# Determination of Soil Texture Distribution (Clay, Sand and Silt) by using Spectral Measurement: A Review

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***Abstract:*** The relative content of particles of miscellaneous sizes like sand, silt and clay in the soil are indicated by soil texture and is the most important property of soil. An analysis of soil texture is essential process because it determines the characteristics of soil that affects growth of plant and it has agricultural applications such as to determine crop suitability, to predict the response of the soil to environmental and management conditions such as drought or calcium requirements, as well as soil texture has good effect on management and productivity of soil. An achievement of objectives and goal of Analytical Spectral Device Fieldspec4 Spectroradiometer (350-2500 nm) is preferred which require less effort and is very efficient, rapid, more accurate, non-wasting and non-destructive technique. To non-destructively characterize the key soil properties the reflectance spectroscopy provides an alternate method. The research aims to predict soil texture with the use of ASD Fieldspec4 Spectroradiometer. The device is used for obtaining spectral signature measurement of different soil samples. The Partial Least Square Regression (PLSR) technique is a statistical method in which the predicted variables and the observable variables are projecting to a new space to find a linear regression model which can be a best method to determine soil texture distribution. This paper describes the observations of various researches to determine soil texture. The further research gives the best results for soil texture determination which is beneficial for growth of plant because the good soil texture is important to allow water into the soil which is vital for healthy plant growth.

***IndexTerms*** **- ASD Fieldspec4 Spectroradiometer, PLSR, Soil Texture, Spectroscopy.**

## I. INTRODUCTION

In texture of soil there are composition of the soil regarding the amounts of clays (small), silts (medium) & Sand (large) particle size. Soils are the upper layer of earth, typically consists of loose mineral or organic materials, rock particles and clay in which plants grow. Particularly, soils are made up of about 25% air, 25% water, 45% mineral and 5% organic matter (i.e. plant residues, humus as well as living micro-organisms). Soil plays a vital role in degradation of soil, water transport processes (infiltration), controlling quality and productivity of soil, so that, soil texture is called as an important land environmental variable [1].

### 1.1 Need of Soil Texture Determination

In a typical soil, there are three main components found i.e. sand, silt and clay. Soil texture is the most important property of soil and is determined by those three end members [2]. For sustainable agriculture management and quality assessment of soil, the texture of soil (i.e. Sand, silt, clay) is one of the key indicators [3]. For agricultural growth, the soil texture is considered as an important environment factor. Now-a-days, various stakeholders including soil scientists, environmental managers, land use planners and traditional agricultural user's demands for the precise soil information in large scale [4].

### 1.2 Soil Particles

The soil texture or the particle size distribution of the soil can be defined as the percentage content of groups of particles with specific sizes in the soil. The probability of finding a particle with a specific size in the set of all particles is determined by soil texture [5]. We can analyze the soil characteristics by using spectral reflectance of soil [6]. For the analysis of soil texture by spectral reflectance we can use an efficient tool i.e. ASD Fieldspec4 Spectroradiometer [7]. Regarding the texture of soil, we can classify the soil texture by using mineral particles like sand, silt & clay [8]. From 0.002 mm to 0.05 mm in diameter are the silt particles, 0.05 mm to 2.00 mm are the sand particles and less than 0.002 mm are the clay particles. Due to efficient, accurate, effective and rapid method, the reflectance spectroscopy gives convenient option to traditional methods and also provides time and cost effective technique for the estimation of soil texture [9, 10].

### 1.3 Reflectance Spectroscopy

Over the past four decades, soil Vis-NIR technology has captured the attention of many researchers who realized that soil spectroscopy consists of remarkable quantitative information for precision agriculture, digital soil mapping and soil resource surveys. Moreover, most of the previous studies have focused more on the laboratory measurement of air-dried, ground and sieved

soil samples using VNIR spectroscopy (350-2500 nm). The visible (400-700 nm) and near-infrared (700-2500 nm) levels of the spectral range gives fast acquisition of soil information [11]. The ASD fieldspec4 spectroradiometer is the spectral reflectance spectroscopy technique.

The following Fig.1. Shows the reflectance spectra of 10 soil samples.

