Cloud Publications
International Journal of Advanced Remote Sensing and GIS
2016, Volume 5, Issue 6, pp. 1787-1794
ISSN 2320 - 0243, Crossref: 10.23953/cloud.ijarsg.60

Research Article **Open Access**

Creation of Soil Spectral Library for Marathwada Region

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Publication Date: 27 June 2016

DOI: https://doi.org/10.23953/cloud.ijarsg.60

Abstract This paper reports the development of the soil spectral library using Analytical Spectral Device (ASD) FieldSpec 4 Spectroradiometer with 350-2500 nm wavelength band. In this experiment we have used visible and Near-infrared band. The particular instrument is used to analyze the chemical properties of soil such as Carbon (C), Nitrogen (N), Phosphorus (P), and physical properties of soil such as soil texture (sand, silt, clay) and moisture content. It is observed that physical and chemical properties can be analyzed using hyperspectral band. The database used for experiment have 80 samples of soil which are collected from Aurangabad, Jalna, Parbhani, Hingoli, Nanded, Lature, Osmanabad and Beed from Marathwada region of Maharashtra state with their GPS coordinates. Linear Discriminant Analysis (LDA) technique is implemented for classification of soil spectral signature of chemical properties. Soil texture of Marathwada region comes under the silt clay loam. We got the 100% accuracy of Phosphorus content, where as Carbon and Nitrogen content found 75%, 87% respectively for Marathwada region.
Keywords *LDA; Spectral Signature; Spectroradiometer; Soil Property*

1. Introduction

There are many natural things on or surrounding of the earth like water, soil and air which are necessary for survival of living being. Soil is a natural form and it is a combination of minerals, organic matter, gases, liquids, and the countless organisms. Life on the earth can be supported by these things together. Soil is used as a medium for plant growth, as water storage, as a modifier of earth's atmosphere and also helpful for supply and purification. Soil continually undergoes development by way of numerous physical, chemical and biological processes, which include weathering with associated erosion [1]. This work is concentrated on soil and its properties.

The three basic types of soil properties are physical, chemical and biological. The physical properties of soil are texture, structure, density, consistency and color. Chemical properties of soil are Cation-Exchange Capacity (CEC), soil pH, minerals and organic matter (carbon, nitrogen and phosphorus) [2]. Biological property include soil biota, including flora (plants), fauna (animals) and microorganisms which perform functions that contribute to the soil’s development, structure and productivity [3]. Soil properties are influenced by texture such as drainage, water holding capacity, Cation-Exchange

Capacity (CEC), pH buffering capacity and organic matter content. It was best effected on management and productivity of soil.

The physical and chemical properties of the soil are essential nutrients which are important for crops and basic resource for maintaining the Earth's ecosystems [4]. In agriculture field or in natural resources like ecosystem, requires the appropriate use of soil which having good physical, chemical and biological properties. Different crops need different type of soils, different types and amounts of nutrients, and different types and amounts of water. The amount of water required by the plant is also dependent on the growing season and the climate where it is grown. By selecting the right crop for the given soil conditions and climate, one can optimize yields and save water requirements for irrigation. Soil texture refers to the size of the particles that make up the soil and depends on the proportion of sand, silt and clay-sized particles and organic matter in the soil. Sandy soils feel gritty when rubbed between the fingers. Silts feel smooth – a little like flour. Most clays are sticky and moldable. Soils that are a mixture of sand, silt and clay are called loams [5]. Black soil contains a large amount of clay which have moderate amount of phosphorous but is poor in nitrogen. This type of soil is also used for rice, wheat, sugarcane and cotton. It is additionally used to grow groundnut, millet and oilseeds. Sandy and dry soils contain nitrogen, but are suitable for agriculture only if there is a sufficient water supply. Generally only drought-resistant crops such as barley and millet can grow in this type of soil [6]. The nitrogen, phosphorus and potassium (K) plays very important role for the production of rice crop [7]. For getting information about physical, chemical, biological, and fertility properties of soils, soil science is useful. It has found to develop techniques that help for better characterization of soil types.

In recent studies, Remote sensing techniques for soil application have gained much concentration, because these techniques have been shown to generate faster and cheaper characterizations. The application of remote sensing techniques in soil studies started in the 1960s and developed for various applications, including fast and nondestructive quantification of soil properties [8]. The basic requirement for this is the creation of a spectral signature database. We have created our own soil spectral signature database for Marathwada region.

