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Estimating SPAD Value, Chlorophyll, and Mineral Components Using Hyperspectral Data of Maize Leaves

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Chlorophyll , Feed Quality, Hyperspectral Remote Sensing, Maize, Partial Least Squares Regression (PLSR)

Summary

In this study, as a preliminary step to the estimation of feed contents, we attempted to estimate the SPAD value, chlorophyll (a, b and a+b), and mineral components (T–N, T–P, and T–K) contained in leaves from the hyperspectral data (400–1,000 nm, 60 bands) of maize leaves. Regarding the estimation method, we compared the estimation accuracy of two kinds of partial least squares regression (PLSR) using either all bands (60 bands) or only selected ones as explanatory variables. When all bands were used as explanatory variables, estimation was possible with accuracy that is sufficient for practical use for all parameters except chlorophyll b, phosphorus (T–P) and potassium (T–K) (R^2 = 0.82–0.90, EI = 19.7–24.5, EI Rank = B). When waveband selection was conducted, it was judged that all parameters except phosphorus (T–P) and potassium (T–K) can be estimated with accuracy that is sufficient for practical use (R^2 = 0.78–0.91, EI = 19.6–21.7, EI Rank = B). Based on the relation between measured values and estimated ones in verification, it was judged that actual estimation was possible for three parameters: the SPAD value, chlorophyll a+b and nitrogen (T–N). The results described above demonstrate that the SPAD value related to the greenness (depth of green color) of the leaf blade, chlorophyll a+b and nitrogen (T–N) can be estimated by applying PLSR, or PLSR with band selection, to hyper - spectral data of maize leaves.

Introduction

Background

Visible-infrared hyperspectral data have been widely used recently in remote sensing for nondestructive crop-quality estimation in the field.

Aim of this study

The authors applied hyperspectral remote sensing to the field of feed maize to investigate the estimation of feed contents of the whole maize plant (including leaves, stems, and grains) from the hyperspectral data of maize community.

Materials and Methods

(1) Study period and Study site

June to September 2009

Maize field within the Field Science Center affiliated with Kitasato University located in Towada, Aomori.

(2) Test sample

Maize for livestock feed. Outdoor and Pot cultivation

(3) Acquisition of hyperspectral data

Sensor : Imspector V10

Wavelength range : 400-1,000 nm (60 bands)

(4) Data analysis

The obtained spectral reflection intensity was subjected to a normalization process to stabilize luminance levels.

Furthermore, we calculated the first derivative values from the normalized spectral reflection intensity. Subsequently, we formulated a model equation for estimation by applying a multiple linear regression analysis (forward selection method; F value: 4.0) with the either normalized spectral reflection intensity(RS) or first derivative values(FSD) used as the explanatory variables and the SPAD Value, chlorophyll(a, b and a+b), and mineral components(T-N, T-P, and T-K) in the maize leaf as the objective variable. 104 samples were used for analysis.

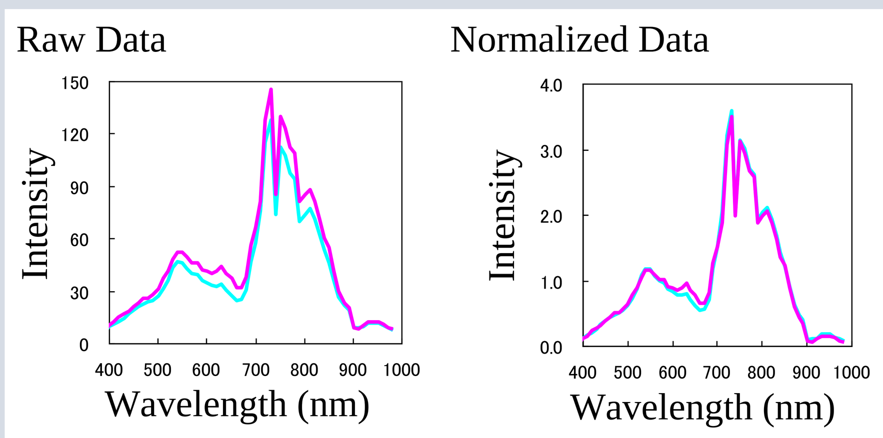
Study site

Fig.1 Study site and samples.

Acquisition of hyperspectral data

Fig.2 Hyperspectral sensor.

Normalization of hyperspectral data



$$N_i = \frac{S_i - S_{\min}}{S_{mean} - S_{\min}}$$

Normalized method of Okamoto et al., (2004) and Murata et al., (2004)

Fig.3 Normalized method of hyperspectral data.

