SPECTRAL REFLECTANCE SELECTION FOR ASSESSING ORGANIC CARBON CONTENT OF CLAY SOIL IN PADDY FIELD

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Abstract: Organic matter is a key factor that represents abundance of fertility in soil. In paddy field, soil organic matter (SOM) varies depending on differences of soil environment and management. Therefore, this study aims to find appropriate spectral wavelengths corresponding to SOM in term of soil organic carbon (SOC) under variation of environmental and management factors influencing amount of organic matter in paddy soil. Statistical and GIS techniques were used to investigate spatial SOC variation under different soil environmental and management factors. The 18 plots, sized 30*30 meter, were surveyed for sampling field parameters including SOC, soil moisture, brown residue cover, green residue cover, soil color, and soil reflectance. Using a regression model, soil reflection which highly correlated with SOC was selected to estimate carbon storage. The result showed that terrain sites; lowland, upland, and high land; did not influence to amount of SOC in paddy soil. Soil spectral wavelength at 508 and 952 nm showed the best agreement with SOC.

INTRODUCTION

The amount of organic matter is a factor that represents the abundant of fertility in soil. In paddy field, differences on soil environment and soil management influence soil organic matter. Cultural activities, particularly straw burning and tillage, can emit carbon to atmosphere which impact on global temperature rising. Naturally, carbon can be accumulated in soil by transforming crop residue into soil organic matter. Organic matter in soil is important not only as a source of carbon accumulation, but also a source of plant nutrients accumulation as well. Typically, content of soil organic matter is analyzed by chemical approach in a laboratory. Nowadays, new methods for estimation of soil organic carbon content were proposed aiming for rapid analysis and avoid the destruction of soil surface. Shibusawa et. al. (1999) found relationship between spectral reflectance and soil properties such as moisture content, pH, CEC, and organic matter ($R^2 = 0.61$ to 0.87). Thus, this study aims to find appropriate wavelengths for carbon estimation focusing on clay soil in paddy field.

Study sites

The study site was in Phitsanulok province, 17°28’N 99°41'E and 16°23'N 101°7'E, located in lower north of Thailand (Fig. 1). The majority of LDD soil groups in the study sites are number 7, 4, 15, and 6 which occupies 434, 372, 197, and 174 square kilometer of Phitsanulok province, respectively. Texture of these soil groups are clay derived from recent alluvium.

Methodology

Field Measurements and Soil Sample Analysis

Field surveys of 18 sites (Fig. 1) were performed during January and May, 2012. Sampling size of each site was 30*30 meters. Soil sample at 0-5 cm from soil surface and soil color using Munsell soil book were collected at position 1 to 9 while soil reflectance using FieldSpec® 3 Spectroradiometer (ASD,) were collected at position 1, 3, 5, 7 and 9. Soil samples were analyzed for soil moisture and SOM in laboratory. The majority of soil colors measured at 9 points was used as a representative of soil color. Reflection spectra were measured at 1 nm intervals from 350 to 2500 nm and were recorded at 40 times per plot on bare soil. An average of bare soil reflectance measured from 9 points was used as a representative of soil reflectance. Crop residue cover was collected by a transect method (Shelton and Jasa, 2009) at 3 times from position 1 to 9. Crop residue cover was measured into 2 types; brown residue cover representing non-living biomass and green residue cover representing living biomass. In laboratory, soil samples taken from field survey were immediately analyzed for soil moisture. SOM in air dried-soil samples were analyzed by using standard method and analyzed SOM values were transformed in terms of soil organic content (SOC).

