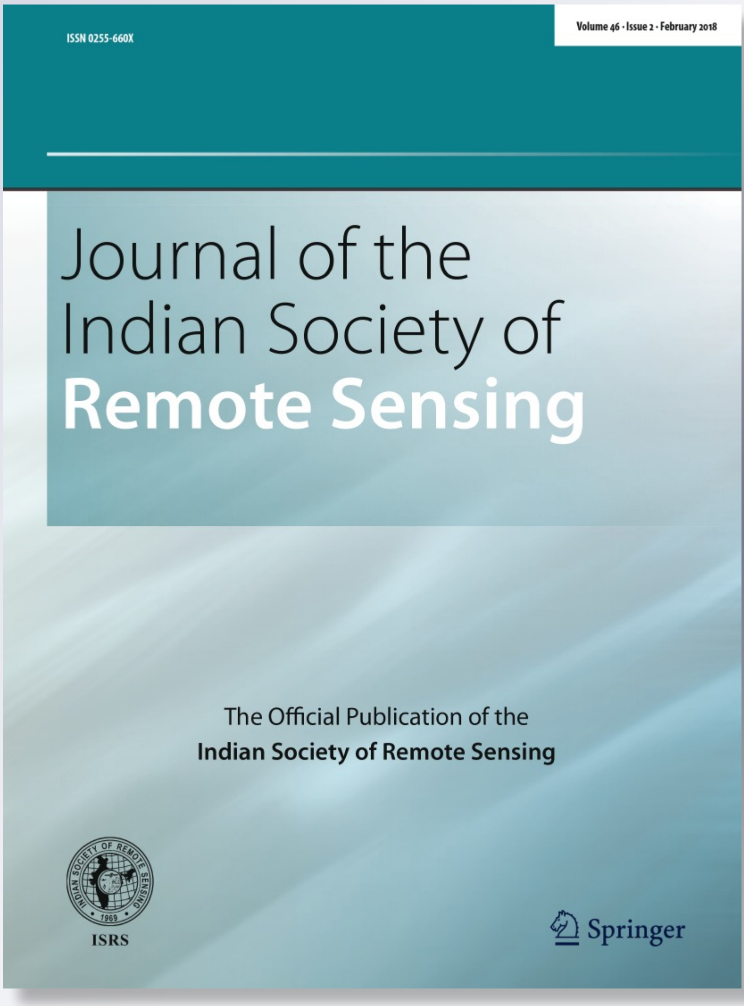
Comparison of Vegetation Indices from Two Ground Based Sensors

S. Pradhan, V. K. Sehgal, K. K. Bandyopadhyay, R. N. Sahoo, P. Panigrahi, C. M. Parihar & S. L. Jat

Journal of the Indian Society of Remote Sensing

ISSN 0255-660X
Volume 46
Number 2

J Indian Soc Remote Sens (2018)
46:321-326
DOI 10.1007/s12524-017-0671-0



Springer

J Indian Soc Remote Sens (February 2018) 46(2):321–326
https://doi.org/10.1007/s12524-017-0671-0

SHORT NOTE

ISRS

Comparison of Vegetation Indices from Two Ground Based Sensors

S. Pradhan[1] · V. K. Sehgal[2] · K. K. Bandyopadhyay[2] · R. N. Sahoo[2] · P. Panigrahi[1] · C. M. Parihar[2] · S. L. Jat[3]

Received: 13 December 2016 / Accepted: 4 April 2017 / Published online: 7 June 2017

