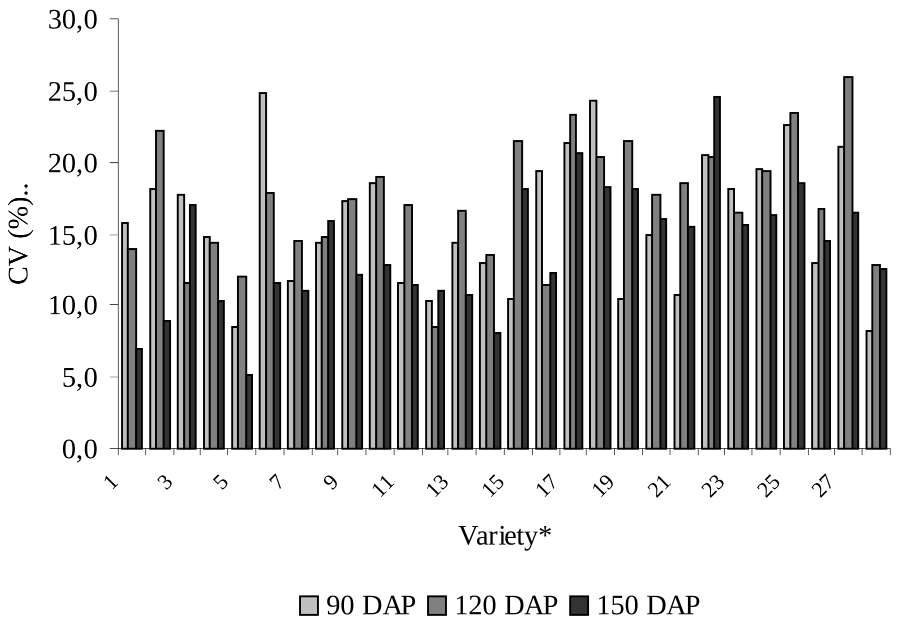

Figure 2 - NDVI coefficients of variation (CV) for each sugarcane variety, at the three readings.

* 1-CT963206, 2-CT951390, 3-RB867515, 4-CT931595, 5-CT943410, 6-RB985823, 7-RB986955, 8-CT963024, 9-CT963335, 10-SP91-1049, 11-CT961234, 12-CT963334, 13-CT951086, 14-CT951209, 15-RB985840, 16-CT961014, 17-RB985814, 18-RB986952, 19-CT951373, 20-RB985846, 21-SP83-2847, 22-CT963346, 23-RB72454, 24-RB855536, 25-RB985829, 26-RB985844, 27-IACSP97-3402, 28-CT961226.

In relation to NDVI temporal variability analysis, it is observed that it increases (Figure 2), for each variety, in the three readings. This behavior characterizes sugarcane growth and development. In the beginning of the cycle NDVI values were lower, due to the low development of the crop and low amount of biomass. However, after the beginning of the rain season sugarcane started an intense vegetative process and NDVI values increased sensibly at 120 and 150 DAP. The Tukey test confirmed such behavior, as presented in Table 2, and for almost all varieties the behavior was the same. The reading done at 90 DAP differs from the readings obtained at 120 and 150 DAP. Exception of varieties CT951373, RB985844 and CT961226, the resulting means are statistically different for the three readings.

Table 2 - Comparison of NDVI means readings at 90, 120 and 150 DAP for 28 sugarcane varieties.

	NDVI means					
Variety	90 DAP		120 DAP		150 DAP	
CT963206	0,429	B	0,603	A	0,586	A
CT951390	0,422	B	0,536	A	0,556	A
RB867515	0,415	B	0,597	A	0,550	A
CT931595	0,413	B	0,565	A	0,530	A
CT943410	0,385	B	0,549	A	0,562	A
RB985823	0,384	B	0,548	A	0,568	A
RB986955	0,365	B	0,476	A	0,536	A
CT963024	0,350	B	0,454	A	0,476	A
CT963335	0,341	B	0,483	A	0,520	A
SP91-1049	0,336	B	0,444	A	0,541	A
CT961234	0,334	B	0,476	A	0,500	A
CT963334	0,334	B	0,489	A	0,520	A
CT951086	0,324	B	0,423	A	0,479	A
CT951209	0,322	B	0,446	A	0,493	A
RB985840	0,316	B	0,451	A	0,505	A
CT961014	0,315	B	0,445	A	0,496	A
RB985814	0,305	B	0,374	A B	0,467	A
RB986952	0,301	B	0,415	A	0,499	A
CT951373	0,293	C	0,451	B	0,505	A
RB985846	0,292	B	0,436	A	0,502	A
SP83-2847	0,290	B	0,457	A	0,507	A
CT963346	0,288	B	0,417	A	0,448	A
RB72454	0,287	B	0,399	A	0,478	A
RB855536	0,283	B	0,375	A	0,419	A
RB985829	0,280	B	0,404	A	0,415	A
RB985844	0,276	C	0,401	B	0,480	A
IACSP97-3402	0,266	B	0,350	A B	0,418	A
CT961226	0,265	C	0,383	B	0,464	A

* Means followed by the same letter in the line do not differ statistically by the Tukey test (p < 0,05).

PONTES et al. (2005), using orbital remote sensing in sugarcane, observed that in the beginning of the vegetative cycle the difference on NDVI values among varieties were not significant. The NDVI saturation occurred immediately after the rain season, where the difference between the fields that showed the higher and lower biomass was more perceptible. After this saturation period, corresponding to the plants senescence and sugar concentration, there was no significant difference in NDVI values. The maximum NDVI value corresponds to the peak of the vegetative cycle of the crop. On the studied sugarcane varieties, in spite of showing the same temporal behavior on the NDVI index, they showed differences in the spectral response.

CONCLUSION

For the varieties and environment where the study was conducted sugarcane varieties interfered in the sensor readings, confirming the need for calibrating the sensor in the areas where it is going to be used. Regarding the temporal evolution of NDVI, readings obtained earlier (90 DAP) were lower when compared to those obtained at 120 and 150 DAP, which did not present significant statistical differences.

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