MACHINE DESIGN, VOL.10(2018) NO.3, ISSN 1821-1259 PP. 123-128

DOI: 10.24867/MD.10.2018.3.123-128
Research paper

RESEARCH CORRELATION VEGETATION INDEX OF CORN WITH SPEED OF MOVEMENT SENSOR AND ELEVATION OF FIELD

V. SIMONOVIĆ[1,*] - S. DELIĆ[1] - M. TASIĆ[1] - N. TASIĆ[1] - P. PEŠIĆ[1] - A. JOKSIMOVIĆ[1] - I. CVETKOVIĆ[1]
[1] University of Belgrade, Faculty of Mechanical Engineering, Belgrade, Serbia

Received (22.05.2018); ***Revised*** (04.06.2018); ***Accepted*** (06.06.2018)

Abstract: *This paper presents field scouting of corn in order to determine the content of nitrogen in the green parts of the plants. The aim was to measure the vegetative index using two optical sensors by OptRx AGL Technology. The sensors are positioned at a distance of 3.5 m, individually observing five rows of corn. The speed of movement of the tractor and also elevation of field are varied. The measured vegetative index of the plants is correlated, in first, with the speed of the sensor on the platform. The measured vegetative index of the plants is correlated after that with elevation also. Both of that case are shown that the Normalised Difference Red Edge (NDRE) as represent of vegetative index is not correlated with speed and elevation. This Results represented with Pearson Correlation Coefficient and Spearman's Correlation Coefficient are statistical signatifical. This conclusions are valid only for short rang of speed and elevation research. Average speed was 6,39 km/hr and rang of elevation was 1.6 m (106.8-108.4 m).*

Key words: *vegetative index, sensor, corn, speed, elevation.*

1. INTRODUCTION

Nitrogen (N) is one of the major limiting mineral nutrients for plant growth. World consumption of fertilizer N was 8 733 900 tonnes in 2002 [10]. Due to the continuous increase in fertilizer costs and growing environmental concerns associated with fertilizer use, application of N fertilizer according to plant need becomes increasingly popular due to its potential for increasing NUE and reducing input costs. To determine the optimum N rate based on the plant need, optical sensing technologies have been developed to detect N status in plants. The development of sensors to measure spectral reflectance or emittance created opportunities to quantitatively describe agronomic parameters and during past 100ys the application of remote sensing to agronomic problems created new methods for improved management of crops [5].

Numerous spectral vegetation indices have been developed to characterize vegetation canopies. The most common of these indices utilize red and near infrared canopy reflectances or radiances in the form of ratios or in linear combination.

Light reflected by vegetation in the visible region of the spectrum is predominantly influenced by the presence of chlorophyll pigments in the leaf tissues, which have been found to relate to the concentration of leaf N [4]. Chlorophyll a and b absorb light in the red (around 670 nm) and blue (around 450 nm) portions of the spectrum [3,6], providing diagnostic absorption features.

Although spectral indices have been shown to be sensitive to leaf N, many factors can confound the relationship between the canopy-level spectral signal and target property, such as cover, plant size, plant age, leaf angle, etc. The Canopy Chlorophyll Content Index (CCCI) [1] was designed to provide a more accurate measure of the N status of crop canopies relative to existing vegetation indices. It is a two dimensional approach [2] that uses the Normalised Difference Vegetation Index (NDVI) as an estimate of percent canopy cover and the Normalised Difference Red Edge (NDRE) index as a measure of leaf chlorophyll concentration or nitrogen content [1].

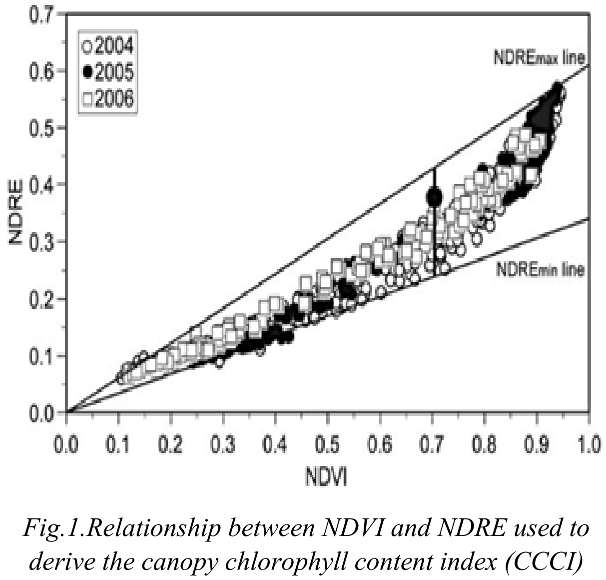

Fig.1.Relationship between NDVI and NDRE used to derive the canopy chlorophyll content index (CCCI) 2004–2006 from the normalised difference vegetation index (NDVI) and normalised difference red edge (NDRE). The vertical black line with dark point is a fictitious point that demonstrates the CCCI is derived as the distance a point lies from the minimum line as a fraction of the total distance between the minimum andmaximum lines. Upper and lower limits were fit by eye and forced through zero for the entire 3-year data set