Abstract The best and commonly used ground-based sensor to monitor crop growth, ASD FieldSpecPro Spectroradiometer (Analytical Spectral Devices, Boulder, CO, USA) is a passive sensor, which can be used under adequate light condition. However, now-a-days active sensors such as GreenSeeker^{TM} (GS) handheld crop response (Trimble Agriculture division, USA) are used for monitoring crop growth and are flexible in terms of timeliness and illumination conditions besides being cheaper than the ASD. Before its wide use, the suitability and accuracy of GS should be assessed by comparing the NDVI measured by this instrument with that by ASD, under diverse wheat growing conditions of India. Keeping this in view, the present experiment was undertaken with the following objectives: (1) to find out the temporal variation of NDVI measured both by ASD and GS treatments, (2) to find out relationship between the NDVI measured through ASD and GS and, (3) to evaluate the suitability of GS for NDVI measurements. It was observed that the numerical value of NDVI as measured by GS was always significantly ($P < 0.05$) lower than that measured by ASD for all the experiments under study. The NDVI-ASD and NDVI-GS were significantly positively correlated ($P < 0.01$) with the correlation coefficients being +0.94, +0.88 and +0.87 for irrigation and nitrogen experiment, irrigation and cultivars experiment, and tillage, residue and nitrogen experiments, respectively. Further, the regression equation developed between the NDVI-ASD and NDVI-GS: [NDVI-GS = 1.070 × (NDVI-ASD − 0.292] can be successfully used to compute the NDVI of ASD from that computed by GS.

Keywords Wheat · Spectroradiometer · Green seeker · NDVI

Introduction

The normalized difference vegetation index (NDVI), the difference between the reflectance in the near infrared and visible red divided by the sum of both, is one of the most widely used indices for monitoring plant N status, green leaf cover, green leaf biomass and grain yield (Gitelson et al. 2003; Pradhan et al. 2013, 2014; Yao et al. 2013). It is also used as an indicator of plant development and can be one of the inputs in many crop models (Dorigo et al. 2007). The NDVI can be estimated over a large area from remotely sensed data from a number of satellites, but the satellite image requires geometric and atmospheric corrections (Tremblay et al. 2009) through trained professionals. For field scale crop management, ground-based systems are preferable as they deliver instantaneous information, which does not need any correction and can be applied online (Erdle et al. 2011). The ground-based remote sensing devices, may work either actively or passively to produce vegetation indices like NDVI for monitoring vegetation photosynthetic activities and biophysical properties (Yao et al. 2013). Passive sensors use sunlight as the source of light whereas active sensors are equipped with light emitting components to provide radiation in specific wavelength regions. Therefore, active sensors compared

✉ S. Pradhan
sanatan28@gmail.com

[1] ICAR-Indian Institute of Water Management, Bhubaneswar 751 023, India

[2] ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India

[3] ICAR-Indian Institute of Maize Research, New Delhi 110 012, India

to passive sensors don't depend much on irradiation conditions though both passive and active remote sensing methods measure amount of light reflected by the crop by converting the light signal into electrical output (Erdle et al. 2011; Yao et al. 2013).

Passive sensors are mostly hyperspectral, which enable the user to calculate numerous vegetation indices. Hence passive sensors are more flexible and applicable though it can be used under adequate light conditions also. Active sensors use few central wavelengths and can be used to calculate limited vegetation indices independent of solar radiations (Erdle et al. 2011; Yao et al. 2013). The best (Yao et al. 2013) and commonly used passive sensors such as the ASD FieldSpec Pro Spectroradiometer (Analytical Spectral Devices, Boulder, CO, USA) use sunlight as the source of light. Active sensors such as GreenSeeker™ (GS) handheld crop response (Trimble Agriculture division, USA) are equipped with light emitting components and provide radiation in specific wavelength regions. The GS now a days, is used for nitrogen management in a number of crops (Mohanty et al. 2015). The capability of active and passive sensors to reproduce vegetation indices has been compared by many authors and found that though passive sensors were slightly more precise than the active sensors, the later were flexible in terms of timeliness and illumination conditions (Tremblay et al. 2009; Erdle et al. 2011). Besides that, the easy operation of active sensors like GS without radiometric calibration outweigh passive sensors like ASD (Yao et al. 2013). In developing countries like India, the GS would be more preferred than ASD because of its low cost and ease of operation. Before its wide use, the suitability and accuracy of GS should be found out by comparing the NDVI measured by this instrument with that by ASD, a reliable source for NDVI measurement under diverse wheat growing conditions of India. Keeping this in view, the present experiment was undertaken with the following objectives: (1) to find out the temporal variation of NDVI measured by both ASD and GS under different irrigation, cultivar, nitrogen and tillage treatments, (2) to find out relationship between the NDVI measured by ASD, a reliable source for NDVI measurement with that by the GS, a more affordable green seeker and, (3) to evaluate the suitability of GS for NDVI measurements.

