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PENGANTAR REDAKSI

Dengan mengucapkan puji syukur kepada Allah yang Maha Kuasa, Jurnal Teknik Pertanian (J-TEP) Volume 8 No 3, bulan September 2019 dapat diterbitkan. Pada edisi kali ini dimuat 8 (delapan) artikel dimana salah satu artikel pada volume ini berbahasa Inggris yang merupakan karya tulis ilmiah dari berbagai bidang kajian dalam dunia Keteknikan Pertanian yang meliputi prototipe unit perontok jagung, variasi digester anaerobik, analisis performa fluida pada model ORC, karakterisasi pelet pupuk organik berbahan *slurry*, analisis perubahan penggunaan lahan di DAS Air Dingin, pengaruh ketinggian tempat dan metode pengeringan pada tanaman pegagan, *exploration of soil spectral reflectance*, dan potensi biogas dari rekayasa aklimatisasi.

Pada kesempatan kali ini kami menyampaikan ucapan terima kasih yang sebesar-besarnya kepada para penulis atas kontribusinya dalam Jurnal TEP dan kepada para reviewer/penelaah jurnal ini atas peran sertanya dalam meningkatkan mutu karya tulis ilmiah yang diterbitkan dalam edisi ini.

Akhir kata, semoga Jurnal TEP ini dapat bermanfaat bagi masyarakat dan memberikan konstribusi yang berarti bagi pengembangan ilmu pengetahuan dan teknologi, khususnya di bidang keteknikan pertanian.

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Halaman

PEDOMAN PENULISAN ARTIKEL BAGI PENULIS

1) **Naskah:** Redaksi menerima sumbangan naskah/tulisan ilmiah dalam bahasa Indonesia atau bahasa Inggris, dengan batasan sebagai berikut :

   a. Naskah diketik pada kertas ukuran A4 (210mm x 297mm) dengan 2 spasi dan ukuran huruf Times New Roman 12pt. Jarak tepi kiri, kanan, atas, dan bawah masing-masing 3 cm. Panjang naskah tidak melebihi 20 halaman termasuk abstrak, daftar pustaka, tabel dan gambar. **Semua tabel dan gambar ditempatkan terpisah pada bagian akhir naskah (tidak disisipkan dalam naskah)** dengan penomoran sesuai dengan yang tertera dalam naskah. Naskah disusun dengan urutan sebagai berikut: Judul; Nama Penulis disertai dengan catatan kaki tentang instansi tempat bekerja; Pendahuluan; Bahan dan Metode; Hasil dan Pembahasan; Kesimpulan dan Saran; Daftar Pustaka; serta Lampiran jika diperlukan. Template penulisan dapat didownload di ***http://jurnal.fp.unila.ac.id/index.php/JTP***

   b. **Abstrak (Abstract)** dalam bahasa Indonesia dan bahasa Inggris, tidak lebih dari 200 kata. Mengandung informasi yang tertuang dalam penulisan dan mudah untuk dipahami. Ringkasan (abstract) harus memuat secara singkat latar belakang, tujuan, metode, serta kesimpulan dan yang merupakan *high light* hasil penelitian.

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EXPLORATION OF SOIL SPECTRAL REFLECTANCE CHARACTERISTICS RELATING TO THE SOIL ORGANIC MATTER CONTENT

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ABSTRACT

The visible and near-infrared (Vis-NIR) diffuse reflectance spectroscopy has emerged as a rapid and low-cost tool for extensive investigation of soil properties. The objective of this research was to explore how significant the relationship between the soil spectral reflectance and soil organic matter (SOM) content was. There were 80 soil samples from soybean fields in Yogyakarta were taken for SOM content and spectroscopy measurements. The SOM was analyzed using Walkley and Black method, while the spectral reflectance was determined using ASD Field-spectrophotometer by scanning the sample with the Vis-NIR spectrum. The research showed that soil with less organic matter content performed higher reflectance. The soil reflectance and soil organic matter have strong negative relationships with Pearson's coefficient range from -0.56 to -0.67.

Keywords: Soil organic matter, Pearson's correlation coefficient, soil reflectance, Vis-NIR spectroscopy

I. INTRODUCTION

1.1. Soil Spectral Reflectance

All objects reflect, absorb, transmit, or radiate electromagnetic energy in the form of electromagnetic waves or radiation. Radiated or reflected energy can be characterized by its wavelength (NAS, 1977). Classification of electromagnetic waves is most often performed according to the location of the wavelengths in the electromagnetic spectrum. Figure 1 shows the spectrum of visible light and near-infrared region.

