Use Of Spectral Reflectance For Sensitive Waveband Determination For Soil Organic Matter

Mrs. Chitra. M. Gaikwad, Prof. Dr. S. N. Kakarwal, Mrs. A. N. Ghule, Prof. Dr. R. R. Deshmukh, Dr. D. V. Kurmude

Abstract: Soil plays an important role in producing healthy crops. The chemical analysis method for recognising the soil contents for good yield is time consuming and complex. An alternative method using VNIR spectral reflectance of soil can make the task easier. In the present study samples of soil were taken from the state of Maharashtra, India. The ASD field spec 4 spectroradiometer is used to record the spectra of soils. Nine different transformations were performed on spectral reflectance for noise removal. The predictions carried out using correlation show that the first derivative of reflectance, logarithm of reflectance and reciprocal of logarithm of reflectance predicts sensitive wavelengths for SOM. The multiple linear regression models reached the coefficient of determination to 0.92. The optimal wavelengths for SOM were found using analysis of variance technique (ANOVA).

Index Terms: ASD Field spec4 spectroradiometer, Reflectance, Correlation, ANOVA, Multiple Linear Regression,

1. INTRODUCTION

Along with minerals, organic matter is the important resource from soil for plant growth. Fertile soil consists of organic matter which in turn helps in good yield [1]. To predict the yield farmers can test soil in laboratories using the chemical assessment methods. These methods are complex time consuming and expensive [2]. To extract this information in an easy, non-destructive and economical way is to use the soil spectral signatures. Remote sensing using reflectance spectroscopy does not harm the nutrients in the soil [3]. Also, we can measure the various soil contents present in the soil sample [4-5]. The spectral signatures obtained using spectroscopy is spread over a wide range of wavelengths from visible region 350 nm – 700 nm and infra-red region 700 nm – 2500 nm. The reflectance values obtained from the laboratory spectrometer is used for predicting the correlation between spectral reflectance and actual values of contents present in soil obtained from chemical analysis [6-8]. Soil organic matter (SOM) is an essential nutrient amongst other nutrients for suitable vegetation growth. The soil which consists of organic matter is dark in colour. Due to which the correlation between SOM content and reflectance is strong [9]. Different soil nutrients are spread in the VIS region, IR region and SWIR region of electromagnetic spectrum. Studies show that the electromagnetic spectrum the visible (VIS (400-700 nm)) range gives the information about colour of soil, bands near 500-700 nm represent iron oxides, oxy hydroxides, hydroxides, narrow bands near 1400-1900 nm are for hydroxyl and water molecules. Clay minerals, organic constituents, carbonates, salt minerals are found beyond 2000 nm wavelength [10]. Soil organic matter in soil is the main source of nutrients to plants and vegetation. In the global C cycle soil has a huge amount of carbon [11]. The objective of this work is to determine relation between soil reflectance values with organic matter (SOM) and to predict the sensitive wavebands in VIS and NIR region for soil organic matter. The work is carried out on soil samples from different locations of Maharashtra, India.

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2 DATA PREPARATION

The samples of soil were obtained from various locations in the Maharashtra state of India. 8 topsoil samples were collected. The soil types are yellow-brown, brown-red, and paddy. The soil samples were dried in air and sieved with the mesh having size 2mm. The reflectance was measured in the dark laboratory using ASD Field Spec 4 spectroradiometer. The wavelength covered by ASD Field Spec Pro Analytical Spectral device ranges from 350 nm-2500 nm. Before obtaining the spectral reflectance of soil the spectroradiometer was calibrated and optimized using the white Spectralon panel to get absolute reflectance values. The fiber optic probe was kept at a 10 degree angle in a dark laboratory. A Petri dish having a thickness of 2cm and diameter of 20cm was utilized as a container to hold soil in the laboratory. Each soil sample was rescanned 20 times. Then the mean of the 20 scans was calculated. Using the RS3 software soil spectra in ASD format was read. The values of reflectance were obtained and then they were exported to spreadsheet software using Viewspec pro software.

3 SOIL ORGANIC MATTER CONTENT

The biological decomposition of residues, roots and litter in soil is the soil organic matter. Soil chemical properties were determined using the standard laboratory methods. The SOM values of soil organic matter were used to find the correlation with the spectral reflectance. The water absorption wavelength bands from 1350 nm -1416 nm, 1796 nm – 1970 nm, and 2470 nm – 2500 nm were removed by studying various conclusions from literature. To find the wavelength sensitive to organic matter the following steps are performed:

1. Nine various transforms were performed on reflectance values.
2. The correlation of actual values of SOM with reflectance and its transforms were measured.
3. The wavelengths with highest coefficients correlation were selected.
4. Multiple linear regression is used to find the prominent wavelengths for soil organic matter.
5. On these set of wavelengths analysis of variance was performed to find the amount of SOM predicted by these wavelengths.