Data analysis flow

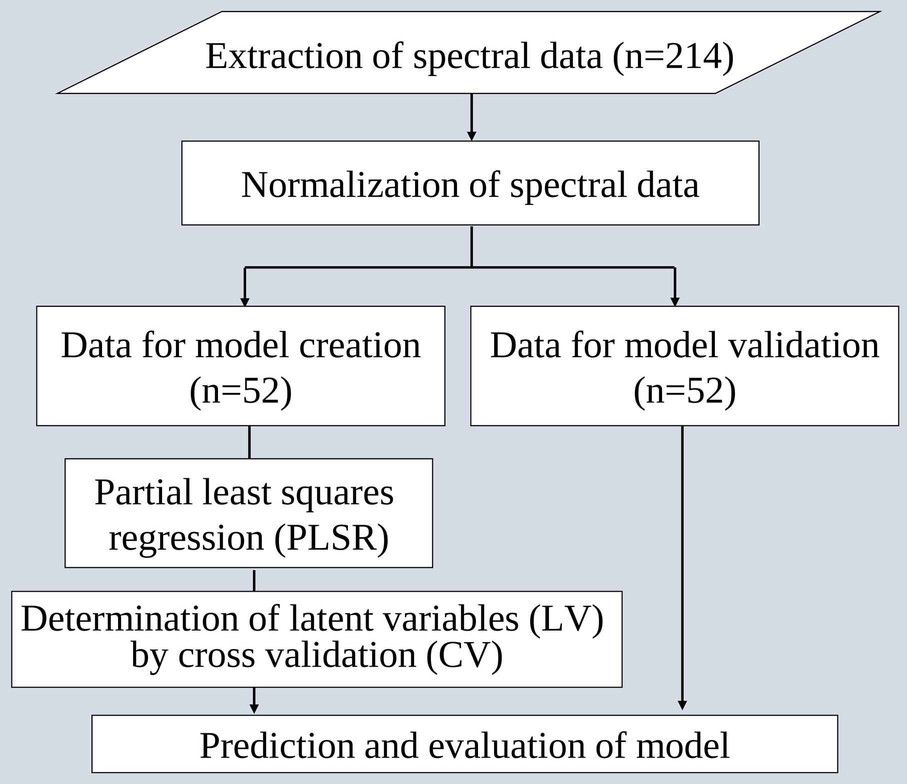


Fig. 4 Procedure of creating model.

Evaluation Index (EI)

EI was calculated by:

$$EI(\%) = \frac{SDP}{range} \times 100$$

(A) very high (EI < 12.4%)
(B) high (EI 12.5 – 24.9%)
(C) low (EI 25.0 – 37.4%)
(D) very low (EI 25.0 – 37.4%)
(E) estimation impossible (EI > 50.0%).

When EI is more than rank C, it is considered that usable precision has been achieved (Mizuno *et al* 1988) .

