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Soil Macronutrients Analysis of Vaijapur Taluka from Spectral Signatures Using Hyperspectral Non-Imaging Data

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Abstract—

As we know soil is a vital part of the environment, survival and humanistic welfare .Soil is formed by minerals, organic matter and living organism components. From the point of view of agriculture, the soil offers support to plants and acts as a reservoir of water and nutrients Soil physical, biological and chemical properties plays a very crucial role in agricultural sector. Accelerated low cost and predictable assessment of soil quality under agricultural management is necessary to accomplish convenient observation of the effects of various management practices on soil conditions to avoid soil degradation and ensure feasible soil productivity and also soil security for improvement of agriculture sector . The objective of this study is to find soil macronutrient contents from top surface (0-20cm) of agricultural soil. FieldSpec4 Spectroradiometer (350-2500 nm) is a rapid, non-destructive, and cost-effective, time consuming tool for predicting the soil properties such as soil texture, water, carbon, nitrogen, phosphorus to better crop production .We also analyze soil samples using traditional laboratory methods .To achieve these objectives some preprocessing techniques and several statistical procedures were implemented using partial least squares-regression (PLSR).Partial least square regression gives us results for successfully estimation of soil characteristics such as Soil Moisture (RMSE :0.00097 R-square :0.99780 calibration and validation RMSE :0.0011 R-square 0.9971), For Nitrogen(RMSE :0.0012 R-square :0.9974 calibration and validation RMSE :0.0013 R-square 0.9972) Carbon(RMSE:0.0017 R-square :0.9943 calibration and validation RMSE :0.0019 R-square 0.9928), Phosphorus(RMSE:0.0015 R-square :0.9953 calibration and validation RMSE:0.0016 R-square 0.9947).All preprocessing, statistical analysis and classification have done using R-tool, ViewSpec and Uncrambler 10.5 software

Keywords— PLSR, FieldSpec4 Spectroradiometer, ViewSpec

1. INTRODUCTION

Soil characteristics assessment has abundant application for agricultural management. Soil Properties shows conspicuous aspect in soil quality. The soil quality is depending on soil physical, chemical and biological features. Soil physical features include Water Holding capacity, Soil texture (Sand, Silt, Clay),soil structure, soil color, soil surface roughness,soil depth,soil density,etc. Inversely, soil chemical features are soil organic matter ,Cation Exchange Capacity(CEC),soil pH,Soil Nitrogen ,Soil Organic Carbon, soil sailinity with sodicity and soil minerology,etc. All sixteen nutrients have been disclose and are percieved to be important for crop and plant growth and living organisms in the soil. It is needed to extent the soil fertility and specify deficiencies in nutrients level that need to be remedied for increasing crop production. This leads to an efficient fertilizer use, Environment protection, product quality enhancement and increase in yield Predictable quantification of soil characteristics is established by laboratory analysis and integrative keys that can be expensive ,time consuming and also needed expert operator to obtain chemical analysis. There are various domains provides us various tools for soil monitoring ,one of them is Remote Sensing .Remote sensing is nothing but to extract the information of an object on earth surface without any physical contact with it. It gives us different tools like a) Point spectroscopy-In that spectra are measured one point at a time. And b) Imaging spectroscopy- Here spectra are recorded as a two dimensional array of measurements[1].A goal of Remote Sensing is to disentangle the spectral response recorded from a surficial soil and be able to identify the proportions & influence of the characteristics within the instantaneous field of view of the sensor system. In this Reflectance spectroscopy provides an equivalent techniques to physical and chemical laboratory soil analysis for assessment of a enormous range of key soil properties. Reflectance spectroscopy divides in Visible Near Infrared having wavelength (VNIR: 400-1100nm) and Short Wave Infrared (SWIR: 1100-2500nm) .Visible Near Infrared and Short Wave Near Infrared Spectroscopy is a rapid ,timely, less expensive, nondestructive analytical technique which can be provide a robust and reliable approach to evaluate contradictory soil properties without the need of chemicals[2].Thus, it is a promising tool for studying soil properties and can be used as an alternative to traditional method and according to their absorbance or reflectance in the specific wavelengths it allows material identification through a characterization of its spectrum. Spectral measurements need to be accurate and precise representations of the target material. **(R.A. Viscarra Rossel T, D.J.J. Walvoort**