The variety of earth's surface materials is enormous. A typical spectral reflectance curve of the most common earth surface materials viz. soil, water, and vegetation is shown in Figure 2.

The soil reflectance properties depend on numerous soil properties. Field soil reflectance is reduced, particularly in the visible portion of the spectrum, when organic matter, iron oxides, or moisture content is high. The soil has an easily distinguishable characteristic reflectance pattern in the visible, near-infrared, and mid-infrared wavelengths (Hoffer, 1978).

A soil spectrum can be generated by directing the radiation containing all relevant frequencies in the particular range to the sample. The radiation will cause individual molecular bonds to vibrate, and they will absorb light, to various degrees, with a specific energy quantum corresponding to the difference between two energy levels. As the energy quantum is directly related to frequency, the resulting absorption spectrum produces a characteristic shape that can be used for analytical purposes (Miller, 2001).

Spectroscopy in the ultraviolet (UV, 250–400 nm), visible (VIS, 400–700 nm), and near-infrared (NIR, 700–2500 nm) ranges allows rapid acquisition of soil information at quantitative, and qualitative or indicator, levels for use in agriculture and environmental monitoring (Islam et al., 2003). The molecules containing strong bonds between relatively light atoms influence the reflectance in the NIR

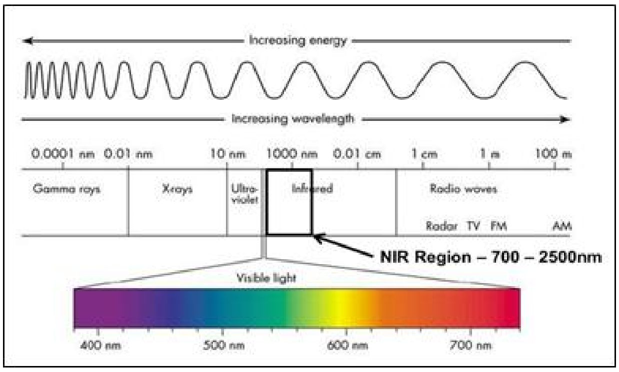

Figure 1. Electromagnetic Spectrum (Process sensors corp., 2018)

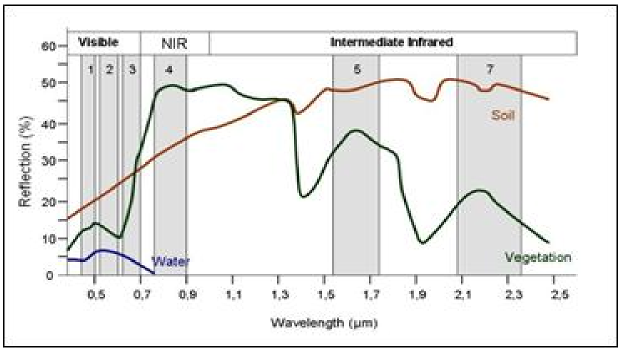

Figure 2. Typical Spectral Reflectance Curves of Common Earth Surface Materials in The Visible And Near to Mid-Infrared Range (Siegmund and Menz, 2005)

portion of the electromagnetic spectrum. These bonds tend to absorb energy at overtones and combinations of the mid-infrared fundamental vibration frequencies. The powerful absorbers in the NIR region are the C–H, N–H and O–H functional groups, making the NIR region ideal for quantifying forms of carbon, nitrogen, and water, respectively (Naes et al., 2002).

1.2. Proximal soil sensing

Soil properties are an essential factor to indicate the nutrient status in the field. Several soil properties have distinguishable reflectance patterns at a particular spectral wavelength. Ultraviolet, visible, or infrared measurement techniques offer soil measurements that are rapid, relatively inexpensive, safe, non-invasive and provide simultaneous measurements of multiple soil properties (Adamchuk, et al., 2012). A large number of proximal soil sensing systems are based on measuring the soil's ability to reflect energy in different parts of the electromagnetic spectrum. Proximal soil sensing is the use of field-based sensors to obtain signals from the soil when the sensor's detector is in contact with or close to (within 2 m) the soil (Viscara Rossel et al., 2011). The sensors provide soil information because the signals correspond to physical measures, which can be related to soils and their properties. The advantages of proximal sensing are that one can measure the soil with minimal preparation, no interferences such as in remote sensing systems (e.g. from the atmosphere, clouds or vegetation), and to depth (Viscara Rossel et al., 2016).