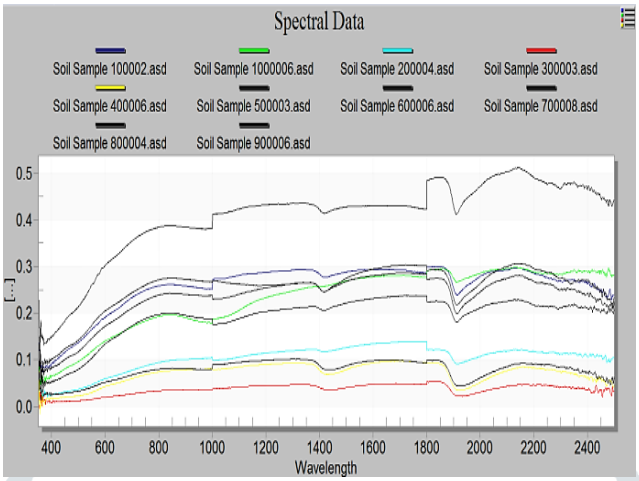


Fig.1. Reflectance spectra of 10 soil samples

There are several physical, chemical & biological properties of soil. Generally, it is observed that, soil texture is the most important basic physical property of soil [12]. Many researchers have concluded that, the texture of soil significantly correlates with the reflectance of soil in the Visible and near infrared region (400-2500 nm) [13].

This paper describes literature review in section 2; section 3 defines the methods and statistical analysis. Some discussions obtained from previous studies are described in section 4.

## II. LITERATURE REVIEW

The Visible (400-700nm) and Near Infrared (700-2500nm) spectroscopy technique allows more accurate and faster access of information of soil based on quantitative as well as qualitative basis. As a result, Vis-NIR reflectance spectroscopy is very beneficial choice to determine soil texture from different soil samples.

In 2013, the research paper of D. Curcio, G. Ciraolo, F. D'Asaro, and M. Minacapilli concluded that, a satisfactory level of prediction of soil texture can be obtained using only the PLSR technique, whereas a moderate level of prediction was obtained only for clay content using the CR approach. In this study, for the prediction of soil textures, PLSR allowed to assess the key wavelengths of the entire spectrum that should be considered essential.

In 2018, the study of Sari Virgawati, Muhjidin Mawardi, Lilik Sutiarso, Sakae Shibusawa, Hendrik Segah and Masakazu Kodaira demonstrated that, the soil texture was first analyzed by using Robinson's pipette method to determine the percentage of sand, silt & clay and then the spectroscopy measurement was performed by using the ASD Fieldspec3 (350-2500 nm) spectroradiometer then they have applied Savitzky-Golay method and PLSR technique to fulfill the results.

The research of Caio T. Fongaro in 2018 stated that, the spectral signature obtained from the Synthetic Soil Image (SYSI) presented very similar patterns to the equivalent spectral signature of the laboratory data. He has used the multispectral satellite images to map the outcomes by applying SG-FDT and PLSR method.

The study of Tzu-Shun Lin and Fang-yi Cheng stated that, the soil textures with large-sized particles of soil reveal higher soil conductivity. The water infiltrates into the land surface and drains rapidly through the soil column, which produces a higher subsurface runoff than that from soil textures with fine-sized soil particles [14].

In the research of Benjamin Muller, Matthias Bernhardt, Conrad Jackisch and Karsten Schulz, they have used the ASTER instrument on board of the TERRA satellite in their study. The relationship between soil texture data of the collected samples of soil and PCs derived from time series of TIR data was analyzed by Multiple Linear Regression. They have also created maps for soil texture fractions [15].

In 2015, Massimo Conforti, Raffaele Froio, Giorgio Matteucci, Gabriele Buttafuoco demonstrated that, for predicting soil texture fractions (Sand, silt and clay content ) the soil Vis-NIR (350-2500 nm) reflectance spectra contain valuable information & also concluded that the reflectance spectroscopy is an alternative to laboratory standard methods for determining the soil texture fractions [16].

The study of N. M. Dhawale, V. I. Adamchuk, S.O. Prasher, R.A. Viscarra Rossel, A. A. Ismail, and J. Kaur showed more overlaps and distortion in the spectra of the wet soil samples than in those for air-dried samples. They have used Mid-IR spectrometer for proximal soil sensing of soil texture. They also stated that, the main disadvantage of Mid-IR analysis is the need for more sample preparation than for Vis-NIR [17].