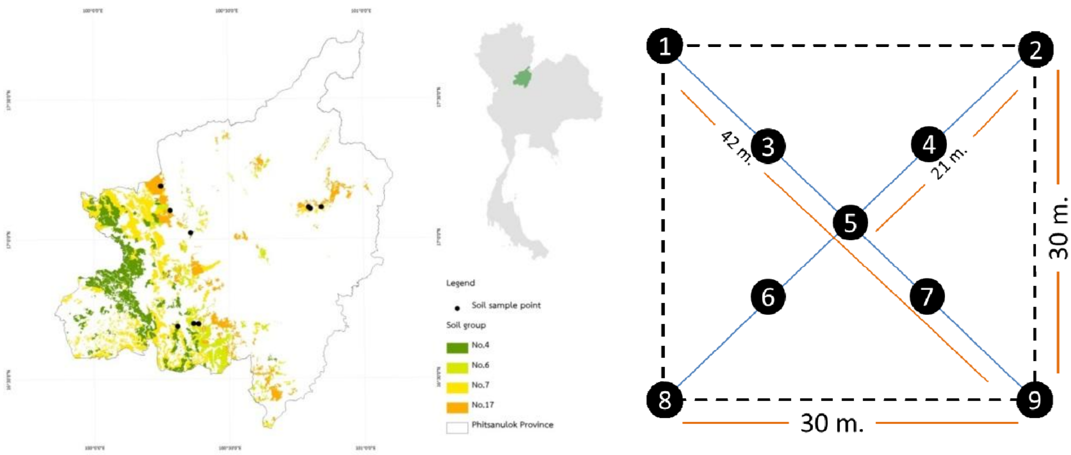


Fig. 1. Study Area, Field Sampling Sites and Plot Design

Statistical analyses

All samples (ID 1-18) collected from field survey were separated into two groups (Table 1). The first group (ID 1-9) was used to build models while the remaining (ID 9-18) data were used to test the validity of the model. The analysis of variance (ANOVA) was used to determine the difference of soil organic, soil moisture, and crop residue cover measured from three topographic terrains; lowland, upland, and highland. The coefficient of correlation was performed to select wavelength which showed high correlation between soil reflectance and SOC. Linear regression equations between soil reflectance and SOC were used to create model for estimating SOC.

RESULTS AND DISCUSSION

Effect of terrain on soil organic carbon and soil environments

Descriptive statistics of 18-sampling plots and comparison of Paddy Field Variables Taken from Difference Terrain Types were shown in Table 1 and Table 2, respectively, the ANOVA analysis of SOC taken from different terrains; lowland, upland, and highland; showed that SOC were not significantly different due to terrain types.

Table 1 Descriptive Statistics of 18-Sampling Plots

ID	Terrain	SOC	BM_G	BM_B	SM	SC	Wavelength (nm)								
							508	686	952	1,149	1,349	1,495	1,786	2,022	2,209
1	L	1.79	0	58	23.9	5YR4/2	0.07	0.15	0.28	0.34	0.38	0.32	0.37	0.30	0.30
2	L	2.04	12	49	20.9	5YR3/2	0.06	0.12	0.27	0.33	0.34	0.26	0.30	0.22	0.23
3	L	1.45	0	60	6.5	10YR5/2	0.08	0.16	0.30	0.38	0.42	0.34	0.39	0.30	0.29
4	U	1.37	6	68	14.3	5YR4/2	0.08	0.16	0.30	0.37	0.42	0.32	0.39	0.29	0.30
5	U	1.24	3	53	5.8	5YR5/2	0.09	0.19	0.33	0.41	0.48	0.38	0.46	0.36	0.35
6	U	1.17	2	60	11.0	10YR4/4	0.09	0.19	0.36	0.46	0.52	0.41	0.48	0.38	0.37
7	H	1.38	12	0	3.8	10YR7/6	0.10	0.20	0.31	0.37	0.42	0.39	0.43	0.40	0.37
8	H	1.19	7	0	3.4	10YR7/8	0.11	0.21	0.31	0.37	0.42	0.39	0.43	0.39	0.35
9	H	1.65	3	0	3.3	10YR7/8	0.08	0.16	0.25	0.30	0.35	0.33	0.37	0.34	0.31
10	L	1.06	14.5	0.5	27.4	10YR4/2	0.06	0.10	0.19	0.24	0.24	0.16	0.21	0.10	0.14
11	L	0.70	14	4	23.7	10YR5/4	0.12	0.24	0.41	0.54	0.59	0.46	0.55	0.39	0.42
12	L	0.56	9.5	7.5	10.3	10YR4/3	0.08	0.16	0.24	0.30	0.32	0.24	0.30	0.18	0.23
13	L	1.09	1.5	0	10.2	10YR6/4	0.13	0.27	0.38	0.52	0.60	0.61	0.63	0.61	0.44
14	L	1.72	13	2	19.0	10YR5/2	0.08	0.13	0.21	0.26	0.29	0.24	0.28	0.20	0.21
15	L	1.20	0	25	7.6	5YR7/2	0.04	0.07	0.12	0.14	0.16	0.15	0.17	0.16	0.16
16	L	1.28	0	42	9.7	10YR7/2	0.04	0.08	0.13	0.15	0.17	0.16	0.18	0.17	0.16
17	L	1.31	0	23	10.4	10YR6/2	0.06	0.11	0.16	0.20	0.23	0.20	0.23	0.20	0.20
18	H	0.86	51	12	11.1	10YR3/4	0.06	0.11	0.28	0.34	0.36	0.23	0.31	0.20	0.22