There are several soils attributes that often are well estimated with visible - near-infrared (Vis-NIR) spectroscopy. The most obvious ones are soil texture, especially clay content, mineralogy, the content of SOC or SOM and soil water. Several other soil attributes, such as pH, nutrients, elements, are often shown to be accurately predicted by some studies, but not by others. The explanation for this is the lack of direct relationships between the spectra and soil properties like pH, CEC, nutrients, etc. (Stenberg et al., 2010). Measurements can be viewed as direct, when relationships are based on a physical phenomenon that affects light reflectance in a specific part of the spectrum (e.g., predicting soil mineralogy or water content using water absorption bands), or indirect, when the relationships are deterministic for a finite domain and the combined effects of several soil attributes can be related to a given soil characteristic (e.g., predicting soil organic matter) (Adamchuk et al., 2015).

1.3. Soil Reflectance and Soil Property Relationships

Soil moisture and organic matter increase soil absorbency and result in overall lower soil reflectance. Water also reduces the reflectance at regions in the short-wave infrared, particularly around 900, 1400, 1900 and 2200 nm (Figure 3).

Hedley and Roudier (2010) conducted proximal soil spectroscopy research for soil Carbon estimation and mapping a semi-arid (S), allophonic (A) and oxidic (X) soils. Figure 4 shows that soils with higher organic matter content exhibit less reflectance.

Conforti et al., (2015) confirmed that soil Vis-NIR (350-2500 nm) reflectance spectra contain valuable information for predicting soil textural fractions. The mean of spectral curves for different soil texture classes is shown in Figure 5. Reflectance was relatively high for soils with loamy sand texture with over 70% sand content. This was probably due to the high amount of quartz in the sand fraction, which raised the intensity of spectral reflectance.

Lin et al. (2015), studied that soil reflectance generally decreases with increasing total N (TN) content (Figure 6). In the entire visible-near-infrared spectrum, three remarkable water absorption peaks were observed at 1400, 1905 and 2200 nm. Although the differences of spectral characteristics caused by TN are apparent, it is still extremely difficult to reveal the relationships between spectra and TN content directly, especially when a greater number of samples are considered. Organic nitrogen is a major constituent of SOM, therefore soil reflectance decreases possible correlation with SOM, which can affect estimation accuracy of TN prediction models obviously.

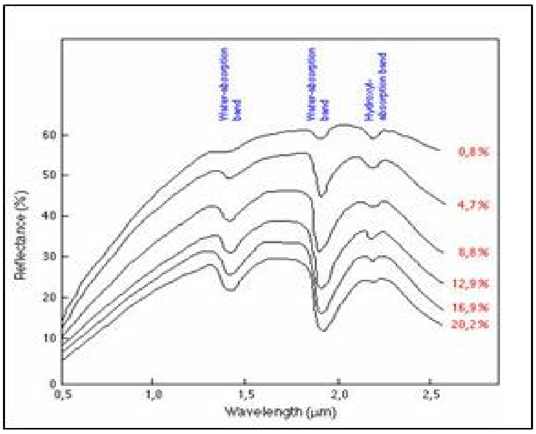

Figure 3. Variation in The Spectral Reflectance Characteristics of Soil According to Moisture Content (Bower and Hanks, 1965)

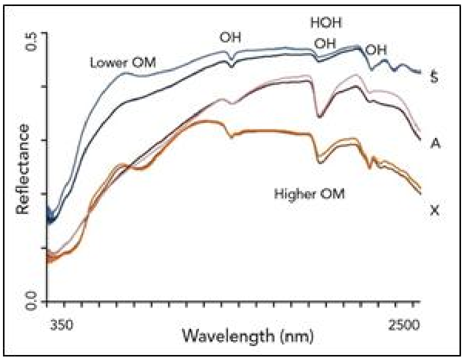

Figure 4. Soil Reflectance at Various Organic Matter (Hedley and Roudier, 2010)

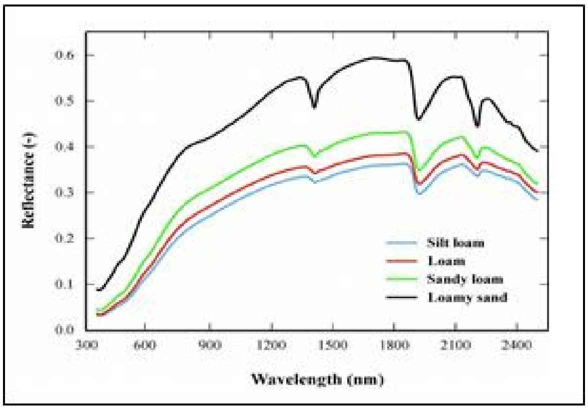

Figure 5. Mean Reflectance Spectra for Different Soil Texture Classes (Conforti et al., 2015)

