Estimating Optimal-Band of NDVI and GNDVI by Vegetation Reflectance Characteristics of Crops.

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ABSTRACT: Information on the area and spatial distribution of crop fields is needed for biomass production, arrangement of water resources, trace gas emission estimates, and food security. The present study aims to monitor crops status during the growing season by estimating its aboveground biomass and leaf area index (LAI) from field reflectance taken with a hand-held radiometer. Field reflectance values were collected over specific spectral bandwidths using a handheld radiometer(LI-1800). A methodology is described to use spectral reflectance as indicators of the vegetative status in crop cultures. Two vegetation indices were derived from these spectral measurements.

In this paper, first we analyze each spectral reflectance characteristics of vegetation in the order of growth stage. Vegetation indices (NDVI, GNDVI) were calculated from crop reflectance. And assess the nature of relationships between LAI and VI, as measured by the in situ NDVI and GNDVI. Among the two VI, NDVI showed predictive ability across a wider range of LAI than did GNDVI. Specific objectives were to determine the relative accuracy of these two vegetation indices for predicting LAI. The results of this study indicated that the NDVI and GNDVI could potentially be applied to monitor crop agriculture on a timely and frequent basis.

KEY WORDS: LAI, NDVI, GNDVI, Spectral reflectance

1. INTRODUCTION

Knowledge for reflectance characteristic of interesting targets will provide us with actual application of remote sensing on agriculture. The vegetation indices using green, red, and near-infrared wavelengths relate directly to the green biomass per unit land area(Kimura et al.,2004). The normalized difference vegetation index (NDVI) has evolved as a primary tool for monitoring vegetation changes and land use, and the interpretation of the impact of short and long term climatic events on the biosphere. These indices are thus affected in part by a changing Leaf Area Index(LAI) (Kimura et al.,2004). The configuration of spectral reflectance of curves gives us insight into the spectral characteristics of the crop. Monitoring the crop growth stage, remote sensing techniques have been used successfully for several crop cover. Measurements of LAI and spectral reflectance are critical to understanding many aspects of crop development, growth, and management.

The study of various biophysical plant features by remotely sensed data is complex, because the reflectance of a vegetative canopy is determined not only by plant morphology and phenology but also by soil characteristics (Huete and Jackson, 1985), irradiation, observation angle, and atmospheric condition. In order to maximize the contribution of vegetation reflectance information and to minimize the effects of exogenous factors, several vegetation indices (VIs) were developed during the last decades (Wallace and Campbell, 1989).

As primary objective, the present study will study the relationships between paddy rice spectral information and its ground cover and LAI. Additional objectives were to conduct correlation analysis among NDVI, Green Nomalized Difference Vegetation Index(GNDVI) and LAI of each vegetation, The results refer to figure out which one is the optimal band to monitor. The objective of this study was to assess the nature of relationships between LAI and VI, as measured by the in situ NDVI and GNDVI within South Korea.

2. METHODS AND MATERIAL

2.1 Research site

This study was carried out at the Ochang region in central South Korea (36°45'N, 127°24'E) on fields of Chungbuk Agricultural Research & Extention Services(CARES). The region holds a major potential for irrigated rice, due to abundant water resources from the Miho river.

2.2 Data collection

Reflectance data and LAI were acquired at the CARES at approximately 8-day intervals during the spring of 2008, from the mid of May to mid-October.

Four major crops were chosen for observation: paddy rice, licorice, green perolla, and peanut. Permanent markers were installed at the different observation sites (one for each crop), each forming a rectangle of 2.5 by 2.5 m, to insure monitoring at each site revisit.

We have measured and analyzed reflectivity characteristics based on growing status from transplanting time to harvesting time. Pictures of each crop type are shown field crop and growing period (Figure 1).

Spectral reflectance measurements were taken with a hand-held spectro-radiometer(LI-1800, Li Cor Inc.) during the growing season at CARES's farm in 2008.

For more developed canopies (LAI > 1), an indirect method was applied using the LAI-2000(Licor,1992). This instrument contains five concentric optical detectors, which measure the spherical distribution of light. The ratio of above to below light intensity measurements, corresponds to the probability of non-interceptance of light by the canopy. Measurement of reflectivity characteristics were carried out with a portable spectro-radiometer for frequencies from 300nm to 1100nm during the time period from 11:00 AM to 01:00 PM of clear sky and calm a day(Jang et al.,2000).

