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Estimation of Soil Organic Carbon Content using Visible Near Infrared Reflectance Spectroscopy: A Review

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Abstract: Nowadays, the world is highly dependent on the food production. As a result, food production highly depends on the soil quality. So, knowledge about soil quality along with its components should be known. Organic carbon is an important component in soil as it plays an essential role in important functions. Soil Organic Carbon (SOC) has impact over different physical, compound and organic procedures. It also effects considerably on the interaction between soil and plants. The Visible and Near Infrared (Vis-NIR) reflectance spectroscopy with spectral resolution of 350–2500 nm procedure has been considered as a strategy with fast and minimal effort to determine SOC content. Partial Least Square Regression (PLSR) quantitatively derives information which is an important method from reflectance spectral data. PLSR is the mostly used statistical method for determining SOC contents obtained from the spectral data. This research is based on the estimation of soil organic carbon content using Visible Near Infrared Scpectroscopy.

Keywords:Partial Least Square Regression, Soil Organic Carbon, Spectral Data, Vis-NIR.

1. INTRODUCTION

Human dependency on the soil has now reached to such an extent to, the ecosystem services, such as fiber and food production are at high risk. Soil Organic Carbon (SOC) has impact over different physical, compound and organic procedures. Soil Organic Carbon tends to be found in the topsoil. Organic C ranges from 0.5% to 3.0% in topsoil for most upland soils. Soil containing organic carbon greater than 12 - 18% is mostly classified as organic soil [1]. About 58% of organic matter consists of organic carbon. Thus, we can estimate the amount of organic matter using the total organic carbon content using the following conversion factor:

Organic matter content (%) = Total organic carbon content (%) x 1.72

Spectral reflectance gives substitute to soil elements' analysis due to its better and accurate level. The spectral data lying between the Visible (400-700nm) and Near-Infrared (700-2500 nm) ranges allows faster soil information acquisition. Visible and Near-Infrared diffuse reflectance spectroscopy (Vis–NIR) has been an effective alternative to traditional and conventional laboratory chemical analysis, Vis–NIR spectroscopy is an analytical method based on the multivariate statistical models, such as Principal Components Regression (PCR), Partial Least Square Regression (PLSR), and various data mining techniques, such as Regression Trees and Artificial Neural Network. Among these methods, PLSR is the commonly used method to determine SOC contents from spectroscopic data. The aim of this present study is based on working of reflectance spectroscopy in the VNIR range to estimate the content of soil organic carbon.

2. RELATED WORK

Spectroscopy in the Visible (400-700nm) and Near-Infrared (700-2500 nm) range allows faster access of soil information based on quantitative and qualitative basis on the soil properties[2].

In Shenglu Zhou research, the Partial Least Square Regression (PLSR) was been to estimate the reflectance spectroscopy probability to predict the Soil Organic Carbon content in the soil samples within the Vis–NIR range. They compared PLSR technique with OPLSR [3].

Antoine Stevens et al. indicated that Soil Organic Carbon (SOC) content was used in determination of fluxing in greenhouse gas emission. Visible and Near Infrared Spectroscopy has become an alternative to the process of chemical analysis [4].

M.E. Schaepman et al. done spectral measurements for soil samples were done for testing the several spectral indices. Total 9 varieties of soil types with 40 no. of samples were used by obtaining from different climatic zones and also a large variety of SOC contents [5].

Stevens et al. shown that spatial variability and slow temporal change in SOC stocks at various scales reduce our capacity to detect changes within a short time span. Their measurements showed that there are possibilities to reach an extent of accuracies which are compared with standard analytical method [6].

In Tiejun Zhao et al., Kenshi Sakai et al. research, for assessing the SOC content, spectrograph V10 and N17E were employed at indoor condition, and after that the given model property was applied to different spectrographs accordingly [7].

In Tiezhu Shi et al., Yiyun Chen et al. research; SPA and GA techniques were compared in spectral feature selection to estimate SOC contents using Vis-NIR reflectance spectroscopy in the Yixing and Honghu regions of China [8].

REN Hong-Yan et al. studied on predicting soil contaminations using spectral reflectance data. This study provided valuable information for finding contaminated soil ecosystems with the help of remote sensing [9].
Shamsoddini, S. Raval et al. have done research on the estimation of soil organic carbon metal with the help of reflectance spectroscopy technique. The abandoned Yerranderrie mine range impacts the soil of downstream zones was been demonstrated after the chemical analysis [10].
Hurburgh CRJ et. Al. found that Concentrations of Organic carbon in soil tests from the Hunan Province fields were been collected and spectral reflectance of those soil samples was measured with an ASD Field Spec FR Spectroradiometer [11].
In Selige, T., Bohner et al. research, review was been done to dealt with computerized soil maps ways in light of topographical data frameworks which demonstrates that soil content can be measured from different soils qualities at a similar area [12].

3. METHODOLOGY

To remove the effect of moisture, soil samples will be dried before the measurements. Then, the diffuse reflectance spectra of the samples would be measured in the laboratory in the Vis-NIR (350-2500 nm) range, with a spectral resolution of 3 nm (from 350 to 1000 nm), using a FieldSpec 4 Spectroradiometer (SAP Lab, Dept. of CS & IT, Dr. B.A.M. University Aurangabad, Maharashtra, India). A high-intensity contact probe with a built-in light source (6.5 halogen lamp) will also be used.
In this study, the Partial Least Square Regression (PLSR) method would be used to correlate the spectral data with laboratory SOC measurement. The soil samples would be divided into calibration and validation data sets [13]. The prediction accuracy of the model for the calibration and validation datasets would be evaluated through parameters such as R^2 (Coefficient of Determination), RMSE (Root Mean Square Error) and RPD (Ratio of Prediction to Deviation). The equations employed are as follows [14]:

$$R^2 = \sum_{i=1}^{N} \frac{(\hat{y} - \bar{y})^2}{(y - \bar{y})^2} \quad (1)$$

$$RMSE = \sqrt{\sum_{i=1}^{N} \frac{(\hat{y} - y)^2}{N}} \quad (2)$$

Where,
$\hat{y}$ is the predicted value,
y is the observed value,
$\bar{y}$ is the mean of observed values,
N is the number of sample data,
SD is the standard deviation of the observed values.

4. RESULT AND DISCUSSION

M. Clairotte et al. found that based on the French national soil library, much better predictions got achieved using VNIR spectra after random selection of calibration samples, and using local rather than global PLS regression [15]. However, local PLSR applied on MIR spectra gave accurate predictions using 30% of the calibration samples (SEP = 2.6 g kg^{-1}, RPD > 2.5, RPIQ > 3). In their research, the most accurate models gave SOC content predictions of SEP≤ 2 g kg^{-1}, RPD > 3 and RPIQ > 4. These results show that a standard method can be the laboratory infrared DRS to assess SOC Contents [16].
Tiezhu Shi et. al indicated that Successive Projection Algorithm and Genetic Algorithm can efficiently remove the uninterested spectral variables, clarify the regression models, and increase SOC content estimation accuracy. Better estimation results were obtained using Genetic Algorithm rather than SPA, while SPA was easier than GA [17].

5. CONCLUSION

Spectroscopy is an emerging technology having vast applications in different fields such as cereal industry, dairy industry, meat industry, etc. Carbon being the key component for plant growth, the knowledge about Soil Organic Carbon content will be beneficial for farmers to improve crop production. There is widespread interest for using Visible-Near Infrared Reflectance Spectroscopy (Vis-NIRS) for soil analysis and to provide information for soil mapping.

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