* Correspondence Author's Address University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11000 Belgrade, Serbia, vsimonovic@mas.bg.ac.rs

Table 1. Vegetation indices used for hyperspectral and multispectral analysis

Abbreviation	Name	Vegetation index	Parameter	Reference
RVI	Ratio Vegetation Index	RVI = NIR/RED	Green biomass	[4]
NDVI	Normalised Difference Vegetation Index	NDVI = (NIR-RED/(NIR + RED)	Green biomass	[8]
NDRE	Normalised Difference Red Edge	NDRE = $(R_{790}-R_{720})/(R_{790} + R_{720})$	Chlorophyll or %N	[1,7]
MSR	Modified Spectral Ratio	mSR = $(R_{750}-R_{445})/(R_{705} + R_{445})$	Chlorophyll concentration	[9]
CCCI	Canopy Chlorophyll Content Index	Calibrated index using NDRE as function of NDVI	Chlorophyll or %N	[1,7]
MSRpi	Modified Spectral Ratio Planar Index	Calibrated index using mSR as function of NDVI	%N	[7]

There are various methods for measuring the vegetative index through the NDRE as well as the different devices for which this is accomplished. Measurement can be done using satellites, using unmanned aircraft equipped with appropriate sensors for spectrometry or using sensors mounted on a work machine or a special platform that is aggregated by a tractor. Hand-held sensors are also in use. The most precision are sensors mounted on work machine. This paper examines exactly these devices, whether the height of the sensor positioning as well as the optimal speed of the aggregate carrying the sensors affect the measurement results. Sensors are available today which can accurately detect crop nitrogen status during the growing season. Algorithms have been developed which relate crop canopy reflectance in specific wavebands to how much nitrogen fertilizer is needed. Sensors can be either passive (using sunlight) or active (using an internal light source). Sensors can be used on a variety of platforms: handheld, ground or aerial vehicle, satellite. Active sensors can be used around the clock, regardless of cloud cover or sun angle.

2. MATERIAL AND METHODS

OptRx Crop Sensors uses a red-edge light wave to scan plants. Most competitive products use only a red wavelength, which has been shown in studies to be non-responsive at high plant density. The red-edge lightwave stays responsive to health-stress on plants at later growth stages than other competitive products. OptRx crop sensors use a single algorithm application. Trials have been conducted in multiple states that have shown positive results of using a single algorithm in comparison to multiple algorithms. Design of OptRx Crop Sensor is shown in Figure 2.

Fig.2. Design of OptRx Crop Sensor

The sensors are positioned at a distance of 3.5 m, individually observing five rows of corn, Figure 3. The sensors-stand are designed and constructed to allow sensors to be moved in altitudes relative to the ground and the green part of the plant, adjusting is manual, so that the height of the sensor varies from 50 to 70 cm above the plants, or at 5 different distances for 5 cm shifts. The speed of movement of the tractor also varied. Measuring was implemented on field near Banatsko Novo Selo. The length of the field was about 250 meters, Figure 4.

Fig.3. Design of sensors-stand and measuring on the field

Fig.4. Fild BNS

There are various methods for measuring the vegetative index through the NDRE as well as the different devices for which this is accomplished. Measurement can be done using satellites, using unmanned aircraft equipped with appropriate sensors for spectrometry or using sensors mounted on a work machine or a special platform that is aggregated by a tractor. Hand-held sensors are also in use. The most precision are sensors mounted on work machine. This paper examines exactly these devices, whether the height of the sensor positioning as well as the optimal speed of the aggregate carrying the sensors affect the measurement results.

3. RESULTS AND DISCUSSION

3.1. Descriptive statistics

Results od descriptive statistics are shown in Table 2, histogram in Figure 5 and normal as well detrended normal P-P Plot of NDRE are shown in Figure 6.