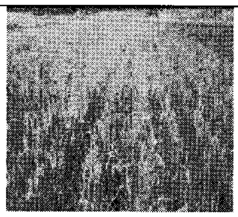
Field Crop		
	Paddy rice	**Licorice**
Growing Period	**April ~ October**	**June ~ September**
Field Crop		
	Green perolla	**Peanut**
Growing Period	**June ~ September**	**June ~ September**

Figure 1. Field investigation of the study area.

2.3 Vegetation Indices

Vegetation indices are computed as a carefully chosen combination of reflection coefficients in various wavebands. The main function of vegetation indices (VIs) is to minimize the effect of disturbing factors on the relationship between reflectance and crop characteristics of interest such as crop type, LAI, or canopy biomass (Bouman, 1995). Spectral vegetation indices, using the characteristic shape of the spectrum, are estimated by combining the low reflectance in the visible part with the high reflectance in the near-infrared part. The combination may be in the form of a ratio, a slope, or some other formulation.

The vegetation indices of general formula follow Table1:

Table 1. Vegetation Indices

Vegetation Index	Method of transformation	Reference
Normalized Difference Vegetation Index (NDVI)	$NDVI=\frac{NIR-RED}{NIR+RED}$	Rouse et al., 1974; Deering et al., 1975
Green NDVI	$GNDVI=\frac{NIR-GREEN}{NIR+GREEN}$	Gitelson & Merzlyak, 1998

Respectively, NIR, RED and GREEN are near-infrared, red and green reflectance.

3. RESULTS AND DISCUSSION

3.1 Spectral reflectance characteristics

For the purposes of this study, we retained only the most significant crops, i.e., paddy rice, licorice, green perolla, and peanut; paddy rice and licorice having similar behavior as those selected.

At the canopy level, the changes of canopy reflectance are the largest in the near-infrared wavelengths throughout the growing season due to increase of biomass and, thus, scattering, whereas the visible portions of the spectrum show less, but significant, seasonal variation that relates to absorption of light by photosynthetic and photoprotective pigments (Figure 2).

All measured field plants are changed of canopy reflectance between around 550 nm and 700 nm. With increased Chl. content, visible wavelength absorption increases, reaching more than 90% in the blue (400–500 nm) region by both chlorophylls *a* and *b* and carotenoids and the red (~670 nm) region where both chlorophylls absorb. Paddy, licorice, and peanut around 700 nm(red edge) indicate 10 percent of reflectance, and green perolla indicates 27 percent of reflectance. For green and red edge wavelengths, depth of light penetration into the leaf was found to be four to six fold higher than for the blue and red. In NIR wavelength, it indicates approximately paddy - 52%, licorice - 60%, green perolla - 90% and peanut - 75%. The reflectance line for the soil shown in Figure 2 reveals a fairly linear relationship across the wavelengths compared with the changes as the canopy develops. Visible wavelength leaf reflectance decreases with increasing leaf greenness (Figure 3). As the graph shows, there is a big difference of derivative change in 4 wavelength areas. The most change indicates especially around 700 nm (red edge) due to influence of chlorophyll.

Spectral features of leaf reflectance are: (1) minimum sensitivity to pigment content in the blue between 400 and 500 nm and in the NIR; (2) reflectance of leaves with moderate to high Chl are essentially insensitive to Chl content in the red absorption band of chlorophyll *a* near 670 nm; (3) the green and red edge reflectances are related very closely hyperbolically for a wide range of leaf greenness, and (4) the highest sensitivity of reflectance and absorption to pigment variation is in the green from 530 to 590 nm and in the red edge around 700 nm. As a point crossing between wavelength absorption in red range and spectral reflectance in NIR range, it could be analyzed as a result of a difference between field plants growth and concentration. Now that reflectance characteristics of both areas are used arithmetically, it is able to get the information about the field plants as vegetation index.