When soil absorbs the energy from energy source then it reflects that radiation differently in various bands. The soil spectral signature is the radiation reflected as a function of the wavelength [9]. Recent researchers have indicated that visible and near-infrared, diffuse reflectance spectroscopy (VINR-DRS) and specific band from hyperspectral sensor data [10, 11-15]. Near-Infrared spectroscopy can be used to analyze heavy metal contents in soil such as zinc (Zn), copper (Cu), lead (Pb), chrome (Cr), and nickel (Ni) [16].

China has large area of rice fields and created Chinese Soil Spectral Library (CSSL). Spectral library data achieved that consist of spectral signatures measured on selected natural soil. 1st derivative, 2nd derivative, savitzky-Golay method, multiplicative scatter correction (MSC) and standard normal variate (SNV) are the pretreatment methods. Spectroradiometer has used for the measurement, soil physical and chemical properties such as clay, sand content, moisture content, carbon, nitrogen and phosphorus. Near-infrared is used to assess clay, sand, moisture content and other soil properties and small studies area [10, 12, 17, 18]. The soil spectral library developed in the artificial dark room. Landsat Thematic Mapper (TM) six band 1, 2, 3, 4, 5 and 7 used for soil analysis. Partial least square regression and artificial neural network used mathematical tools in the analysis of soil properties [19-21].

2. Materials and Methods

2.1. Creation of Database and Study Area

For this experiment we created soil database, which consists of 80 samples of soil from farms. The samples include top soil (0-20 cm depth from land surface) denoted as A and sub soil (20-40 cm depth from land surface) denoted as B in Table 1. Soil samples were collected from the Marathwada region of India during Oct-Nov 2015 between 10: 00 am to 4: 00 pm on a sunny day. Soil samples collected from 8 districts such as Aurangabad, Jalna, Parbhani, Hingoli, Nanded, Lature, Osmanabad, Beed and details of sample is presented in Table 1. It has been collected from different cropping systems, including arable. A global position system (GPS) was used to determine the coordinates of the sampling point. Distance between two samples is 2-3 km. We have collected 5 soil samples from each district of Marathwada region. The samples were stored in air tight bags to restore the moisture.

Table 1: *Details of soil samples from study area*

Sr. No.	City/Village Name	Presented Crop	Top Soil	Subsoil
1.1	Hingoli	Red gram, Soybean	A	B
1.2	Risol, Hingoli	Cotton	A	B
1.3	Savarkheda, Hingoli	Soybean	A	B
1.4	Savarkheda, Hingoli	Jowar	A	B
1.5	Savarkheda, Hingoli	Soybean	A	B
2.1	Ardhapur, Nanded	Green Gram	A	B
2.2	Nanded	Banana	A	B
2.3	Nanded	Vegetables (Chilly)	A	B
2.4	Nanded	Soybean	A	B
2.5	Nanded	Black soil	A	B
3.1	Khanapur, Parbhani	Soybean	A	B
3.2	Parbhani	Black soil	A	B
3.3	Parbhani	Jowar	A	B
3.4	Parbhani	Jowar	A	B
3.5	Parbhani	Soybean	A	B
4.1	Bharahnpur, Latur	Lady Finger	A	B
4.2	Latur	Jowar	A	B
4.3	Malwati, Latur	Jowar	A	B
4.4	Kasarkheda, Latur	Black soil	A	B
4.5	Chikalthana, Latur	Soybean	A	B
5.1	Thoki, Osmanabad	Soybean	A	B
5.2	Rui, Osmanabad	Black soil	A	B
5.3	Kavadgaon, Osmanabad	Black soil	A	B
5.4	Bhadachiwadi, Osmanabad	Corn, Sugarcane	A	B
5.5	Upala, Osmanabad	Soybean	A	B
6.1	Anandwadi, Beed	Black soil	A	B
6.2	Ramnagar, Beed	Black soil	A	B
6.3	Pendgaon, Beed	Jowar	A	B
6.4	Palwan chowk, Beed	Jowar, soybean	A	B
6.5	Palwan, Beed	Cotton	A	B
7.1	Badnapur Tahsil, Jalna	Cotton	A	B
7.2	Badnapur, Jalna	Cotton	A	B
7.3	Selgaon, Jalna	Corn	A	B
7.4	Jalna	Cotton, Red gram	A	B
7.5	Jalna Toll Plaza	Soybean	A	B
8.1	Aurangabad	Wheat	A	B
8.2	Kanchanwadi, Aurangabad	Red gram	A	B
8.3	Gevrai Tanda, Aurangabad	Bajra (millets)	A	B
8.4	Gevrai, Aurangabad	Black soil	A	B
8.5	University, Aurangabad	Back soil	A	B