Materials and Methods

Experimental Design

The data included in this study were obtained from three different experiments of spring wheat carried out during 2014–2015 at MB-4C of ICAR-IARI, New Delhi experimental farm. Treatments included: irrigation and nitrogen interaction (Exp. 1), irrigation and varieties interaction (Exp. 2) and tillage, residue and nitrogen interaction (Expt. 3). The detailed description of the treatments are presented in Table 1.

Field experiments were conducted during dry season (winter) of 2014–2015 at the experimental farm (MB-4C) of ICAR-IARI, New Delhi (77° 89′E, 28° 37′N and 228 m above mean sea level), Delhi, India. The area comes under semi-arid subtropical climatic belt. The soil is sandy loam (Typic Haplustept) with medium to angular blocky structure, non-calcareous and slightly alkaline in reaction for the surface soil.

Measurement of NDVI

ASD FieldSpec Spectroradiometer (ASD)

The canopy reflectance was measured in the spectral range of 350–2500 nm with 1 nm bandwidth with the help of hand held ASD FieldSpec Spectroradiometer (Analytical Spectral Devices Inc., Boulder, CO, USA). The reflectance measurements were made on sunny days between 11.00 and 13.00 h. The field of view (FOV) was 25° and the distance between the optical head of the Spectroradiometer and the top of the plant was kept at 1 m for all observations. For optimization of ASD instrument, a Spectralon (Labsphere, Inc., Sutton, NH, USA) white panel was used to obtain reference signal prior to canopy reflectance measurement. The canopy reflectance was computed as the ratio of canopy radiance to the radiance from the white reference panel. Four scans were obtained for each plot and averaged to produce final canopy reflectance. NDVI (normalized difference vegetation index), the difference between the reflectance in the near infrared and visible red divided by sum of both, is calculated from the spectral reflectance using the wavelength commensurate with the GreenSeeker handheld crop response (GS).

GreenSeeker Handheld Crop Response (GS)

The GreenSeeker handheld crop crop response (GS) has been developed by Trimble's agriculture division. This sensor has its own light source (active sensor), which allows measurements to be taken during the day or night, nullifying the effects of atmospheric interference. The GS used two LEDs as a light source and detected the reflection in the visible (660 ± 20 nm) and near infrared (780 ± 25 nm) spectral regions. The sensor's field of view is an oval; its size increases with the height of the sensor (approximately 10″ wide at 24″ above the ground, 20″ wide at 48″ above the ground). The sensor continues to sample

Table 1 Treatment details of the experiments

Experiment-1	*Irrigation × Nitrogen interaction in wheat*
	Design of experiment: split plot
	Mainplot factor: irrigation (3)
	I2: two irrigations (CRI and flowering stages), I3: three irrigations (CRI, flowering and grain filling stages) and I5: five irrigations (CRI, tillering, Jointing, flowering and grain filling stages)
	Subplot factor: nitrogen (2)
	N_{40}: 40 kg N ha^{-1} and N_{160}: 160 kg N ha^{-1}
Experiment-2	*Irrigation × Cultivar interaction in wheat*
	Design of experiment: split plot
	Mainplot factor: irrigation (4)
	I_2: two irrigations (CRI and flowering stages), I_3: three irrigations (CRI, flowering and grain filling stages), I_4: four irrigations (CRI, tillering, flowering and grain filling stages) and I_5: five irrigations (CRI, tillering, Jointing, flowering and grain filling stages)
	Subplot factor: cultivar (2)
	V_1: cv. HD 2967 and V_2: HD 3043
Experiment-3	*Tillage × Residue × Nitrogen interaction in wheat*
	Design of experiment: split-split plot
	Mainplot factor: tillage (2)
	Conventional tillage (CT) and no tillage (NT)
	Subplot factor: residues (2)
	Maize residue @ 5t ha^{-1} (R +) and without residue (R_0)
	Sub-Subplot factor: nitrogen
	$N_{50\%}$ (60 kg N/ha), $N_{100\%}$ (120 kg N/ha) and $N_{150\%}$ (180 kg N/ha)

the scanned area as long as the trigger remains engaged. The sensor displays the measured value in terms of an NDVI reading (ranging from 0.00 to 0.99) on its LCD display screen. Its greatest advantages are its small size, light weight and ease of use, and lower cost. Similar to ASD, the distance between the optical head of the GS and the top of the plant was kept at 1 m for all observations. Four NDVI readings were obtained for each plot and averaged to produce final NDVI.

