HYPERSPECTRAL ASSESSMENT OF CANOPY NITROGEN CONTENT IN RICE - COMPARATIVE ANALYSIS USING MULTIPLE DATASETS -

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1. INTRODUCTION

Assessment of canopy nitrogen content (CNC) is an important basis for growth diagnosis, precision management, and yield prediction in rice crop. High-resolution spectral reflectance measurement (Hyperspectra) has been suggested to have significant roles in assessment of crop variables, especially biochemical components (e.g., chlorophyll content) and physiological functioning (e.g., light use efficiency) as well as biotic and abiotic stresses (e.g., water deficit, disease infection) [1, 2]. Nevertheless, optimal use of hyperspectra for each target variable has not been well examined. Therefore, our objective was to explore accuracy and robustness of hyperspectral indices and multivariable methods for assessment of CNC based on comparative analysis using multiple datasets obtained in a wide range of sites, sensors, and conditions.

2. MATERIALS AND METHODS

Experimental datasets obtained in five different sites in China and Japan were used.

2.1. Hyperspectral reflectance measurements

Ground-based hyperspectral reflectance data were obtained using FieldSpec-FR(ASD; 350-2500 nm@1nm) and LI-1800 (Li-Cor; 350-1100nm@5nm) around midday (10:00-14:00LST) under clear sky conditions. The field of view of the sensors was 25°. Spectral measurements were taken at nadir-looking from 2 m above the canopy. Spectral reflectance was derived as the ratio of reflected radiance to incident radiance estimated by a calibrated white reference (Spectralon, Labsphere). Airborne hyperspectra were obtained using CASI-3 sensor from the height of 3000 m. The spatial resolution of the hyperspectral imagery was 1.5 m on the ground. Spectral reflectance data at 34 continuous bands (400-1050nm@20nm) were obtained. Atmospheric correction was made based on ground-based reflectance data.

2.2. Plant measurements

Data were taken over rice canopies of 9 varieties under 4 different management conditions in 4 years. All spectral measurements were made during the panicle formation stage (25 - 10 days before heading) which is the most critical stage for diagnosis for fertilizer management and well as for yield prediction. Plants were sample just after the spectral measurements. Plant size, biomass, and water and nitrogen contents were determined by standard methods. The range of nitrogen concentration, canopy nitrogen content, and biomass was 1.0-3.6 %, 0.31～16.5 g m^{-2} and 9～710 DWg m^{-2}, respectively, that cover the whole range of realistic values in Monsoon Asia.

2.3. Analytical methods

2.3.1 Mapping of spectral indices using a few number of wavelengths

We derived the maps of predictive ability of Normalized Difference Spectral Index (NDSI) and Ratio Index (RVI) using reflectance (R) and first derivative (FD) values in thorough combinations of two wavelengths (i and j nm) over the whole spectra [3, 4, 5].

$$\mathrm{NDSI}\ (i, j) = (R_j - R_i) / (R_i + R_j) \qquad \mathrm{RVI}(i, j) = R_i / R_i$$

The NDSI(FDi, FDj) and RVI(FDi, FDj) are defined in similar formulations. Major indices proposed in the literature were calculated for comparison [6].

2.3.2 Multivariable methods

We examined the PLS (Partial least squares regression) method to avoid the multi-colinearity problem inherent to the ordinary liner regression method. An improved PLS mehtod (IPLS) was also investigated. IPLS uses only some informative wavebands based on systematic waveband selection while PLS always uses the whole spectra [7, 8].

3. RESULTS AND DISCUSSION

In case of indices using reflectance values, NDSI and RVI using 825 nm and 735 nm were found to have the highest predictive ability for CNC. NDVI, SAVI and OSAVI showed the poorest ability among the all spectral indices from the literature. FD values at 730-745 nm regions had high correlation with CNC, but the regression equations for each datasets were not consistent. In general, the predictive ability of RVI(FDi, FDj) was higher than in NDSI(FDi, FDj), and the most promising index was found in the combination of two wavelengths at red edge and green regions. The predictive ability of the PLS model using the whole spectra (233 wavebands) was higher than those of all conventional indices but lower than the newly explored indices in this study. The IPLS using selected 56 wavebands had higher predictive ability than PLS, but rather comparable with the new indices using FDs at red edge and green regions.

The best index explored in this study was applied to the airborne dataset for spatial assessment of CNC. Measured CNC values agreed well with the predicted values (RMSE=0.8 g m^{-2}). It was demonstrated that the CNC map was quite informative of diagnosing within and between variability over large paddy areas.

In such cases that spectral reflectance at some limited number of discrete wavebands can be measured, NDSIs using two wavebands at the 700-850 nm region proved to be best among the thorough combination of two wavebands. If FD spectra can be derived, the ratio index using FD at red-edge and green wavebands would be most promising in predicting CNC, the predictive ability of which was better or comparable to that of PLS or IPLS approaches. IPLS using smaller number of wavebands showed higher predictive ability than PLS using the whole wavebands.

6. REFERENCES

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