Table 2. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
NDRE	1188	,087	,283	,16659	,027146
Speed(km/hr)	1188	,74	8,18	6,3924	1,40275
Valid N (listwise)	1188				

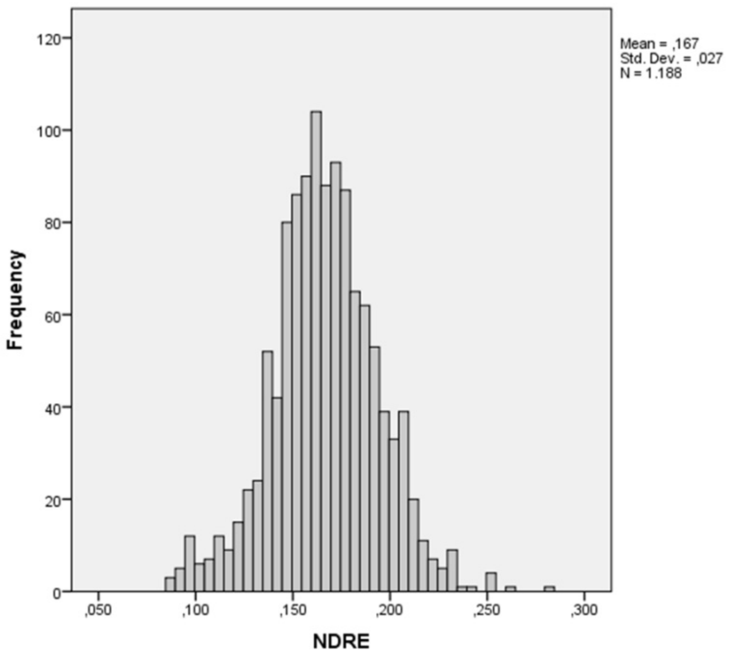

Fig.5. Histogram of NDRE

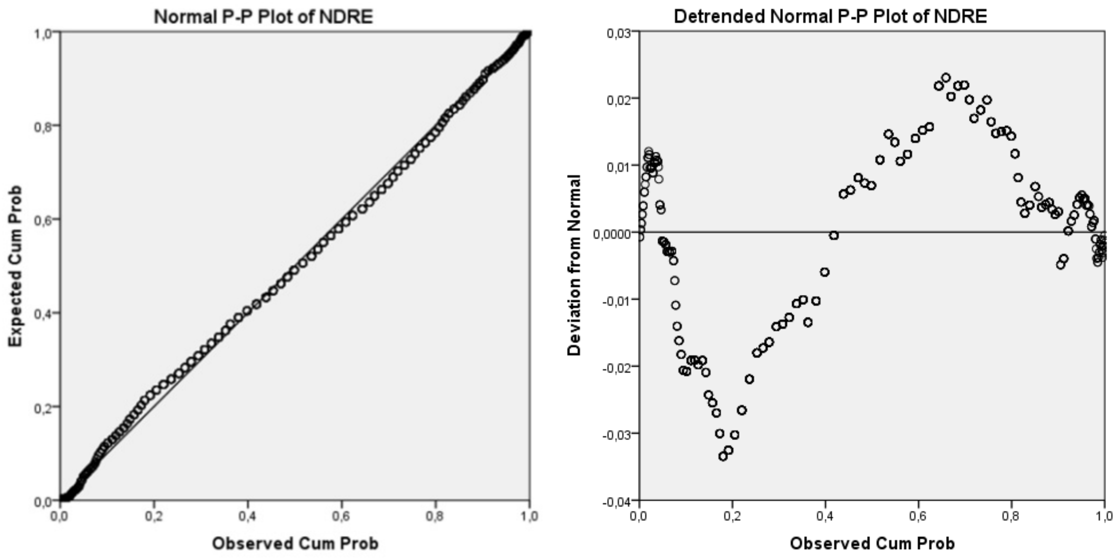

Fig.6. Normal and Detrended Normal P-P Plot NDRE

3.2. Impact of speed movement sensor to NDRE

The results of both the speed movement sensor and NDRE, and Pirson's and Spirman's correlations are shown in tables 3 and 4. The level of significance and the number of cases analyzed in the sample is given.

Table 3. Correlations for the speed movement sensor and NDRE

		Speed(km/hr)	NDRE
Speed(km/hr)	Pearson Correlation	1	,216**
	Sig. (2-tailed)		,000
	N	1188	1188
NDRE	Pearson Correlation	,216**	1
	Sig. (2-tailed)	,000	
	N	1188	1188

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4. Correlations for the speed movement sensor and NDRE - Spearman's rho

			Speed(km/hr)	NDRE
Spearman's rho	Speed(km/hr)	Correlation Coefficient	1,000	,066*
		Sig. (2-tailed)	.	,024
		N	1188	1188
	NDRE	Correlation Coefficient	,066*	1,000
		Sig. (2-tailed)	,024	.
		N	1188	1188

*. Correlation is significant at the 0.05 level (2-tailed).

The relationship between speed motion sensor and NDRE is expressed by the Pearson linear correlation coefficient. Preliminary analyzes were carried out to prove the satisfaction of the assumptions about the normality, linearity and homogeneity of the variance. The weak positive correlation of these two variables was calculated, r = 0.216, n = 1188, p <0.05. The weaker connection in the case of Spirman's coefficient, r = 0.066, n = 1188, p <0.05.