All spectral reflectance measurements were made under clear sky conditions between 11.00 and 14.00 (New Delhi local time). In each experiment, data were obtained at booting, flowering and milk stage.

Data Analysis

ASD ViewSpecPro software (Analytical Spectral Devices Inc., Boulder, CO, USA) was used to export spectral data in MS Excel. The data were analyzed by analysis of variance as outlined by Gomez and Gomez (1984). The significance of the treatment effect was determined using F-test, and to determine the significance of the difference between the means of the two treatments least significance difference (LSD) at 5% probability level and Duncan's multiple range test were used. Correlations and regressions were determined using the data analysis tool pack of MS Excel (2003).

Results and Discussion

Variation of NDVI in Experiment 1

The NDVI measured by ASD was significantly ($P < 0.05$) higher than that by GS (Table 2) in all the stages. The NDVI measured by both ASD and GS was highest at booting stage followed by flowering stage and milk stage. The highest value of NDVI at booting stage is attributed to the highest amount of green leaf area and the highest leaf area index observed at this stage (Prasad et al. 2007). The decreasing trend of NDVI from booting stage to milk stage is due to the reduced reflectance in the NIR region and increased reflectance in the visible region due to loss of green tissue with advancement of plant growth (Prasad et al. 2007; Pradhan et al. 2013).

The NDVI measured by ASD was not affected significantly by irrigation levels in any of the stages of measurement (Booting, flowering and milk stage). Similarly, the NDVI measured by GS was not affected significantly by irrigation levels at any stage except the flowering stage. The I_5 irrigation treatment (0.70) registered significantly highest NDVI, which was at par with the I_4 treatment (0.69). I_2 treatment (0.64) showed lowest NDVI as measured by GS at flowering stage. The NDVI measured both by ASD and GS were not significant among the cultivars at booting and flowering stage. However, at milk stage, the

Table 2 Temporal variation in NDVI by ASD and GS for experiment 1

	NDVI by ASD			NDVI by GS		
	Booting stage	Flowering stage	Milk stage	Booting stage	Flowering stage	Milk stage
Effect of irrigation (I)						
I_2	0.92	0.88	0.81	0.72	0.64	0.58
I_3	0.92	0.88	0.79	0.71	0.65	0.57
I_4	0.92	0.89	0.82	0.74	0.69	0.61
I_5	0.93	0.90	0.83	0.77	0.70	0.62
CD (0.05)	NS	NS	NS	NS	0.04	NS
Effect of cultivar (C)						
V_1	0.92	0.89	0.83	0.73	0.67	0.62
V_2	0.92	0.88	0.79	0.73	0.67	0.56
CD (0.05)	NS	NS	0.03	NS	NS	0.03

NS Not significant at $P < 0.05$

Table 3 Temporal variation in NDVI by ASD and GS of experiment 2

	NDVI by ASD			NDVI by GS		
	Booting stage	Flowering stage	Milk stage	Booting stage	Flowering stage	Milk stage
Effect of irrigation (I)						
I_2	0.89	0.86	0.75	0.65	0.62	0.54
I_3	0.90	0.88	0.78	0.68	0.64	0.57
I_5	0.92	0.91	0.82	0.73	0.68	0.59
CD (0.05)	0.01	0.03	NS	0.05	0.02	NS
Effect of nitrogen (N)						
N_{40}	0.89	0.87	0.77	0.64	0.61	0.53
N_{160}	0.91	0.89	0.80	0.73	0.68	0.61
CD (0.05)	0.01	0.01	NS	0.04	0.04	NS

NS Not significant at $P < 0.05$

NDVI of the V_1 cultivar (0.83 in ASD and 0.62 in GS) was significantly higher than that of the cultivar V_2 (0.79 in ASD and 0.56 GS). It could be attributed to the higher green area and LAI in cultivar V_1 compared to the cultivar V_2 owing to the longer duration of the V_1 cultivar. The interaction effect of irrigation and cultivar was not significant on the NDVI measured by both ASD and GS at all the stages of measurement.