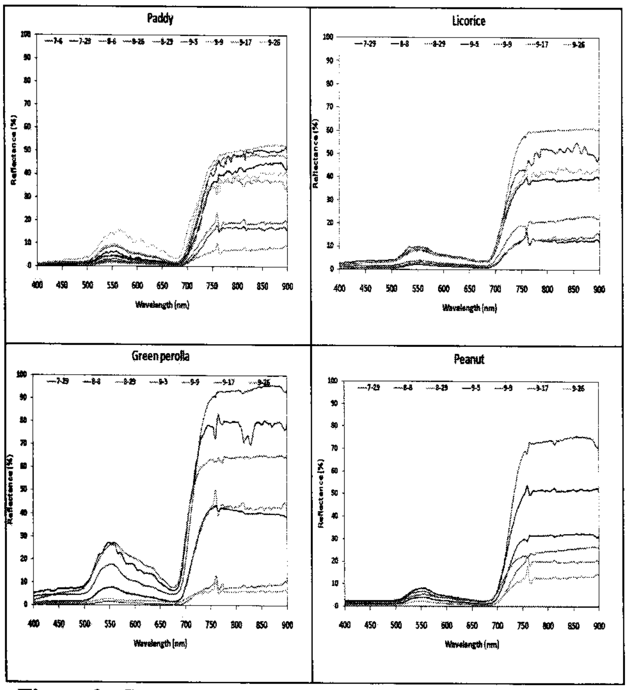
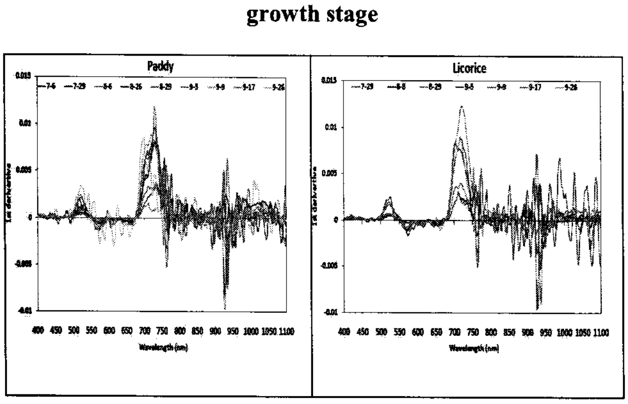


Figure 2. Spectral reflectance of the four crops during the growth stage



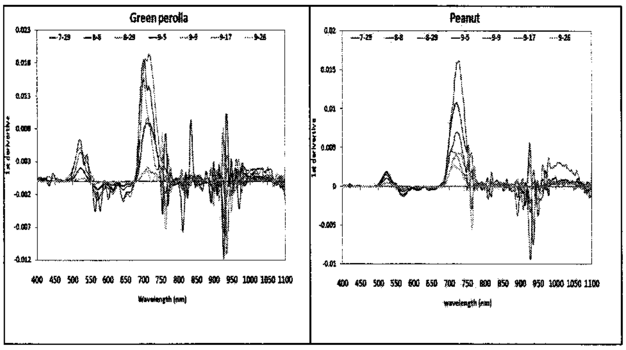


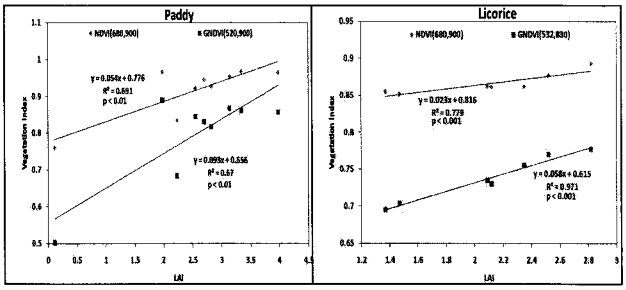
Figure 3. Variation of first derivative of four crops with time