Results and discussions

(1) All bands

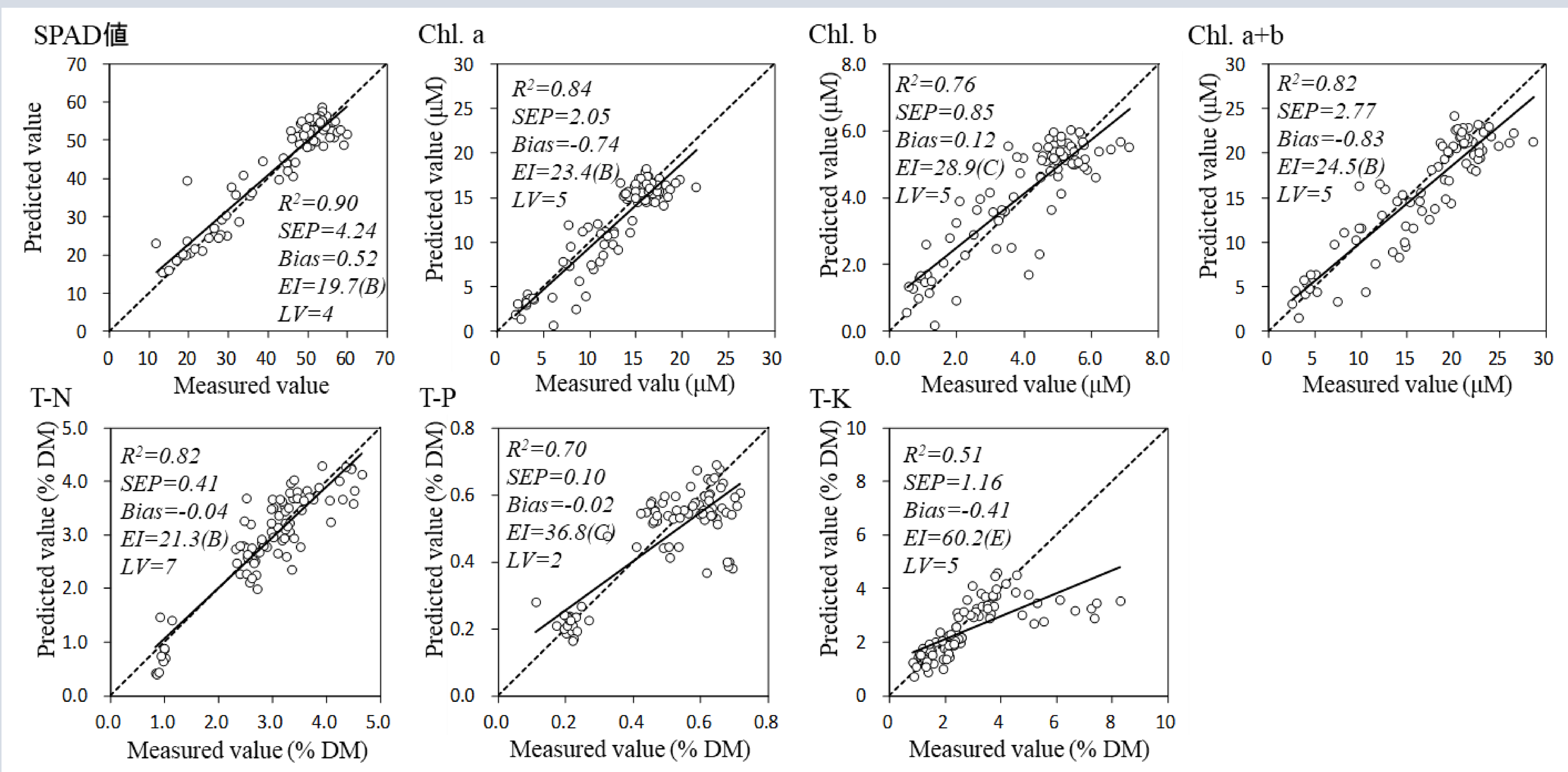


Fig.5 Relationship measured value and predicted value.

Regarding the estimation method, we compared the estimation accuracy of two kinds of partial least squares regression (PLSR) using either all bands (60 bands) or only selected ones as explanatory variables. When all bands were used as explanatory variables, estimation was possible with accuracy that is sufficient for practical use for all parameters except chlorophyll b, phosphorus (T–P) and potassium (T–K) (R^2 = 0.82–0.90, EI = 19.7–24.5, EI Rank = B). When waveband selection was conducted, it was judged that all parameters except phosphorus (T–P) and potassium (T–K) can be estimated with accuracy that is sufficient for practical use (R^2 = 0.78–0.91, EI = 19.6–21.7, EI Rank = B). Based on the relation between measured values and estimated ones in verification, it was judged that actual estimation was possible for three parameters: the SPAD value, chlorophyll a+b and nitrogen (T–N).