2.2. Spectral Measurement through FieldSpec 4

FieldSpec 4 Spectroradiometer is scanned and absolute reflectance of samples is recorded for 350-2500 nm wavelength and collects spectra at the rate of 0.1 seconds per spectral scan. Spectral resolution is 3 nm @ 700 nm (350-1000 nm) and 10 nm/ 8 nm/ 30 nm @ 1400/2100 nm (100-2500 nm). Data sampling interval is 1.4 nm (350-100 nm) and 2 nm (1000-2500 nm) and spectral resolution of 3 nm at 700 nm and 10 nm at 1400 nm and 2100 nm. The total number of 2151 data points per spectrum using FieldSpec 4 Spectroradiometer (Analytical Spectral Devices Inc., Boulder, Colorado, USA). Its input is 1.5m permanent fiber optic cable and it is having 25 degree, 8 degree and 1 degree field-of-view (FOV). Fiber optic cable is flexible. FieldSpec 4 is a very flexible instrument, it can use in lab and on the field. It has some accessories like pistol grip tripod, lamp, reference panels, backpack, battery, AC power supply and laptop. The laptop is required to communicate the instrument through Ethernet wired interface or Wi-Fi Ethernet interface. It has some software such as RS3, ViewSpec Pro, Indico Pro and third party software. RS3 software is used for data collection and file saves as .asd extension.

ViewSpec Pro software is used for data analysis and pre-process data. It has the same tools like reflectance, absolute reflectance, log 1/ T, log 1/ R, 1st and 2nd derivative, and parabolic correction and so on. It can export .asd file into the ASCII code (text file) and shows the latitude and longitude coordinates of the field location (GPS).

Each soil sample was scanned 5 times. Database is created by FieldSpec 4 Spectroradiometer. Database size is 400. The reflectance of each sample was calculated by taking the average of 100 scans performed by the sensor. The spectrum of the sample was the average of 30 successive scans. Soil samples are scanned with a spectral range of 350-2500 nm; Soils were scanned from below using a high intensity source instrument FieldSpec 4 and Spectralon panel for white reference. It is used 8°FOV. It was placed on a tripod with a nadir position. Distance between optical head and soil sample was 20 cm with a lamp mounted on distance 45 cm form sample. All spectral data were collected by RS3 software.

2.3. Spectral Characteristic Analysis

It is non imaging hyperspectral data and able to predict the soil properties. ViewSpec Pro software was used for pretreatment and each spectral signature transformed into ASCII format by using the ViewSpecPro software. The analysis is conducted for five spectral signature. The wavelength bands for carbon is (2040-2260 nm), nitrogen (1702 nm, 1870 nm and 2052 nm), and phosphor (2021-2025 nm, 2240-2400 nm), texture Particles (1323 nm, 2081 nm) and water contents (1400 nm, 1900 nm, 2200 nm). Figure 1 shows the reflectance of all soil samples and Table 2 represents soil texture of all soil samples. Mean of reflectance value of soil is calculated for statistical analysis which is shown in Table 3.

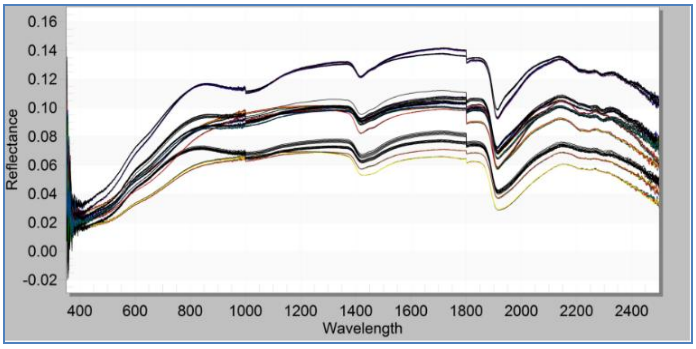

Figure 1: *Reflectance of all soil samples*

Table 2: *Soil texture of all soil samples*

Marathwada Region	Sand %	Clay %	Silt %	Total
Beed	23	37	40	100
Hingoli	20	29	51	100
Jalna	9	28	63	100
Latur	13	26	61	100
Nanded	15	27	58	100
Osmanabad	18	26	56	100
Parbhani	17	52	31	100
Aurangabad	29	22	49	100