ID: 1-9 = calibrated group, 10-18 = validated group
Terrian : L= Lowland, U = Upland, H = Highland
SOC= Soil organic carbon (%) Res_G = Green residue (%) Res_B = Brown residue (%)
SM = Soil moisture (%) SC = Soil Color

Table 2. Comparison of Paddy Field Variables Taken from Difference Terrain Types

Variables Taken from Paddy Fields	Terrain			F	Sig.
	Lowland	Upland	Highland		
SOC	1.76±0.30	1.26±0.10	1.41±0.23	3.84	0.08
Green residue	4.00±6.93	3.67±2.08	7.33±4.51	0.51	0.63
Brown residue	67.67±24.95	60.33±7.51	0.00±0.00	18.28	0.00
Total residue	71.67±21.13	64.00±9.17	7.33±4.51	20.18	0.00
Soil moisture	17.06±9.31	10.37±4.26	3.50±0.26	3.95	0.08
Red value	112.00±22.52	123.33±13.05	213.33±4.62	39.71	0.00
Green value	93.67±25.01	101.00±14.73	165.67±1.16	16.75	0.00
Blue value	80.33±21.01	81.33±24.5	88.67±13.28	0.15	0.86

Spectral Signature of Bare Soil

Even though reflectances of bare soil in three terrains were different but they showed similarly responding to all observed wavelength (Fig. 2). Normally, SOC and soil moisture in lowland are higher than those in upland and highland. High SOC and soil moisture can absorb more reflectance energy. Therefore, lowland reflectance was lower than upland and highland terrains. Line graph of highland differs from lowland and upland due to soil color and crop residue cover. Mostly soil color in highland was 10YR.

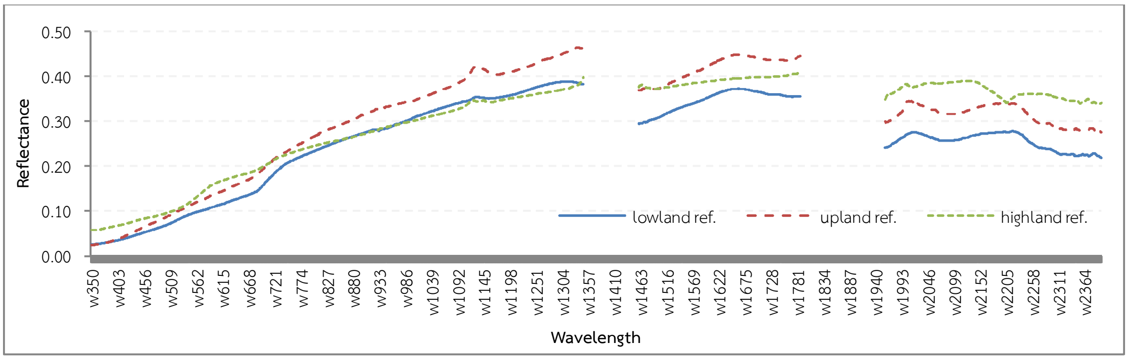


Fig. 2 Bared Soil Reflectance Measured from Lowland, Upland, and Highland

Relationship between Bare Soil Reflectance and SOC

In fig.3, High correlation coefficient between bare soil reflectance and SOC were found at wavelength 508 nm, 686 nm, 952 nm, 1149 nm, 1349 nm, 1495 nm, 1786 nm, 2022 nm, and 2209 nm. Ting et al. (2008) found high organic carbon reflectance of various soil texture at wavelength 1501 nm and 2137 nm. Energy absorption can be influenced by soil organic matter (Jensen, 2007), thus, the more SOC increases, the more soil reflectance decreases.