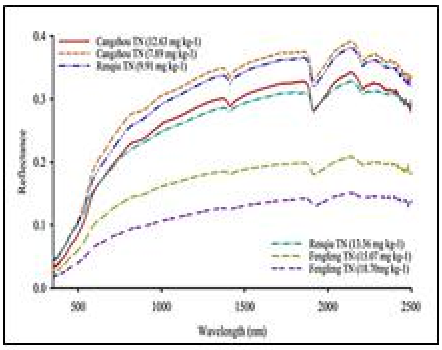

Figure 6. Reflectance Curve of Soil Samples with Different TN Contents (Lin et al., 2015)

1.4. Research Objectives

The capability of the soil to supply nutrient for plant growth is greatly influenced by the soil properties. Soil organic matter, for example, affects the soil structure and porosity, the water infiltration rate and moisture-holding capacity of soils, the diversity and biological activity of soil organisms, and plant nutrient availability. Various types of human activity decrease soil organic matter contents and biological activity. However, increasing the organic matter content of soils requires a sustained effort (Bot and Benites, 2005). Therefore, information on soil properties is important to support the agronomic decisions for farm management.

Soil sensing can facilitate the measurement and monitoring of the soil's physical and biochemical attributes to better understand their dynamics, their interaction with the environment while considering their large spatial heterogeneity (Viscara Rossel and Bouma, 2016). Recently, the visible and near-infrared (Vis-NIR) diffuse reflectance spectroscopy has emerged as a rapid and low-cost tool for extensive investigation of soil properties. The objective of this research was to explore the relationships between the character of soil spectral reflectance in the visible - near-infrared (Vis-NIR) regions with the soil organic matter content.

II. MATERIALS AND METHODS

The research was conducted at soybean farms in two locations, i.e. Natah Village, Nglipar District, Gunung Kidul Regency (7°51'39.0"S, 110°39'19.4"E) and Jatimulyo Village, Dlingo District, Bantul Regency (7°55'22.5"S, 110°29'08.7"E) in Yogyakarta Province. Each field was about 1,500 m.sq. area. The soils type at Nglipar was tentatively classified as *Hapludults* and *Dystrudepts*, while at Dlingo was *Hapludalfs, Eutrudepts,* and *Udorthents* (BBSDLP, 2016).

2.1. Materials

The soil was the main material to be observed in this research. There were 10 sample points for each field, and every point was sampled 4 times within one cropping season of soybean from October 2016 to January 2017, i.e. before planting, vegetative stage, generative stage and after harvesting. Each point was taken using auger at a depth of 5-15 cm about 500 grams and stored in a labeled zip-lock plastic bag. The total samples from 2 locations and 4 stages sampling were 80 samples for SOM analysis and spectroscopic measurements. All samples were air-dried, then gently crushed to break up larger aggregates, afterward removed the visible roots and each sample was sieved at 2 mm strainer.

2.2. Methods

The soil organic matter (OM) was analyzed by the Soil Analytical Services Laboratory at UPN "Veteran" Yogyakarta using Walkley and Black method, i.e. wet destruction using oxidizing agents through volumetric analysis. It utilized a specified volume of acidic dichromate solution reacting with a determined amount of soil in order to oxidize the OM. The oxidation step was then followed by titration of the excess dichromate solution with ferrous sulfate. The OM was calculated using the difference between the total volume of dichromate added and the volume titrated after reaction (Afany, 2015).

The spectroscopy measurement was performed at the University of Palangka Raya, Central Kalimantan, using ASD Field-spec®3 350-2500 nm (Analytical Spectral Devices Inc., Boulder, Colorado, USA). Some additional tools to ease the measurement process were used, such as ring samples (*Eijkelkamp*) with 5 cm height and 5 cm diameter, a black aluminum ring plate to hold up the ASD probe vertically, and white reference panel for spectrometer calibration. Figure 7 shows the ASD instrument and soils sample in spectral measurement.

Each soil sample was placed into the ring sampler and the surface was leveled using a lab spatula. The reflectance of each sample was scanned 10 times with different positions by moving the ring sample circularly, and the results were averaged in post-processing. The reflectance value of each wavelength band was recorded in the computer and translated from binary to ASCII using *ViewSpecPro* (2008).

