Soil P_2O_5 Calibration and Mapping using Real-Time Soil Sensor (RTSS)

Y. Nagami*, S. Shibusawa, M. Kodaira, R. Kanda
Faculty of Agriculture, Tokyo University of Agriculture and Technology, 3-5-8 Saiwai-cho, Fuchu-shi, Tokyo 183-8509, Japan
50010538008@st.tuat.ac.jp

Abstract

There have been few researches using on-the-go measurement of P_2O_5. The objectives of this study were to measure soil P_2O_5 by using an on-the-go Real-Time Soil Sensor (RTSS) and to create soil P_2O_5 maps. The experiment was conducted on a 4-ha commercial farm in Hokkaido, Japan, in 2008 and 2009. The RTSS collected Vis-NIR soil reflectance spectra (350 to 1700 nm, 5-nm intervals). For calibration, a total of 144 soil samples were collected. A multivariate linear regression technique using a partial least squares (PLS) model for the soil P_2O_5 was calculated with full cross validation by Unscrambler 9.8. The multiple coefficient of determination (R^2) and the root mean square error (RMSE) were calculated for evaluation. The recorded soil parameters were provided as an Inverse Distance Weighted (IDW) map with Arc GIS 9, US. In this study, the R^2 and RMSE values of the PLS model for the soil P were 0.66 and 10.12 (mg/100g).

Keywords: P_2O_5, RTSS, PLS, soil map, precision farming

Introduction

Many researches related to P_2O_5 measurement using Vis-NIR spectroscopy have been performed in the laboratory, but few have performed on-the-go measurement. One such research using on-the-go measurement of P_2O_5 was carried out by Mouazen et al. (2006). The objectives of this study were to measure the soil P_2O_5 by using an on-the-go Real-Time Soil Sensor (RTSS) and to create soil P_2O_5 maps for site-specific management.

Materials and methods

<u>Experimental fields</u>
The experimental fields were two contiguous parts of a commercial experimental farm in Memuro, Hokkaido, Japan, after crop harvesting in August and October 2008 and in November 2009. The fields were named No.1 (4.43 ha, 303×146 m) and No.2 (4.51 ha, 303×148.8m). The soil was alluvial.

<u>Spectral data and soil samples</u>
The RTSS equipment simultaneously captured several types of data, including soil reflectance spectra range including visible (Vis) and near infrared (NIR) spectra wavelengths (350 to 1700 nm, 5-nm intervals), underground soil surface color images, soil resistance, electric conductivity (EC), and DGPS data.

The RTSS moved longitudinally along six segments of 24 m spacing and collected Vis-NIR soil reflectance spectra every 2.24 m at a depth of 0.2 m. Soil samples were collected every 24.64 m at the same depth.

In 2008, 144 soil samples and soil reflectance spectral data on fields No.1 and No.2 were collected and used for calibrating the PLS model. In 2009, 72 soil samples and soil reflectance spectral data on field No.1 were collected.

Soil samples were dried in an oven, crushed and passed through a sieve before performing chemical analysis. The soil P_2O_5 was measured with the autoanalyzer QuAAtro by the Truog method, to measure the amount of plant-available phosphorus by the widely-used method in Japan.

<u>Spectral data analysis and soil mapping</u>
To reduce noise and enhance weak signals, Vis-NIR soil reflectance spectra were subjected to Savitzky-Golay second derivative treatment. The sensitivity analysis for calibration was performed using the PLS technique in the Unscrambler v9.8 program (CAMO ASA, Norway). The 144 soil samples were used as the calibration dataset for full cross validation.

The recorded soil parameters were plotted on inverse distance weighted (IDW) maps using ArcMap v9.2 (ESRI, USA).

Results and Discussion

<u>Soil sample parameters</u>
Table 1 shows the maximum, minimum, average and standard deviation values of the soil P_2O_5 content in each year in each field. Figure 1 shows a histogram of the soil P_2O_5 content. Soil P_2O_5 was greater in field No.1 than No.2, and increased slightly from 2008 to 2009.

Table 1. Profiles of soil P_2O_5 content

		Number	P_2O_5(mg/100g)			
			Max	Min	Average	SD※
2008	No.1	72	114.70	33.40	61.66	17.38
	No.2	72	86.30	25.20	46.80	13.73
2009	No.1	72	114.75	40.69	64.36	15.79

※SD = standard deviation

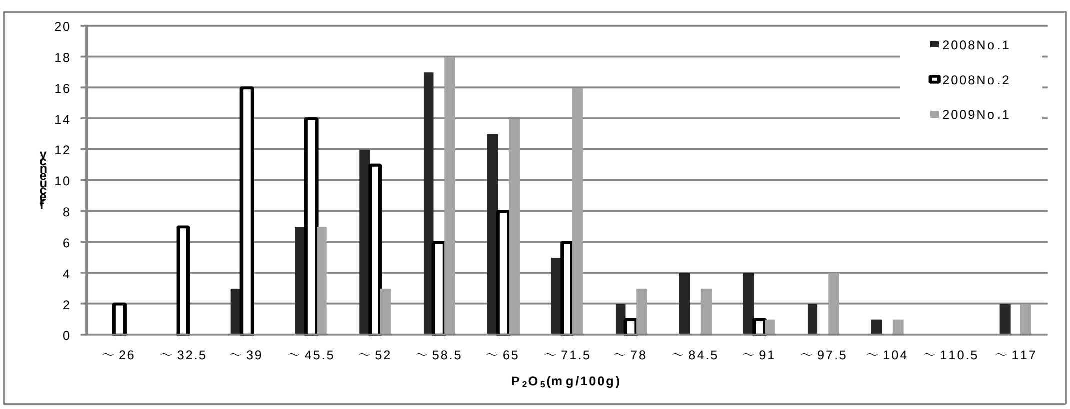

Figure 1. Histogram of soil P_2O_5 content

The PLS model

Spectral data after smoothing and second derivative treatment are depicted in Figure 2. Some peaks are found around 550 nm, 1350 nm and 1450 nm. Measured soil P_2O_5 is plotted against validated soil P_2O_5 for the 144 calibration samples. In this study, the R^2 and RMSE values of validation were 0.66 and 10.12 (mg/100g) (Table 2), which are compared with those of other studies in Table 3. It can be seen from the R^2 value that the PLS model for soil P_2O_5 in this study was at least as accurate as that in other studies.