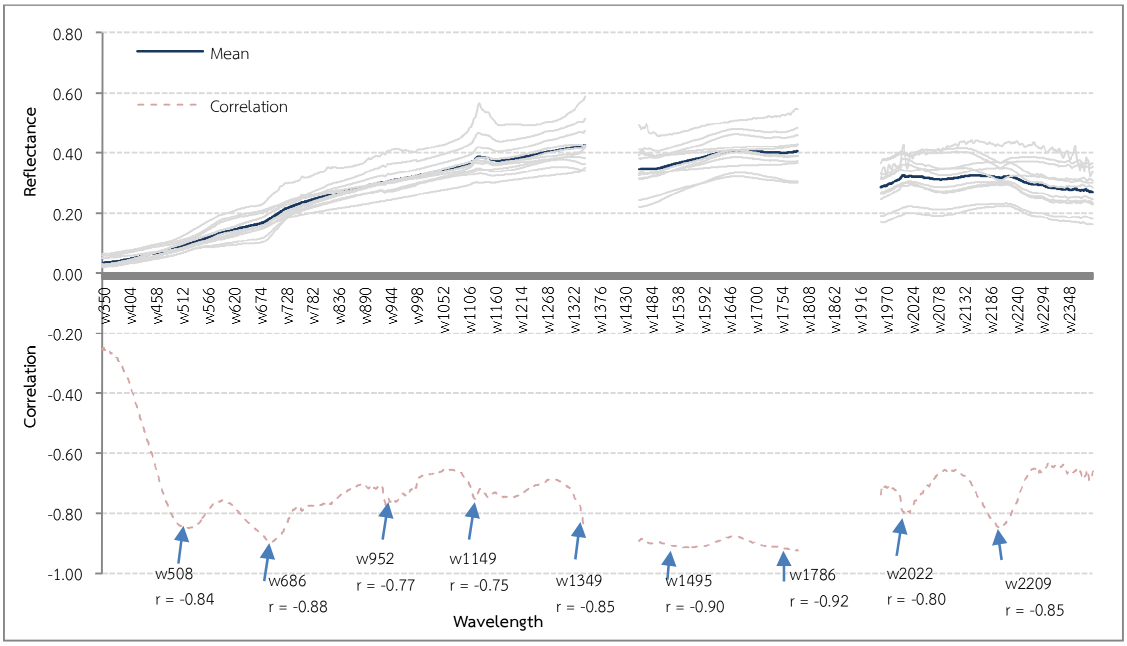


Fig. 3 Mean Soil Reflectance (upper) and Correlation
between SOCs and Soil Reflectance (lower)

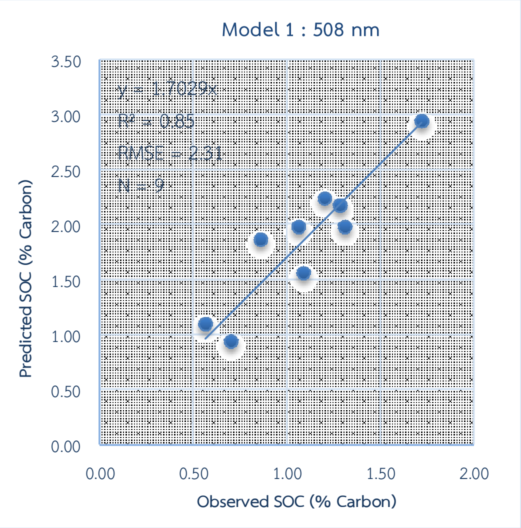
Statistical Modeling for SOC Estimates

Linear regression equations were analyzed between SOC and bare soil reflectance at 9 selected wavelengths which showed high peak correlations. All equations showed relatively high ($R^2 > 0.5$) coefficients (Table 3). Model 7 using reflectance wavelength at 1786 nm showed the highest coefficient. In Table 3, all equations were checked for agreement between predicted and observed SOC with other 9 sites. Model 1 and 3 at wavelength 508 nm and 952 nm showed the highest agreement (R^2 =0.85). Ingleby et al. (2000) used reflectance at wavelength 660 for studying on SOM. However, reflectance at wavelength 686 nm in this study showed lower agreement compared to reflectance at wavelength 508 nm and 952 nm.