(2) Waveband selection

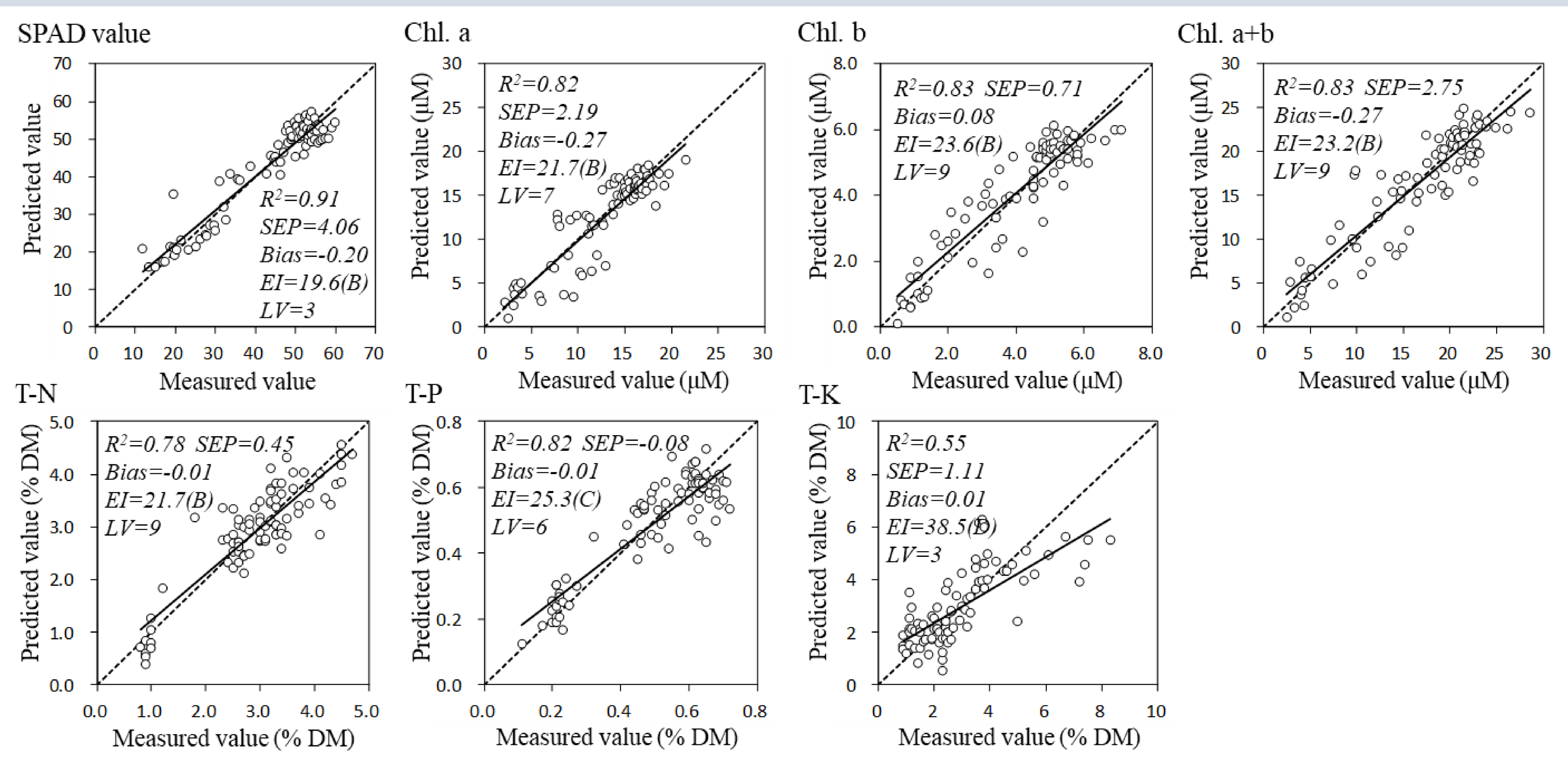


Fig.6 Relationship measured value and predicted value..

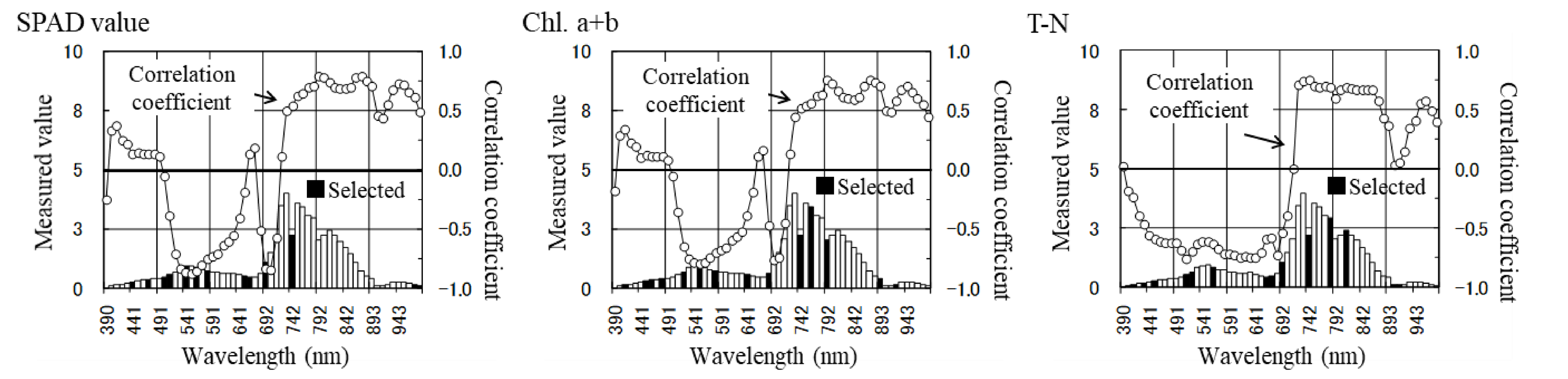


Fig.7 Wavelength selected stepwise selection.

Conclusion

The results described above demonstrate that the SPAD value related to the greenness (depth of green color) of the leaf blade, chlorophyll a+b and nitrogen (T–N) can be estimated by applying PLSR, or PLSR with band selection, to hyperspectral data of maize leaves.