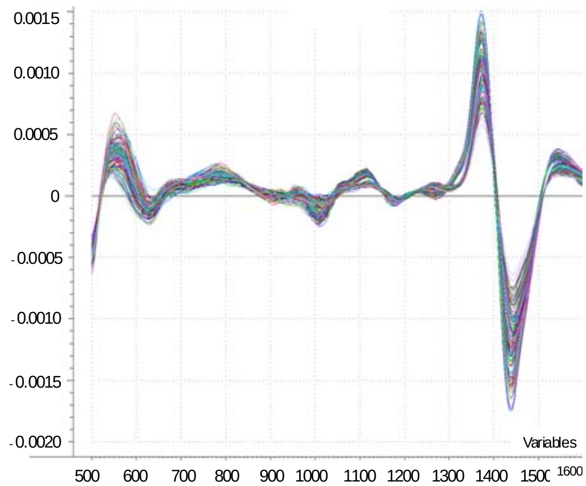

Figure 2. Spectral data after preprocessing

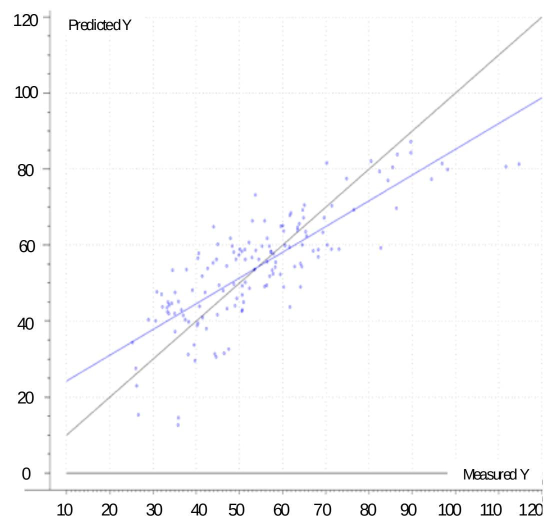

Figure 3. Comparison of measured and predicted soil P_2O_5 values

Table 2. R^2 and RMSE values of the PLS model

	calibration	validation
R^2	0.70	0.66
RMSE (mg/100g)	9.48	10.12

Table 3. Comparison of values

Year	*Method*	*Units*	*Spectral range(nm)*	*Multivariate method*	*No.*	*P*		*RMSE*		R^2		*Authors*
						Max	*Min*	*Cal*	*Val*	*Cal*	*Val*	
	Truog	mg/100g	350-1700	PLSR (4)	144	114	25	9.47	10.12	0.70	0.66	This paper
1992	Truog	mg/100g	1100-2500	MR	120						0.69	Matunaga
2001	MehlichⅢ	mg/kg	400-2498	PCR	779	507.6	0.7	32.28		0.40		Chang CW
2006	Olsen	mg/100g	305-1710	PLSR	126	11.63	2.95	0.943	1.202	0.83	0.73	Mouazen

Soil P_2O_5 maps

Figure 4 shows soil P_2O_5 maps. Each M-map was derived from data of measured soil P_2O_5. Each P-map was derived from predicted soil P_2O_5 calculated with the PLS model from soil reflectance spectra data. In each year and each field, the M-map and P-map showed similar variation patterns.

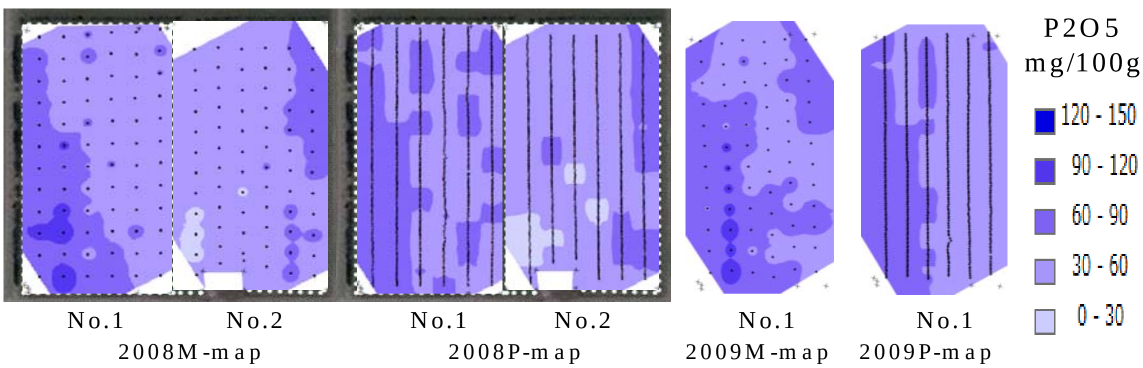

Figure 4. P_2O_5 soil maps

Conclusions

The main conclusions of this study are as follows:

- The R^2 and RMSEV values of the PLS model for soil P_2O_5 were 0.66 and 10.12 (mg/100g).
- The R^2 value showed that the PLS model for soil P_2O_5 in this study was at least as accurate as that in other studies.
- The P-map and M-map showed similar variation patterns.

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