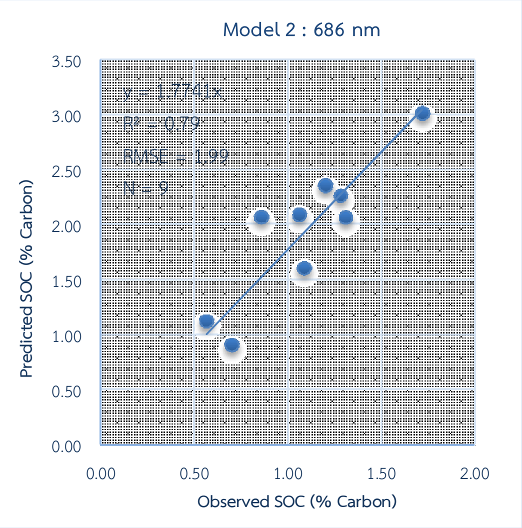
Table 3 simple linear regression equations for SOC estimate

Model	Equation	R^2
1	2.939 - (17.06 * w508)	0.70
2	3.01 - (8.953 * w686)	0.77
3	3.46 - (6.59 * w952)	0.60
4	3.46 - (4.77 * w1149)	0.56
5	3.37 - (4.54 * w1349)	0.73
6	3.395 - (5.496 * w1495)	0.80
7	3.491 - (5.017 * w1786)	0.85
8	2.843 - (4.119 * w2022)	0.63
9	3.273 - (5.643 * w2209)	0.72