Table 3: *Statistic of carbon, nitrogen, phosphorus and water contents*

Soil Properties	Beed	Hingoli	Jalna	Latur	Nanded	Osmanabad	Parbhani	Aurangabad
Range of Carbon content	0.058-0.079	0.125-0.135	0.062-0.073	0.082-0.092	0.096-0.104	0.048-0.061	0.124-0.133	0.09-0.105
Range of Nitrogen content	0.059-0.071	0.129-0.137	0.064-0.082	0.084-0.1	0.097-0.103	0.05-0.066	0.125-0.141	0.092-0.099
Range of Phosphorus content	0.054-0.065	0.118-0.126	0.058-0.069	0.073-0.085	0.09-0.098	0.044-0.058	0.115-0.125	0.082-0.097
Water content	0.043-0.066	0.106-0.128	0.046-0.071	0.064-0.092	0.078-0.1	0.034-0.058	0.101-0.127	0.067-0.098

2.4. Linear Discriminant Analysis (LDA) Technique Implemented for Soil Properties

Linear Discriminant Analysis (LDA) is simple, mathematically robust and often produces models whose accuracy is good. It is based upon the concept of searching for a linear combination of variables (predictors) that best separates the two classes (targets). LDA is a transform-based method which attempts to minimize the ratio of within-class scatter to be between class scatter. The mathematical formulation involved in the theory of LDA is explained in the following sections. A within-class scatter matrix defines the scatter of samples around their respective class centers (means) [22].

We applied LDA classification technique on soil spectral signature classification of chemical properties with reference the wavelengths.

3. Results Analysis and Conclusion

All the soil samples which are tested in this study have similar reflectance spectra. Figure 1 represents the reflectance of soil samples which is a spectral signature of the soil. It shows each wavelength band of the soil. From different band we can get different chemical and/or physical content of the soil. For following wavelength 1323 nm, 1400 nm, 1702nm, 1870 nm, 2052 nm and 2081 nm, we got high reflectance peaks in the spectral signature. As previously mentioned several pretreatments are considered among all, the 1st derivative good result.

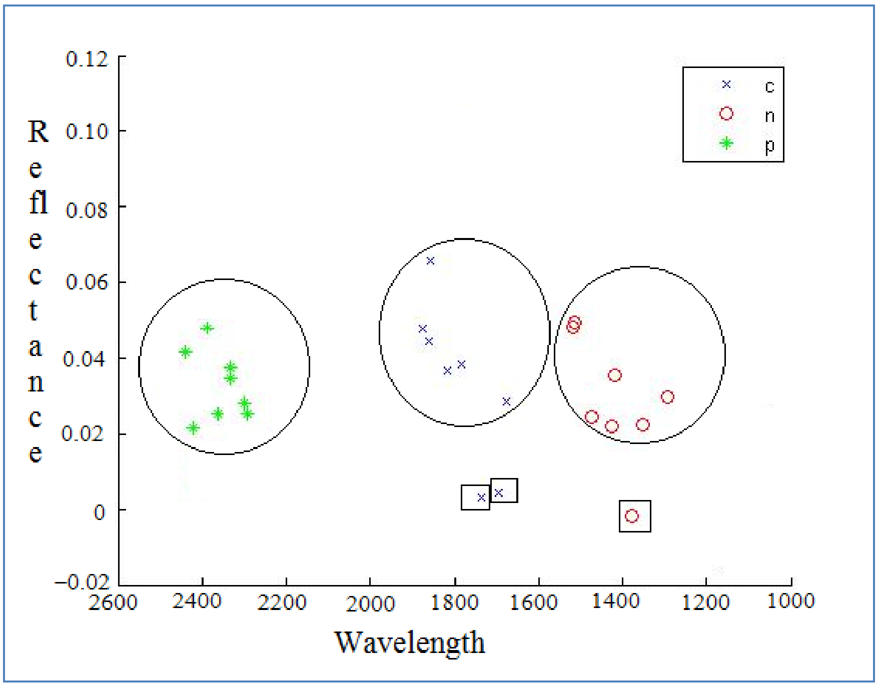

Figure 2: *LDA implementation for soil spectral signature for Carbon, Nitrogen and Phosphorus*