3.2 Vegetation indices and LAI

By using reflectance characteristic of the field plants, this is to find proper wavelength range to monitor NDVI and GNDVI. RED wavelength range (630~700 nm) and GREEN wavelength range (520~560 nm) are made of 2nm distance. And NIR wavelength range (760~900) is made of 10nm distance. The course of LAI over the growing season, LAI continuously increased with time, with saturation towards maturity. The NDVI and GNDVI have been shown to be strongly related to light interception. Results of the multivariate analysis demonstrated that cultivars significantly affected regression relationships between LAI vs. NDVI and LAI vs. GNDVI, although the interaction was greater in the former compared with the latter (Table 2). As a result of, proper wavelength range of NDVI about each field plants are shown on the table. After checking the significance about wavelength range (p>0.01), it was indicated that the LAI increased, the NDVI and GNDVI increased (Figure 4). Simple linear relationships were shown for LAI regressed on NDVI and GNDVI. Among the two VI, NDVI showed predictive ability across a wider range of LAI than did GNDVI.

Table 2. Correlation analysis between VI and LAI

Crop	VI	Reflectance ratio(nm)	R^2	p
Paddy	NDVI	680, 900	0.691	0.01
	GNDVI	520, 900	0.67	0.01
Licorice	NDVI	680, 900	0.779	0.001
	GNDVI	532, 830	0.971	0.001
Green perolla	NDVI	676, 760	0.342	0.001
	GNDVI	552, 780	0.380	0.001
Peanut	NDVI	666, 820	0.476	0.01
	GNDVI	522, 770	0.412	0.01



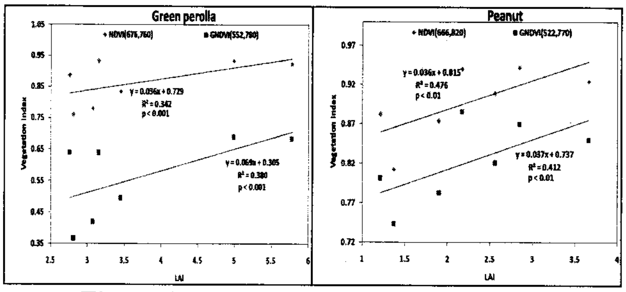


Figure 4. Relationship between VI and LAI

Correlation and regression analyses between vegetation indices (NDVI and GNDVI) and canopy parameters (LAI) were conducted (Figure 5). Regression relationships between LAI with NDVI and GNDVI varied from linear to quadratic to cubic. Interference from underlying soil reflectance, especially for incomplete canopy cover, has been a weakness for two VI. The change pattern between VIs and LAI is almost similar.

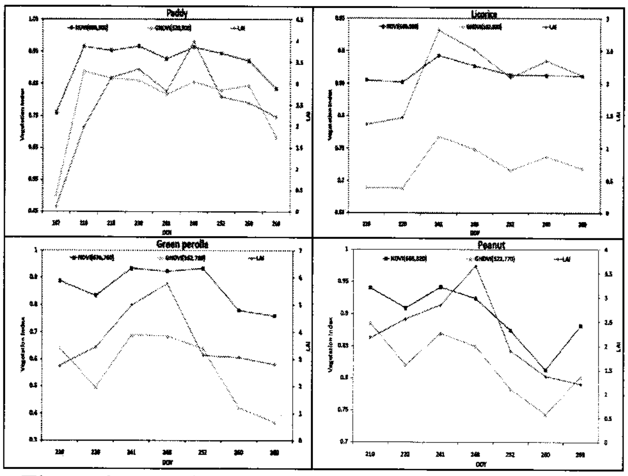


Figure 5. Relation between NDVI, GNDVI and LAI

4. CONCLUSIONS

Our results demonstrated that spectral information can provide acceptable estimates of LAI where it concerns field crop cultures. This does not hold for ground cover, which was probably due to inaccuracy in ground cover field data collection. Vegetation indices NDVI and GNDVI were shown to be useful tools to track changes in LAI in field crops when a wide range of environments and growth stages are considered. Among the two VI, NDVI showed predictive ability across a wider range of LAI than did GNDVI. However, suitability of these VI as predictive tools for LAI within a group of crops being compared at a specific growth stage was poor, probably because crops variability was not large enough to create wide LAI differences.

The inclusion of a categorical growth-stage-dependent variable, derived from the temporal variability of red/VNIR spectral signatures of the crops, improved the models significantly. However, in situ measurements in the present study can serve as a basis for developing satellite-based crop monitoring systems.

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