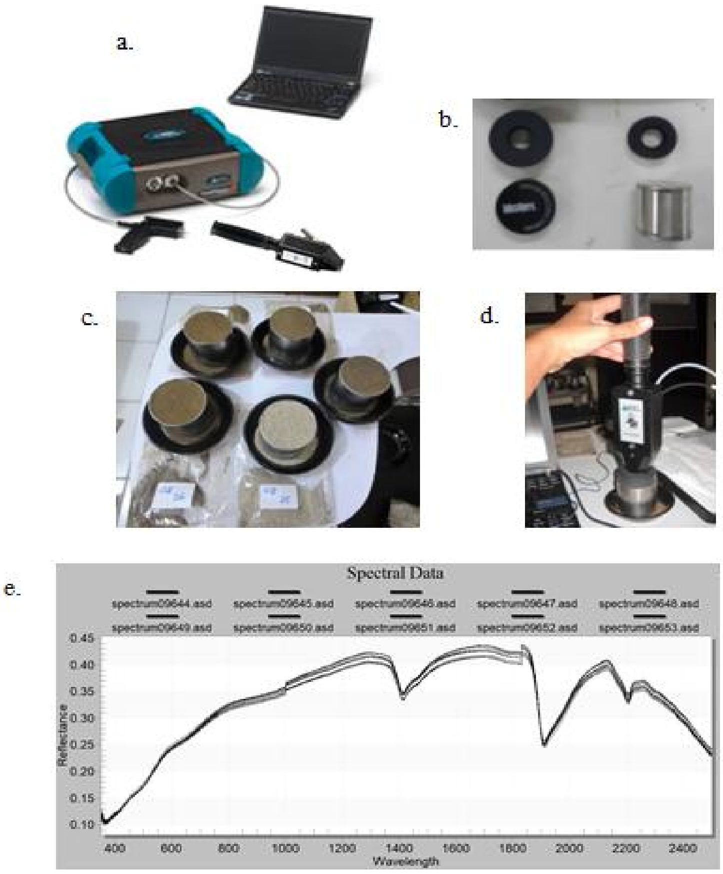

Figure 7. a) ASD Field Spectrophotometer; b)Black Aluminum Ring Plate Modified by TUAT Lab; c) Soil in The Ring Sampler; d) The ASD Probe Scanning The Soil Sample; e) an Example of 10 Times Reflectance Measurements from a Soil Sample

The data of SOM content and soil reflectances were compiled in MS Excel worksheets and named into 8 sampling groups: BI, BII, BIII, BIV, GI, GII, GIII, and GIV. Each group was the result of SOM average values, and soil reflectance average values of 9 different wavelength bands within Vis-NIR regions.

The Pearson product-moment method was used to measure the strength of the relationship between the SOM and the spectral reflectance of the soil value by determining the correlation coefficient (r), a dimensionless index that reflects the extent of a linear relationship between two data sets. The formula of Pearson's correlation coefficient (r) is:

$$r\,xy = \frac{N\sum xy - (\sum x)(\sum y)}{\sqrt{(N\sum x^2 - (\sum x)^2 (N\sum y^2 - (\sum y)^2}}$$

Where, N is number of pairs of scores, Σxy is sum of the products of paired scores, Σx is sum of x scores, Σy is sum of y scores, Σx^2 is sum of squared x scores, and Σy^2 is sum of squared y scores.

The Pearson correlation coefficient, *r*, can take a range of values from +1 to -1. A value of 0 indicates that there is no association between the two variables. A value greater than 0 indicates a *positive association*; that is, as the value of one variable increases, so does the value of the other variable. A value less than 0 indicates a *negative association*; that is, as the value of one variable increases, the value of the other variable decreases. The interpretation of the strength of the relationship used the value of the correlation coefficient as shown in Table 1.

III. RESULTS AND DISCUSSION

3.1. The Temporal Distribution of Soil Organic Matter

All of 80 soil samples from Nglipar and Dlingo were classified as *clay* with very low organic matter content (< 2%), and neutral pH. The SOM at Dlingo had a wider range (0.7-1.8%) rather than Nglipar (0.6-1.3%), with the average SOM at Dlingo (1.31%) was higher than at Nglipar (0.96%). Table 2 shows the average SOM content on four different growth stages of soybean at Dlingo and Nglipar fields.