In Massimo Conforti, Raffaele Froio, Giorgio Matteucci, Tommaso Caloiero, Gabriele Buttafuoco study, for determining soil clay content in forest soils the potentiality of laboratory reflectance spectroscopy in the Vis-NIR domain was tested. In this research an ASD Fieldspec IV 350–2500 nm spectroradiometer was used for Vis-NIR spectral measurements. Their results showed that, on spectral reflectance in the Vis-NIR range the soil clay content has an important influence. For an accurate prediction of soil clay content and for the validation set they have also used PLSR model [18].

## III. METHODS AND STATISTICAL ANALYSIS

Traditionally, the information of soil texture has mainly been obtained through field soil sampling and laboratory analysis, such methods are highly accurate but because they are time consuming, costly and labor-intensive, and it cannot be used for rapid monitoring of soil texture.

Recent research has concluded that, the proximal visible and near-infrared diffuse reflectance spectroscopy could provide inexpensive prediction of soil physical, chemical and biological properties [19]. On the texture and structure of soil, the ability of soils to transport dissolved chemicals depends [20]. An efficient method for determination of soil texture or measurement of soil functional attributes within precision farming framework is the Hyperspectral VNIR spectroscopy [21]. Soil texture is one of the important properties of soil for agricultural management. The relative amounts of sand, silt and clay effects permeability, porosity, ease of tillage and nutrient retention [22].

The water retention, water infiltration, nutrient dynamics and root development are such important processes influenced by clay fraction. The soil texture is directly related to compaction of soil, capacity of air, mechanical resistance, consistency, plasticity, pollutants and interaction of herbicides [23]. Recently, for detecting and identifying minute details of various materials on the surface of earth especially soils with high spectral and spatial reflectance data the enormous information about the surface materials of earth provided by Hyperspectral Remote Sensing dataset. For the determination of soil texture here we will use the ASD Fieldspec4 Spectroradiometer and will apply some methods and algorithms to fulfill our objectives.

**PLSR (Partial Least Square Regression)**

PLSR is a statistical and popular regression method in which the predicted variables and the observable variables are projecting to a new space to find a linear regression model.

To find fundamental relations between two matrices(X and Y) we can use PLSR method. To model covariance structure in X and Y matrices the PLSR is a latent variable approach.

The equations are as follows [24].

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

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

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.

## IV. DISCUSSION

To determine the texture of soil the Visible & near Infrared (VNIR) Reflectance Spectroscopy (RS) plays a vital role. The spectroscopic technology using the VNIR range is very efficient, rapid, non-destructive & non-wasting.

The current status of research on the soil texture consists of the use of VNIR-SWIR reflectance spectroscopy to test the performance of two distinct methods i.e. Continuum Removal (CR) & Partial Least Square Regression (PLSR) method for soil texture estimation. The result of this study concluded that the PLSR method is better than the CR method because the performance of PLSR technique is better & gives best results. In this research by using Root Mean Squared Error (RMSE) the soil texture assessment accuracy performed and the coefficient of determination (R2) showed that CR approach allowed obtaining a moderate prediction only for the clay texture fraction.

Research in a forest area of Southern Italy concluded that, the leave-one-out cross validation determined the optimum number of factors to be retained in the calibration models. Results of cross validation of calibration models indicated that, the models fitted quite well and the values of R2 ranged between a minimum value of 0.74% for silt and a maximum value of 0.84 for sand content. For sand and clay content the results for validation were satisfactory & less satisfactory for silt content.

Mostly, in the research researchers have used the reflectance spectroscopy in the Visible & near Infrared (Vis-NIR, 350-2500 nm) spectral region & is an alternative to standard laboratory methods.

## V. CONCLUSION

Mostly the results of researches concluded that by using PLSR technique we can obtain a satisfactory level of prediction of soil texture and by using CR technique we can obtain a moderate level of analysis only for clay content.

An analysis of soil texture is essential process because it determines the characteristics of soil that affect growth of plant. The ASD Fieldspec4 Spectroradiometer (VNIR Spectroradiometer) is suitable for determination of soil texture of different soil samples acquired from agricultural sites. This spectroscopic technology is very efficient, rapid, non-destructive and non-wasting.

To determine sand, silt & clay i.e. soil texture from different soil samples if we will use the ASD Fieldspec4 Spectroradiometer (350-2500 nm) we can get best results with less effort. We can detect sand, silt & clay within 350-2500 nm spectral range to determine soil texture and then we will apply techniques and methods to fulfill our objectives i.e. to achieve the result.

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