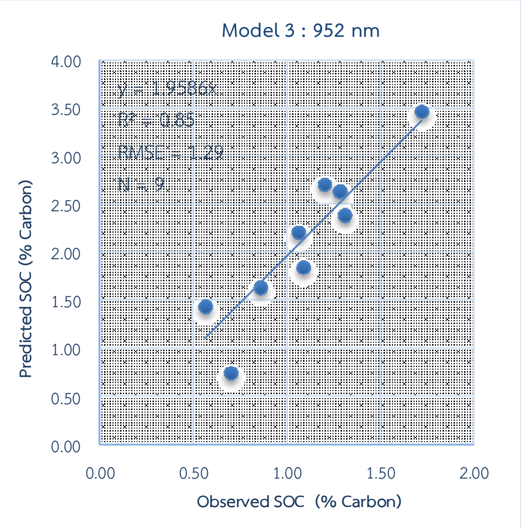
N = 9



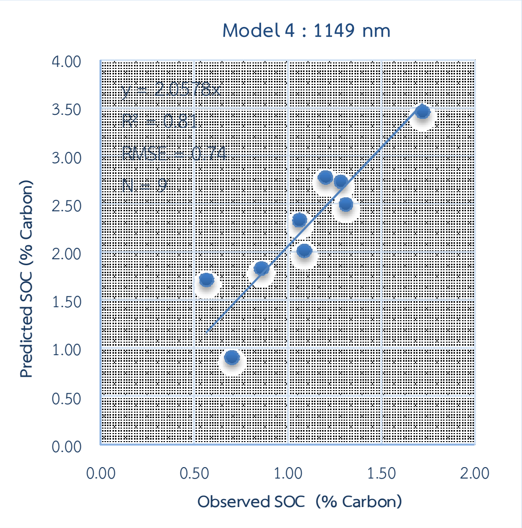
Model 1 : 508 nm



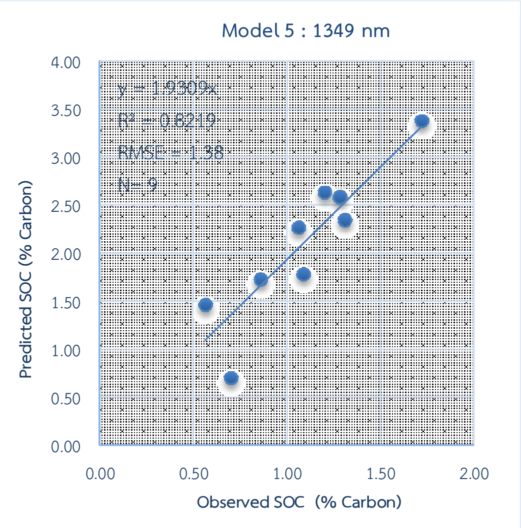
Model 2 : 686 nm



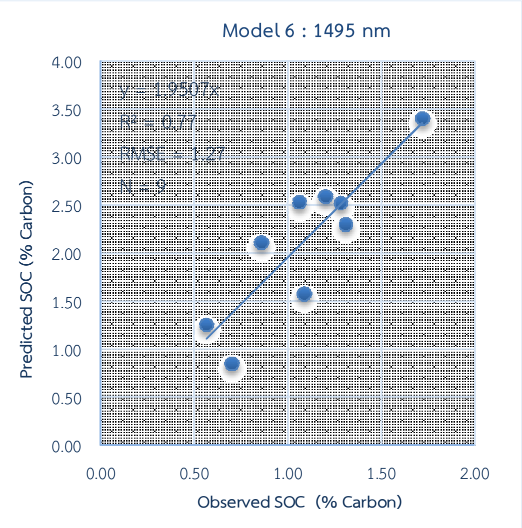
Model 3 : 952 nm



Model 4 : 1149 nm



Model 5 : 1349 nm



Model 6 : 1495 nm

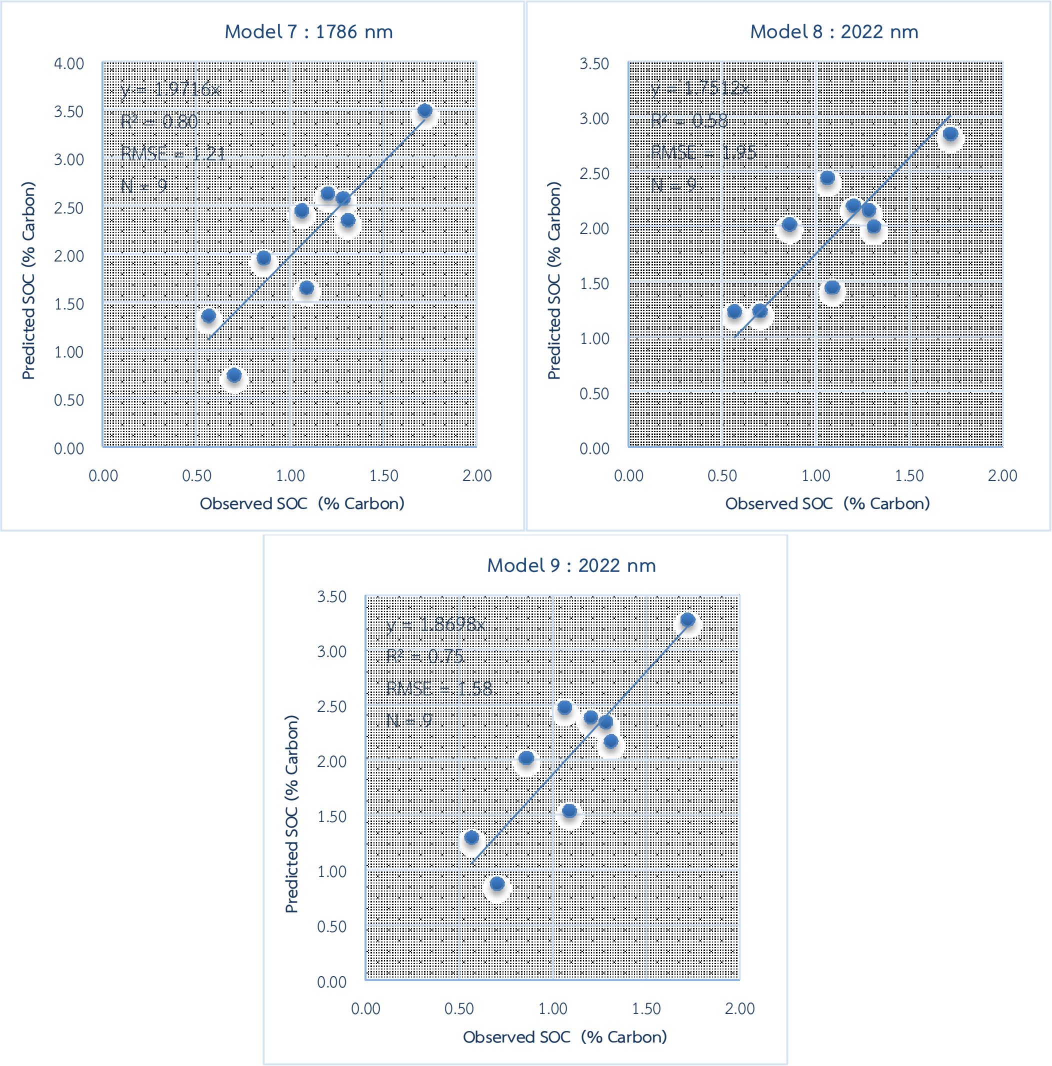


Fig. 4 Agreement Checking between Modeled SOC and Ground Observations

CONCLUSION

SOC in paddy soil was not different among three terrain types; lowland, upland, and highland while biomass was significantly different due to livestock activity. SOC and bare soil reflectance showed high correlation at nine wavelengths. In this study, nine wavelengths at 508 nm, 686 nm, 952 nm, 1149 nm, 1349 nm, 1495 nm, 1786 nm, 2022 nm, and 2209 nm were selected to estimate SOC. The results showed that wavelengths at 508 nm and 952 nm showed the best agreement with ground observations. However, this study was conducted only with clay soil in paddy field. Therefore, further consideration on remote sensing data can be conducted .

References

Daughtry, C.S.T., Hunt, E.R. and McMurtrey III, J.E.. 2004. Assessing Crop Residue Cover Using Shortwave Infrared Reflectance. Remote Sensing of Environment, 90 (1), pp. 47-56.

Shelton, P. D., and Jasa, j.j., 2009. G93-1133 Estimating Percent Residue Cover Using the Line-Transect Method. Historical Materials from University of Nebraska-Lincoln Extension, pp 783, USA.