Variation of NDVI in Experiment 2

Similar to Experiment 1, the NDVI measured by ASD was significantly ($P < 0.05$) higher than that by GS and the highest NDVI was observed in booting stage followed by flowering stage and milk stage (Table 3). The irrigation levels significantly influenced the NDVI measured at booting and flowering stages; I_5 treatment registered highest NDVI and I_2 treatment the lowest NDVI. This can be attributed to better crop growth under I_5 irrigation level than that of I_2 irrigation level. However, the NDVI of I_2, I_3 and I_5 treatments were statistically at par during milk stage. This is in agreement with Pradhan et al. (2013) who also didn't observe any significant difference between the irrigation treatments on NDVI of milk stage. Similar to irrigation treatments, N_{160} treatment registered significantly higher NDVI compared to N_{40} treatments at booting and flowering stages, but not at milk stage. This can be attributed to the poor crop growth and less green leaf area (Pradhan et al. 2013) in N_{40} compared to N_{160} treatment. The interaction effect of irrigation and nitrogen was not significant on the NDVI except for the NDVI measured by ASD at booting stage.

Variation of NDVI in Experiment 3

The highest NDVI of wheat was observed in booting stage followed by flowering stage and milk stage (Table 4). The NDVI was not significantly influenced by tillage (CT and NT) treatments at all stages of measurement. Similar to tillage treatment, the residue application also didn't affect

Table 4 NDVI of ASD and Green seeker for experiment 3

	NDVI by ASD			NDVI by GS		
	Booting stage	Flowering stage	Milk stage	Booting stage	Flowering stage	Milk stage
Effect of tillage						
CT	0.92	0.89	0.77	0.68	0.61	0.52
NT	0.92	0.89	0.78	0.69	0.63	0.53
CD (0.05)	NS	NS	NS	NS	NS	NS
Effect of residue						
R_0	0.93	0.90	0.78	0.70	0.63	0.54
R_+	0.91	0.89	0.77	0.66	0.61	0.51
CD (0.05)	0.01	NS	NS	NS	NS	NS
Effect of nitrogen						
N_{50}	0.91	0.87	0.70	0.61	0.57	0.47
N_{100}	0.92	0.90	0.80	0.72	0.64	0.53
N_{150}	0.93	0.91	0.83	0.72	0.65	0.59
CD (0.05)	0.01	0.02	0.04	0.03	0.04	0.03

NS Not significant at $P < 0.05$

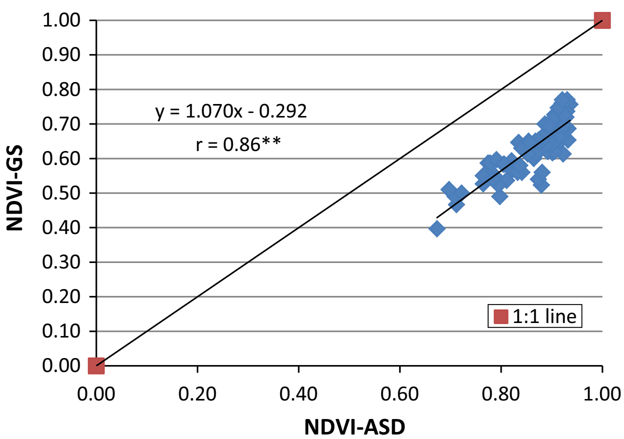


Fig. 1 Relationship between NDVI-ASD versus NDVI-GS for pooled over experiment 1, 2 and 3

NDVI significantly. The non-significant effect of tillage and residue application on NDVI can be attributed to the similar green biomass between no tillage and conventional tillage, and residue application and non-application plots as observed by harvest biomass. However, nitrogen application significantly increased NDVI of wheat at all stages of measurement; the highest being in $N_{150\%}$ followed by $N_{100\%}$ and $N_{50\%}$ treatments, which was attributed to higher biomass recorded at higher N levels.