Table 2 presents the soil texture of all the study area. It is observed that silt percentage in the soil more than sand and clay. The percentage of sand in soil for Aurangabad region is 29%, clay 22%, and slit 49%, due to less rainfall in Aurangabad district. Parbhani districts have 17% sand, clay is more, it is 52% and silt is 31% as generally on an average, there is good rainfall in Parbhani of Marathwada region. The results got for remaining regions are depend upon the rainfall, the geographical condition and structure of that area. Soil texture class depends on percentage of sand, silt and clay. These classes again subdivided into loam, sandy loam, clay loam, sandy clay, silt clay, silt clay loam and sandy clay loam.

The chemical analysis result of the concentrations of Carbon, Nitrogen, Phosphorus and water contents are presented in Table 3 for the calibration and prediction sets respectively. Linear Discriminant Analysis (LDA) classification technique is applied to the soil properties. C, N and P of soil spectral signature are resulted and seen in Figure 2. Reflectance value of Carbon (C), Nitrogen (N) and Phosphorus (P) are shown on X-axis, whereas Wavelength range placed on Y-axis. It is observed that the reflectance value of phosphorus for all the soil samples found to be similar. The accuracy of carbon is 75%. Reflectance value of the carbon for Osmanabad and Beed region is low. For nitrogen is 87%. The reflectance value Osmanabad region is less and for Parbhani and Hingoli, it is near about same. The accuracy rate of soil chemical properties is seen in Table 4.

This paper analyzes the soil properties of eight districts of Marathwada region of Maharashtra state. These districts are Aurangabad, Jalna, Beed, Parbhani, Hingoli, Nanded, Latur and Osmanabad. The distance between the selected areas is approximate (60-100 km). From the result, we have concluded that for the Beed and Hingoli regions, the texture class is clay loam. Jalna, Latur, Nanded and Osmanabad comes under silt clay loam. Aurangabad is loam and Parbhani is Clay texture class. The Carbon reflectance is high (0.128) in Parbhani. Nitrogen (0.133) and Phosphorus (0.123) is high in Hingoli. Carbon, Nitrogen and Phosphorus reflectance is poor in Osmanabad.

Linear Discriminant Analysis (LDA) classification technique is used to classify Carbon, Nitrogen and Phosphorus. Phosphorus got 100% accuracy. We have concluded that the content of phosphorus in soil for Marathwada region is more prominent than nitrogen and carbon. With the help of collected soil samples, Soil Spectral Library is created for Marathwada region. Osmanabad and Beed regions carbon content showed the difference, in reflectance spectra for nitrogen. Parbhani and Hingoli found to be similar whereas Osmanabad region showed the less reflectance value for nitrogen.

References

[1] Wikimedia Foundation, Inc. Wikipedia®. Available at https://en.wikipedia.org/wiki/Soil.

[2] Ramdas D., Gore, Sunil S., Nimbhore, and Bharti W., Gawali. *Understanding Soil Spectral* Signature *Though RS and GIS Techniques.* International Journal of Engineering Research and General Science. 2015. 3 (6) 866-872.

[3] My Agriculture Information Bank. Available at http://agriinfo.in/?page=topic&superid=1&topicid=373

[4] Shuo, Li, Wenjum, Ji, Songehao Chen, Jie Peng, Yin Zhou, and Zhou Shi. *Potential of VIS-NIR-SWIR Spectroscopy from the Chines Soil Spectral Library for Assessment of Nitrogen Fertilization Rates in the Paddy-Rise Region, China.* Remote Sensing. 2015. 7; 7029-7043.