Ting, H., Jing, W., Zongjian, L., and Ye, C., 2008. Study on spectral features of soil organic matter. The International archives of the photogrammetry, remote sensing ans spatial information science. Vol. XXXVII, Part B7, pp.261-268

Ingleby, H. R., and Crowe, T. G., 2000. Reflectance models for predicting organic carbon in Saskatchewan soils. Canadian Agricultural Engineering, 42(2), pp. 57-63

Jensen J.R., 2007. Introductory Digital Image Processing: A Remote Sensing Perspective. Prentice Hall, USA.

Merry R.H., and Janik L.J. (2001). Mid infrared spectroscopy for rapid and cheap analysis of soils. Australian agronomy conference 2001, Hobart, Tasmania.

Ollinger S. V., 2010. Sources of variability in canopy reflectance and the convergent properties of plants. New Phytologist, 189(2), pp. 375-394

Shibusawa, S., Li, M. Z., Sakai, K., Sasao., A., and Sato, H., 1999. Spectrophotometer for real–time underground soil sensing. ASAE Paper No. 99–3030. St. Joseph, Mich.

Soil Survey Division Staff, 1993. Soil survey Manual. USDA Handbook No.18. Issued October 1993

Thomasson, J. A., Sui, R., Cox M. S, AL-Rajehy A. 2001. Soil reflectance sensing for determining soil properties in precision agriculture. American society of agricultural engineers,44(6), pp. 1445–1453.

Viscarra–Rossel, R.A., and McBratney, A.B., 1998. Laboratory evaluation of a proximal sensing technique for simultaneous measurement of soil clay and water content. Geoderma, 85, pp.19–39.