3.2. The Soil Spectral Reflectance Characteristics

Soil reflectance can be influenced by a number of factors, such as soil texture, surface roughness, organic matter content, color and moisture content (Yin *et al*., 2013). The color of the soil is usually closely related to its organic matter content, with darker soils being higher in organic matter, which indicates the relationship between soil organic matter content and its visible light reflectance (Ting et al., 2009). Fig. 8 and 9 describe the soils reflectance of Nglipar and Dlingo at four stages of soybean growth. The soil reflectance curves before planting were tight and low, then spread higher for the next stages. At Nglipar field the soil reflectances showed more heterogeneous than Dlingo field. Field inspection showed that some soil samples at Nglipar, especially at G25, had whitish spots color and shallow topsoil, while Dlingo had darker homogeneous soil color. The effect of whitish color was strong to increase the reflectance. While darker soil might be affected by the combination of higher SOM and soil moisture values that made the reflectance value before planting lower.

Table 1. Level of Coefficient Correlation Value (Sarwono, 2006)

Coefficient interval (+/-)	Level of correlation
0	no correlation
0.00 ~ 0.25	very weak
0.25 ~ 0.50	moderate
0.50 ~ 0.75	strong
0.75 ~ 0.99	very strong
1	perfect correlation

Table 2. The Average Value of Soil Organic Matter

NGLIPAR FIELD, GUNUNG KIDUL							
Before planting		**Vegetative stage**		**Generative stage**		**After harvest**	
Sample	**SOM (%)**	**Sample**	**SOM (%)**	**Sample**	**SOM (%)**	**Sample**	**SOM (%)**
GI 02	1.16	GII 02	1.08	GIII 02	0.96	GIV 02	1.06
GI 05	1.15	GII 05	1.06	GIII 05	1.15	GIV 05	1.25
GI 08	1.06	GII 08	0.97	GIII 08	1.25	GIV 08	1.25
GI 11	0.87	GII 11	0.97	GIII 11	0.86	GIV 11	0.96
GI 17	1.06	GII 17	1.05	GIII 17	0.67	GIV 17	1.14
GI 20	0.77	GII 20	1.15	GIII 20	0.94	GIV 20	1.06
GI 25	0.98	GII 25	0.75	GIII 25	0.76	GIV 25	0.75
GI 27	0.97	GII 27	0.87	GIII 27	0.55	GIV 27	1.36
GI 29	1.06	GII 29	0.97	GIII 29	0.67	GIV 29	1.05
GI 31	0.97	GII 31	0.77	GIII 31	0.76	GIV 31	0.96
Averg.	1.01	Averg.	0.96	Averg.	0.86	Averg.	1.08
DLINGO FIELD, BANTUL							
Before plant		**Vegetative stage**		**Generative stage**		**After harvest**	
Sample	**SOM (%)**	**Sample**	**SOM (%)**	**Sample**	**SOM (%)**	**Sample**	**SOM (%)**
BI 02	1.97	BII 02	1.26	BIII 02	1.07	BIV 02	0.87
BI 05	0.98	BII 05	1.36	BIII 05	1.15	BIV 05	1.06
BI 08	1.88	BII 08	1.36	BIII 08	1.34	BIV 08	0.97
BI 11	1.08	BII 11	0.88	BIII 11	0.96	BIV 11	0.77
BI 14	1.05	BII 14	1.26	BIII 14	1.14	BIV 14	1.06
BI 17	0.96	BII 17	1.16	BIII 17	1.23	BIV 17	1.06
BI 20	0.88	BII 20	0.87	BIII 20	0.86	BIV 20	1.15
BI 23	0.87	BII 23	1.15	BIII 23	1.13	BIV 23	1.05
BI 26	1.06	BII 26	0.97	BIII26	1.14	BIV 26	1.06
BI 29	0.80	BII 29	0.97	BIII 29	1.05	BIV 29	0.96
Averg.	1.15	Averg.	1.12	Averg.	1.11	Averg.	1.00