[5] Demand Media. *Types of Soil & Crops Grown in India.* Available at http://www.gardenguides.com/128581-types-soil-crops-grown-india.html

[6] Science Learning Hub, The University of Waikato. Soil Properties. Available at http://sciencelearn.org.nz/Contexts/Soil-Farming-and-Science/Science-Ideas-and-Concepts/Soil-properties

[7] Henrique Bellinaso, Jose Alexandre Melo Dematte and Suzana Araujo Romeiro. *Soil Spectral Library and Its Use in Soil Classification*. Scielo, Revista Brasileira de Ciencia do Solo. 2010. 34 (3).

[8] Zejian Lei, Mingyin Yao, Muhua Liu, Qiulian Li and Hanping Mao. *Comparison between Fertilization N, P, K and No Fertilization N, P, K in Paddy Soil by Laser Induced Breakdown Spectroscopy*. IEEE Intelligent Computation Technology and Automation. 2011. 1; 363-366.

[9] Shuo, Li, Wenjum, Ji, Songehao Chen, Jie Peng, Yin Zhou, and Zhou Shi. *Potential of VIS-NIR-SWIR Spectroscopy from the Chines Soil Spectral Library for Assessment of Nitrogen Fertilization Rates in the Paddy-Rise Region, China*. Remote Sensing. 2015. 7; 7029-7043.

[10] European Space Agency. Spectral Signatures. Available At http://www.esa.int/SPECIALS/Eduspace_EN/SEMPNQ3Z2OF_0.html

[11] Davin J. Brown. *Using a Global VNIR Soil-Spectral Library for Local Soil Characterization and Landscape Modeling in a 2nd-Order Uganda Watershed*. Geoderma. 2007. 140 (4) 444-453.

[12] Linker, R. *Soil Classification via Mid-Infrared Spectroscopy*. Chapter in Computer and Computing Technologies in Agriculture, Vol. 2. The International Federation for Information Processing Series Vol. 259. 2008. 1137-1146.

[13] Gholizadeh, A., Amin, M.S.M., Boruvka, L., and Saberioon, M.M. *Models for Estimating the Physical Properties of Paddy Soil using Visible and Near Infrared Reflectance Spectroscopy*. Journal of Applied Spectroscopy. 2014. 81 (3) 534-540.

[14] Todorova, M., Mouazen, A.M., Lange, H., and Astanassova, S. *Potential of Near-Infrared Spectroscopy for Measurement of Heavy Metals in Soil as Affected by Calibration Set Size.* Water Air Soil Pollut. 2014. 225 (8) 1-19.

[15] Haiqing Yang, Boyan Kuang, and Abdul M. Mouazen. *Affect of Different Preprocessing Methods on Principal Component Analysis for Soil Classification.* ICMTMA. 2011. 1; 355-358.

[16] Viscarra Rossel, R.A., Walvoort, D.J.J., McBratey, A.B., Janik, L.J., and Skjemstad, J.O. *Visible, Near Infrared, Mid Infrared or Combined Diffuse Reflectance Spectroscopy for Simultaneous Assessment of Various Soil Properties.* Geoderma. 2006. 131 (1-2) 59-75.

[17] Josea M., Dematte, Peterson R., Fiorio, and Suzana R., Araújo. *Variation of Routine Soil Analysis When Compared with Hyperspectral Narrow Band Sensing Method.* Remote Sensing. 2010. 2 (8) 1998-2016.

[18] Changwen Du and Jianmin Zhou. *Evaluation of Soil Fertility Using Infrared Spectroscopy: A Review*. 2009. 7 (2) 97-113.

[19] Rossel, R.A.V., Jeon, Y.S., Odeh, I.O.A., and McBratney, A.B. *Using a Legacy Soil Sample to Develop a mid-IR Spectral Library.* Soil Research. 2008. 46 (1) 1-16.

[20] Gehl, R.J. and Rice, C.W. *Emerging Technologies for in situ Measurement of Soil Carbo*n. Climatic Change. 2007. 80 (1) 43-54.

[21] David J. Brown, Keith D. Shepherd, Markus G. Walsh, M. Dewayne Mays and Thomas G. Reinsch. *Global Soil Characterization with VNIR Diffuse Reflectance Spectroscop*y. Geoderma. 2006. 132 (3-4) 273-290.

[22] Sebastian Raschka. Linear Discriminant Analysis. Available at http://sebastianraschka.com/Articles/2014_python_lda.html