Correlation Between NDVI Measured by ASD and GS

The correlation coefficient between NDVI-ASD and NDVI-GS are +0.94, +0.88 and +0.87 for experiment 1, experiment 2 and experiment 3, respectively which were significant at $P < 0.01$. When all the three experiments were pooled, the correlation coefficient was 0.86 (Fig. 1), which was also significant at $P < 0.01$. So, about 74% variation in the NDVI-ASD could be accounted by the NDVI-GS. Many researchers has also observed good correlation between passive sensors like ASD and active sensors like GS (Tremblay et al. 2009; Erdle et al. 2011). The high and significantly positive relationship between NDVI-ASD and NDVI-GS shows that GS can be safely used for the measurement of NDVI and hence the crop condition. Further, the regression equation developed between the NDVI measured by ASD and GS: $y = 1.070x - 0.292$ can be used to compute the NDVI of ASD from that computed by GS.

Conclusions

It may be concluded that highest NDVI of wheat was observed in booting stage followed by flowering stage and milk stage. The NDVI was not influenced by tillage treatments but increased due to crop residue mulching and with irrigation and nitrogen levels. The NDVI measured by GS was lower than that of ASD at all stages but the NDVI measured by GS was significantly positively correlated with that of ASD (r = 0.86). The regression equation developed in this study can be used to compute the NDVI of ASD using that of GS. However, this equation can be further modified and made robust using large volume of data set under diverse soil, climate and management practices.

Acknowledgements Funding was provided by Indian Council of Agricultural Research.

References

Dorigo, W., Zurita-Milla, R., De Wit, A., Brazile, J., Singh, R., & Schaepman, M. (2007). A review on reflective remote sensing and data assimilation techniques for enhanced agroecosystem modeling. *International Journal of Applied Earth Observation and Geoinformation, 9,* 165–193.

Erdle, K., Mistele, B., & Schmidhalter, U. (2011). Comparision of active and passive spectral sensors in discriminating biomass parameters and nitrogen status in wheat cultivars. *Field Crops Research, 124,* 74–84.

Gitelson, A. A., Vina, A., Arkebauer, J. J., Rundquist, D. C., Keydan, G., & Leavitt, B. (2003). Remote estimation of leaf area index and green leaf biomass in maize canopies. *Geophysical Research Letters, 30*(5), 1248.

Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research*. New York: John Wiley and Sons.

Mohanty, S. K., Singh, A. K., Jat, S. L., Parihar, C. M., Pooniya, V., & Singh, B. (2015). Precision nitrogen management practices influences growth and yield of wheat (*Triticum aestivum*) under conservation agriculture. *Indian Journal of Agronomy, 60,* 617–621.

Pradhan, S., Bandyopadhyay, K. K., Sahoo, R. N., Sehgal, V. K., Singh, R., Joshi, D. K., et al. (2013). Prediction of wheat (*Triticum aestivum* L.) grain and biomass yield under different irrigation and nitrogen management practices using canopy reflectance spectra model. *Indian Journal of Agricultural Sciences, 83,* 1136–1143.

Pradhan, S., Bandyopadhyay, K. K., Sahoo, R. N., Sehgal, V. K., Singh, R., Gupta, V. K., et al. (2014). Predicting wheat grain and biomass yield using canopy reflectance of booting stage. *Journal of Indian Society of Remote Sensing, 42,* 711–718.

Prasad, B., Carver, B. F., Stone, M. L., Babar, M. A., Raun, W. R., & Klatt, A. R. (2007). Potential use of spectral reflectance indices as a selection tool for grain yield in winter wheat under great plains conditions. *Crop Science, 47,* 426–1440.

Tremblay, N., Wang, Z., Ma, B. L., Belee, C., & Vigneault, P. (2009). A comparision of crop data measured by two commercial sensors for variable-rate nitrogen application. *Precision Agriculture, 10,* 145–161.

Yao, X., Yao, X., Jia, W., Tian, Y., Ni, J., Cao, W., et al. (2013). Comparison and intercalibration of vegetation indices from different sensors for monitoring above-ground plant nitrogen uptake in winter wheat. *Sensors, 13,* 3109–3130.