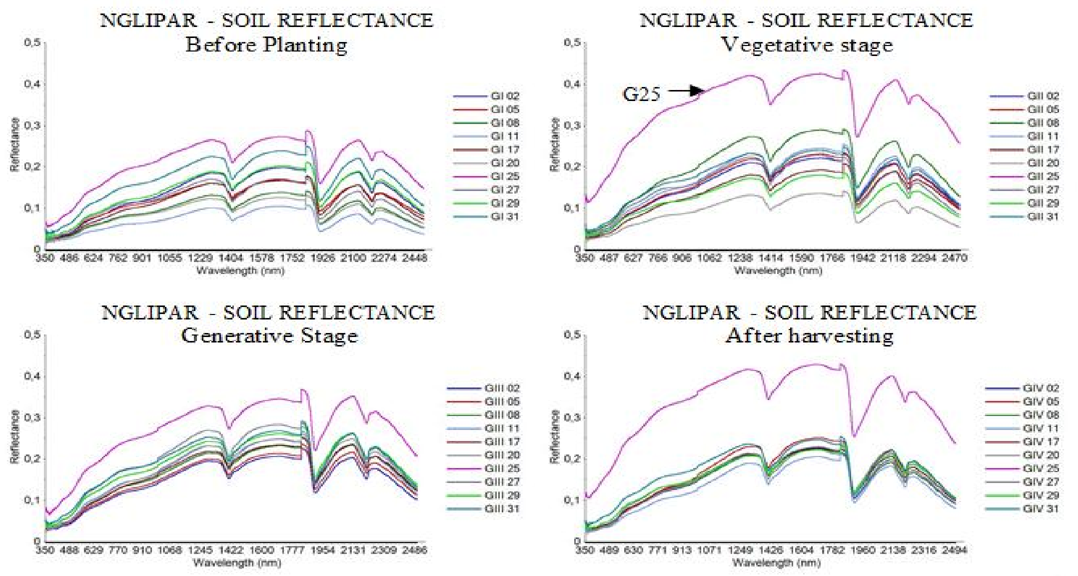

Figure 8. The Soil Reflectance of Nglipar Soybean Field at Four Stages

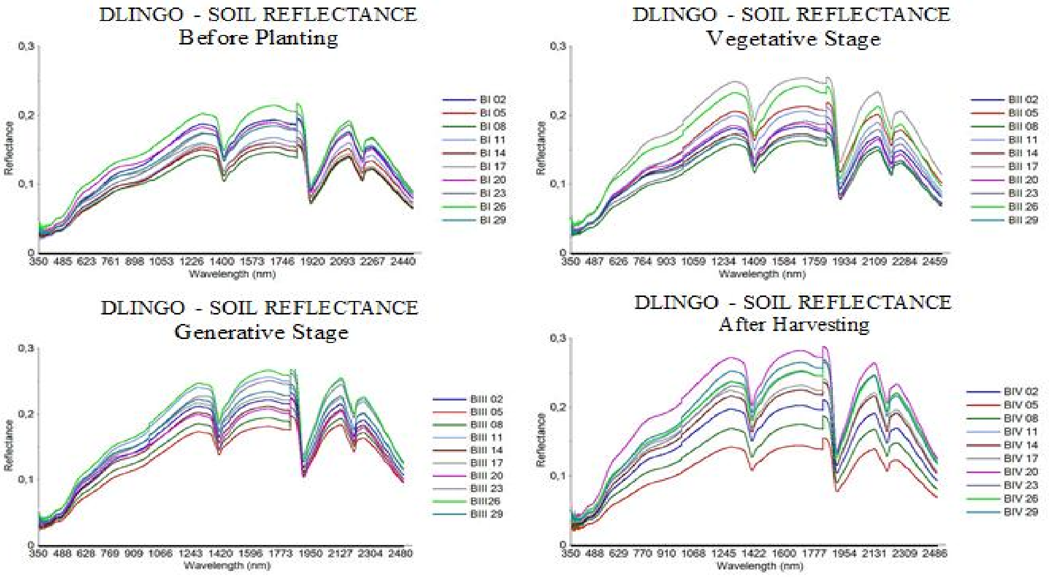

Figure 9. The Soil Reflectance of Dlingo Soybean Field at Four Stages

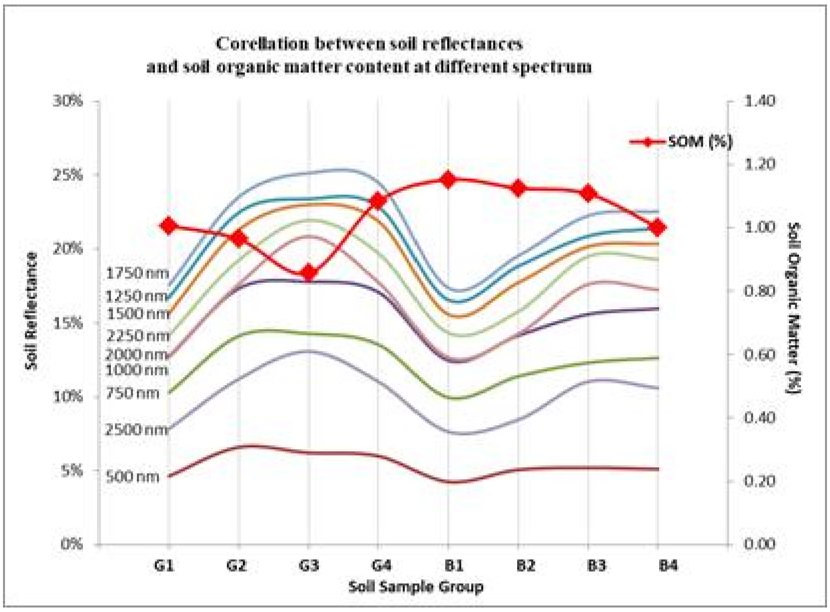

Figure 10. The Curves of Reflectance Value of Particular Wavelength Bands
in The Vis-NIR Region and Soil Organic Matter Content at Different Location and Time

In order to explore the character of soil spectral reflectance relating to the soil organic matter content, the reflectance value from several wavelength bands within Vis-NIR regions were picked for statistical observation. The correlation plot is displayed in Figure 10.

It is figured from the pattern of the correlation curves that the fluctuating value of soil reflectance is following the fluctuating value of soil organic matter inversely.

3.3. Statistical descriptions

The statistical analysis for determining the Pearson's correlation coefficient (r) was performed in MSExcel. Table 3 shows the compilation results of average values of SOM and spectral reflectance for particular wavelengths, as well as their correlation level.

The interpretation from the value of Pearson's coefficient is that soil reflectance and soil organic matter have *negative associations* with *strong*

Table 3. The Statistic Description and Correlation Level Between Soil Reflectances at Different Wavelength Bands with Soil Organic Matter Content

Sample Group	Averg. SOM (%)	Average Soil Reflectance at Different Wavelength Bands								
		500 nm	750 nm	1000 nm	1250 nm	1500 nm	1750 nm	2000 nm	2250 nm	2500 nm
G1	1.01	0.05	0.10	0.13	0.17	0.16	0.18	0.13	0.14	0.08
G2	0.96	0.07	0.14	0.17	0.22	0.21	0.24	0.18	0.19	0.11