4 ANALYTICAL TECHNIQUES

Soil reflectance was analysed, and 9 different transforms of soil reflectance were found for finding sensitive wavelengths to organic matter (SOM) content. Analysis was carried out to find the relationship of SOM content to soil spectral properties as Table 1shows.

These 9 transformations are carried out on reflectance to remove noise. The first derivative technique removes the linear noise, log (R) remove the multiplication noise due to change in illumination. Transformations on reflectance help in building linear relationship between SOM and reflectance. Log transformations improve differences in visible light caused by changes in illumination [9].

5 CORRELATION

The correlation analysis between 8 soil samples' reflectance and the SOM contents was carried out with the following formula:

Correlation - Correlation is a technique used for finding the relation between two variables.

$$corr = \frac{\sum_{i=1}^{N}(r_i - r_i')(s_i - s')}{\sqrt{\sum_{i=1}^{N}(r_i - r'_i)^2 \sum_{i=1}^{N}(s_i - s')^2}} \quad (1)$$

In equation the variables are:

1. r is reflectance for respective waveband and r' mean
2. s is the organic matter content for corresponding soil sample and s' is its mean
3. N is the sample size [12]

Soil properties are linearly correlated with the soil contents' chemical properties [13].

TABLE 1. TRANSFORMATIONS ON REFLECTANCE

Sr.No.	Transform	Formula
1	Reflectance first derivative	R'
2	Reflectance second derivative	R"
3	Reciprocal R	1/R
4	Square root of R	sqrt (R)
5	Logarithm R	log R
6	Logarithm of reflectance first derivative	log(R)'
7	Logarithm of reflectance second derivative	log(R)"
8	Logarithm of reflectance reciprocal	1/log R
9	Reciprocal of logarithm of reflectance first derivative	(1/log R)'

6 RESULTS

6.1 Correlation Analysis

The 8 soil samples were taken from Bhivandi, Kasara, Chikalthana, Igatpuri, Naregaon, Kumbhephal, Shendra, University area located in the state of Maharashtra. The soil organic matter was found out by the chemical analysis of soil for the 8 samples. The correlation between spectral reflectance and SOM values was calculated using Equation 1. Table 2 gives statistical values obtained by performing the chemical analysis of soil to find the organic matter.

The spectral reflectance of soil was recorded for wavelength ranging from 350 nm to 2500 nm. Fig 1 shows the signature spectra of 8 soil samples.

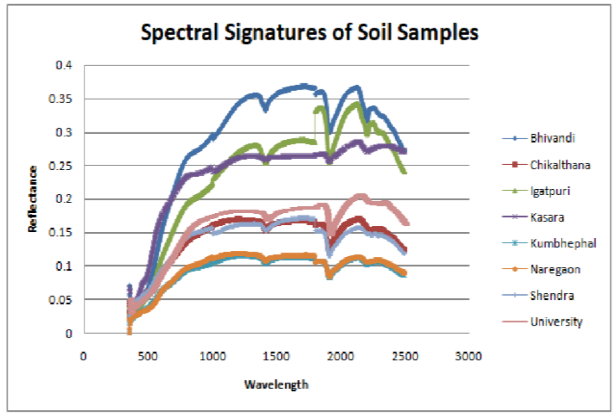

Fig.1. *Spectral signatures of 8 samples*

SOM Content	2.94	6.96	3.96

The maximum value for correlation coefficient between reflectance and organic matter content after removal of water bands was obtained to be 0.7. Table 3 shows the range of wavelengths for which the correlation coefficients values are having higher values for each of the transformations on reflectance for respective wavelengths.

TABLE 3

CORRELATION COEFFICIENTS AND WAVELENGTHS FOR VARIOUS TRANSFORMS OF REFLECTANCE

Sr. No.	Transform	Formula	Corr Coeff	Wave length nm
1	Reflectance first derivative	R’	0.98	2004
2	Reflectance second derivative	R”	0.78	1795
3	Reciprocal R	1/R	0.19	387
4	Square root of R	Sqrt (R)	0.66	2089
5	Logarithm R	log R	0.23	387
6	Logarithm of reflectance first derivative	log(R)’	0.91	2149
7	Logarithm of reflectance second derivative	log(R)”	0.77	425
8	Logarithm of reflectance reciprocal	1/log(R)	0.71	2098
9	Reciprocal of logarithm of reflectance first derivative	(1/log(R))’	0.98	1232
10	Reflectance	R	0.7	2101