3.2 Impact of ground elevation to NDRE

The results of both the speed movement sensor and NDRE, and Pirson's and Spirman's correlations are shown in tables 5 and 6. The level of significance and the number of cases analyzed in the sample is given.

Table 5.Correlations for ground elevation and NDRE

		Elevation(m)	NDRE
Elevation(m)	Pearson Correlation	1	,193**
	Sig. (2-tailed)		,000
	N	1188	1188
NDRE	Pearson Correlation	,193**	1
	Sig. (2-tailed)	,000	
	N	1188	1188

**. Correlation is significant at the 0.01 level (2-tailed).

*Table 6. Correlations for ground elevation and NDRE - Spearman's rh***o**

			Elevation(m)	NDRE
Spearman's rho	Elevation(m)	Correlation Coefficient	1,000	,232**
		Sig. (2-tailed)	.	,000
		N	1188	1188
	NDRE	Correlation Coefficient	,232**	1,000
		Sig. (2-tailed)	,000	.
		N	1188	1188

**. Correlation is significant at the 0.01 level (2-tailed).

The relationship between speed motion sensor and NDRE is expressed by the Pearson linear correlation coefficient. Preliminary analyzes were carried out to prove the satisfaction of the assumptions about the normality, linearity and homogeneity of the variance. The weak positive correlation of these two variables was calculated, r = 0.193, n = 1188, p <0.05. The weaker connection in the case of Spirman's coefficient, r = 0.232, n = 1188, p <0.05.

4. CONCLUSIONS

Sensors are available today which can accurately detect crop nitrogen status during the growing season. Algorithms have been developed which relate crop canopy reflectance in specific wavebands to how much nitrogen fertilizer is needed. Sensors can be either passive (using sunlight) or active (using an internal light source). Sensors can be used on a variety of platforms: handheld, ground or aerial vehicle, satellite. Active sensors can be used around the clock, regardless of cloud cover or sun angle. For ground sensors, impact speed of movement sensor and elevation of field to NDRE are minor.

ACKNOWLEDGEMENT

This research was supported by the Serbian Ministry of Science and Technological Development – projects "Research and development of equipment and systems for industrial production, storage and processing of fruits and vegetables" (Project no. TR 35043).

REFERENCES

[1] Barnes, E M, T R Clarke, S E Richards, P D Colaizzi, J Haberland, M Kostrzewski, P Waller, C Choi, E Riley, T Thompson, R J Lascano, H Li, and M S Moran. 2000. *Coincident detection of crop water stress, nitrogen status and canopy density using ground based multispectral data*. In P.C. Robert et al. (ed.) Proceedings of the Fifth International Conference on Precision Agriculture. ASA, Madison, WI.

[2] Clarke, T R, M S Moran, E M Barnes, P J Pinter, Jr, and J Qi 2001. *Planar domain indices: A method for measuring a quality of a single component in two-component pixels*. In Proceedings IEEE International Geoscience and Remote Sensing Symposium, Sydney, Australia. 9-13 July.

[3] Gates, D M, Keegan, H J, Schleter, J C, Weidner, V R, 1965. *Spectral properties of plants*. Appl. Opt. 4, 11–20.

[4] Haboudane, D, Miller, J R, Tremblay, N, Zarco-Tejada, P J, Dextraze, L, 2002. *Integrated narrow-band vegetation indices for prediction of crop chlorophyll content for application in precision agriculture*. Remote Sens. Environ. 81, 416–426.

[5] Hatfield, J L, A A Gitelson, J S Schepers, and C L Walthall. 2008. *Application of spectral remote sensing for agronomic decisions.* Agron. J. 100:S117-S131. doi:10.2134/agronj2006.0370c

[6] Lawlor, D W, 2001. Photosynthesis, 3rd ed. BIOS Scientific Publishers Inc., Oxford, UK.

[7] Rodriguez, D, G H Fitzgerald, R Belford, and L K Christensen. 2006. *Detection of nitrogen deficiency in wheat from spectral reflectance indices and basic crop eco-physiological concepts*. Sust. J. Agric. Res. 57:781-789. doi:10.1071/AR05361

[8] Rouse, J W, Jr, R H Haas, J A Schell, and D W Deering. 1973. *Monitoring vegetation systems in the Great Plains with ETRS*. p. 309-317. In Proc. Earth Res. Tech. Satellite-1 Symp., 10-14 Dec. 1973, Goddard Space Flight Cent., Washington, DC.

[9] Sims, D A, Gamon, J A, 2003. *Estimation of vegetation water content and photosynthetic tissue area from spectral reflectance: a comparison of indices based on liquid water and chlorophyll absorption features*. Remote Sens. Environ. 84, 526–537.

[10] [FAO] Food and Agriculture Organization of the United Nations. 2002. FAOSTAT [Online]. Available at http://www.fao.org