G3	0.86	0.06	0.14	0.18	0.23	0.23	0.25	0.21	0.22	0.13
G4	1.08	0.06	0.14	0.17	0.23	0.22	0.24	0.18	0.20	0.11
B1	1.15	0.04	0.10	0.12	0.17	0.16	0.17	0.13	0.14	0.08
B2	1.12	0.05	0.11	0.14	0.19	0.18	0.20	0.14	0.16	0.08
B3	1.11	0.05	0.12	0.16	0.21	0.20	0.22	0.18	0.19	0.11
B4	1.00	0.05	0.13	0.16	0.21	0.20	0.23	0.17	0.19	0.11
Mean	1.037	0.054	0.123	0.154	0.204	0.194	0.215	0.163	0.180	0.101
Std. Err.	0.035	0.003	0.006	0.007	0.010	0.010	0.011	0.010	0.010	0.007
Median	1.045	0.052	0.125	0.158	0.211	0.202	0.224	0.174	0.193	0.108
St. Dev.	0.099	0.008	0.017	0.021	0.027	0.028	0.030	0.028	0.028	0.019
Var.	0.010	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.000
Min.	0.856	0.043	0.100	0.125	0.165	0.156	0.173	0.127	0.142	0.076
Max.	1.152	0.066	0.143	0.178	0.234	0.230	0.251	0.208	0.219	0.131
r Pearson		-0.63	-0.64	-0.60	-0.56	-0.58	-0.56	-0.65	-0.59	-0.67
Correlation level		strong	strong	strong	strong	strong	strong	strong	strong	strong

relationships. It means as the SOM gets smaller, the soil spectral reflectance increase with the strongest correlation at a wavelength of 2500 nm, then followed by 2000 nm and 750 nm. Ting et al. (2009) had observed that in the range of wavelength, spectral reflectance is *negatively correlated* with SOM content, and the highest correlation is near 675 nm.

IV. CONCLUSIONS

Correlation is only the early sign that the soil organic matter content variable might affect the soil reflectance. In this research, the soil with less organic matter content performed higher soil reflectance. Soil reflectance and soil organic matter have strong negative relationships with Pearson's coefficient range from -0.56 to -0.67.

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