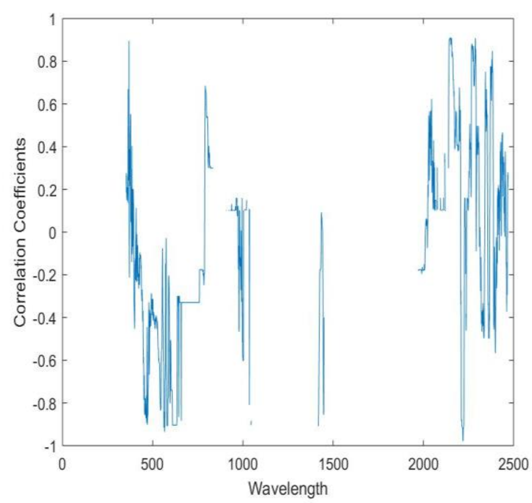

Fig.2. *Wavelength vs Correlation Coefficients for first order derivative of Log(R)*

Fig. 2 shows the graph of Wavelength versus Correlation Coefficients for log(R) first derivative. Results of correlation analysis shows that reflectance first order derivative of log(R) first order derivative, 1/log(R) first order derivative give maximum correlation coefficient.

6.2 Multiple Regression Analysis

Multiple linear regression (MLR) models linearly describe the dependency between the variable y (response) and predictor variables x (more than two).A MLR model with m predictor variables x1, x2, ... , xm and a response y , is given as

$$y = b0 + b1x1 + b2x2 + \cdots bm\ xm + € \quad (3)$$

where,

€ - residual term

b0,b1,b2,…..,bm – regression coefficients

To determine the optimal wavelength for soil organic matter the response variable is actual SOM and the spectral reflectance. According to the results of correlation analysis shown in Table 3 different wavelengths with maximum correlation coefficients in each transformation are obtained. The wavebands obtained for highest correlation coefficient for respective transform were selected for multiple regression analysis. The optimal MLR model with maximum coefficient of determination (R2) consists of five samples randomly selected to set up the predictive model. The results give multiple equations containing different wavelength combinations with respective their R2. The maximum coefficient of determination for five wavebands is 0.92.

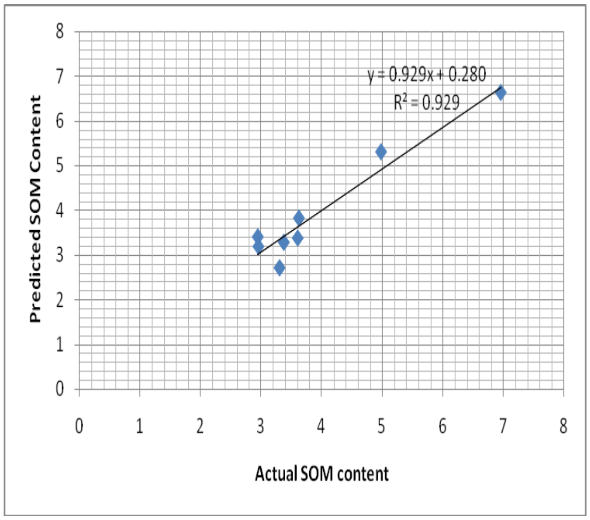

Fig.3. *Actual SOM content Vs Predicted SOM content*

6.3 Analysis of Variance

Analysis of variance (ANOVA) contain statistical models and their corresponding assessment measures to find variation with among and between groups. This analyzes the variation among variable means in a sample. The P value is compared with the significance level to estimate the null hypothesis. The one-way analysis of variance finds the variance between the mean values of more than 3 independent variables. The value of alpha to be 0.05 means there is 5% risk of difference in variables though there is no difference. The following inferences are drawn using P values:

P value <= alpha – as per statistics variation between the mean values is significant and refuse the null hypothesis

P value > As per statistics variation between the mean values is not significant and do not refuse the null hypothesis

A one-way ANOVA analysis was carried out for all the extracted wavelengths (variables) from 9 transforms. From these spectral variables a subset of spectral wavelengths was selected with the significance level alpha set to 0.05. The value of alpha to be 0.05 means there is 5% risk of difference in variables though there is no difference.

In table 4, the P value is 0.93 which is greater than alpha 0.05 so we can say that the difference among the means of wavelengths exists. Therefore we can say that different wavelengths can predict different amount of SOM content in soil.

7 CONCLUSION

In this study, the correlation among soil reflectance and actual soil organic matter was estimated. The 9 different transforms predicted 9 different wavelengths with maximum correlation. The multiple regression analysis models predicted the coefficient of determination to be .92 for the wavelengths 387 nm, 425 nm, 1232 nm, 1795 nm and 2004 nm. The analysis of variance showed that the wavelengths 1232 nm, 2004 nm, 2149 nm were having different means. That is the SOM content predicted at different wavelengths is not equal. In future refined techniques will be used to extract the soil nutrients from soil.

TABLE 3. ANALYSIS OF VARIANCE BETWEEN WAVELENGTHS

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.001	2	0.00057	0.067	0.93	3.46
Within Groups	0.177	21	0.0084			
Total	0.178	23				

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