,2005) They examine several soil properties such as soil pH,Ca, pHw, lime requirement (LR), organic carbon (OC),clay, silt, sand, cation exchange capacity (CEC), exchangeable calcium (Ca), exchangeable aluminium (Al), nitrate–nitrogen (NO3–N), available phosphorus (PCol), exchangeable potassium (K) and electrical conductivity (EC) using VIS, NIR and MIR for data acquisition and more valuable soil analysis[3]**.(H.M.Bartholomeus, M.E.Schaepman et al.,2008)** tested the performance of various spectral indices for Soil Organic Carbon[4]**.(A.Volkan Bilgili,H.M Van Es et al.,2010)**Visible Near Infrared reflectance spectroscopy for assessment of Exchangeable Ca and Mg,Cation Exchange Capacity,Organic Matter,Clay Sand
,Silt and CaCO3 content[5]**.(Luiz Eduardo Vicente ,Carlos Roberto de Souza Filho ,2011)**Estimate Reflectance spectroscopy is an equivalent soil measuring method which uses spectral absorption features between visible(VIS) and Short –Wave Infrared (SWIR) with range between(0.3-2.5 µm) for calculating soil mineralogy[6]. **(Stephan Gmur, Daniel Vogt,2012)** states classification and regression tree are statistical methods in which they used regression tree to determine concentrations of nitrogen, carbon, carbonate and Organic matter as the response variables .Regression tree gives a powerful , rapid and inexpensive method for analyzing nitrogen, carbon, carbonate and organic matter for soil horizons as a nondestructive method which is utilizing by 400 to 1000 nm electromagnetic range[7]**.(HE Ting ,Wang Jing et al.,2012)**Used Step wise Regression for predicting soil Organic Matter[8].**(Jean-Philippe Gras ,2013)**Diffuse Infrared Reflectance Spectroscopy has been considered as an proxy technique for evaluating and observing soil quality.**(D.Curcio, G.Ciraolo**, **Cecile Gomez**, **Philippe Lagacherie**,2013)according to author, reflectance spectroscopy provides an another method to characterize soil texture properties (Sand, Silt, Clay) using two distinct techniques i.e. Continuum Removal and Partial Least Square Regression[9]**.(Mohammad Sadegh Askari ,Sharon M.O'Rourke et al.,2014)** Visible Near Infrared Spectroscopy used to assess Soil quality for agricultural production using Partial Least Square Regression[10]**.(Shou Li ,Wenjun Ji**
,Songchao Chen et al.,2015) Estimate the latent of VIS-NIR- SWIR spectroscopy from the Chinese Soil Spectral Library for investigation of Nitrogen Fertilization Rates in the Paddy- Rice Region ,China[11]. **(Snehal Kulkarni, Dr.Ratnadeep R.Deshmukh 2016),** using PCA researcher investigate the carbon, nitrogen, phosphorous and water content of agricultural soil with the help of Fieldspectroradiometer(**Ramdas D.Gore,Reena H.Chaudhari and Bharti W.Gawali,2016)**,they creates spectral library of soil properties in that they evaluate carbon
,nitrogen, phosphorous and water content using linear discriminant analysis technique.(**Ashwini Dilip Padmanabhi, Saima Ansari, Dr. R. R. Deshmukh,2017)** were used partial least square regression technique for assessment of nitrogen using Fieldspectroradiometer[12].**(Qinghu Jiang ,Qianxi Li et al,2017)** Evaluate Soil Organic Carbon and Total Nitrogen in Dissimilar soil layers using VNIR Spectroscopy[13]**.(Nisha Bao ,Lixin Wu et al .,2017)**Proposed Spectral Difference Index for measuring Soil Organic Matter from large surface coal mine using Fieldspectroradiometer[14].In our perceptive and estimation with respect to soil, its quality and behavior has been accomplished through conventional soil chemical and physical laboratory analysis.

2. Study Area and Field Sampling

The study area Vaijapur is a city and a municipal council in Aurangabad district, Maharashtra, India which is geographically located at 19.92°N latitude and 74.73°E longitude. Mostly Black clay soil found

in study site and it can be classified as light, medium and heavy according to the depth, texture and location. The major crops cotton, sweetcorn and bajra are taken[15]

In June , July, September and October 2017
,35 soil samples were collected. At each site , approximately 1 kg of surface soils was obtained (0-20 cm)and we also used Global Position System to record the corresponding Geographical Coordinates. These fresh soil samples were packed in zip lock plastic bags labeled & taken to the laboratory. These soil samples divided into two portions one for spectral measurement & other for laboratory analysis.

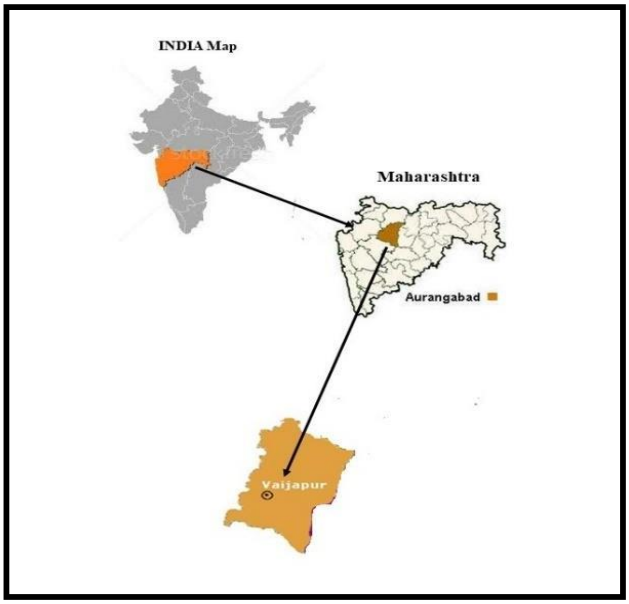
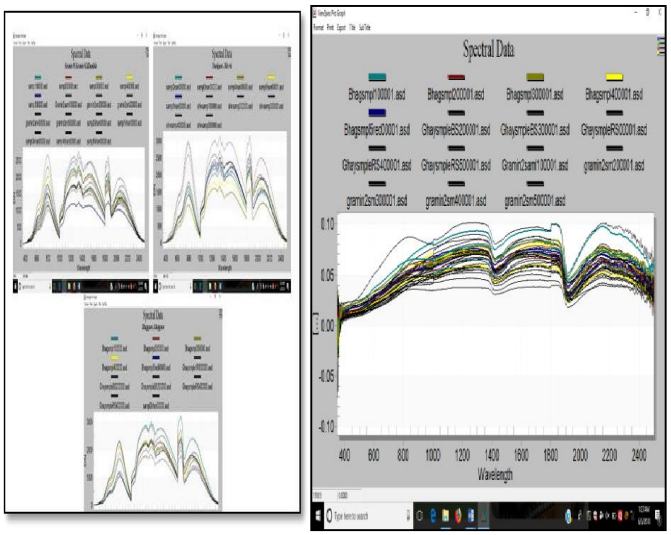


Figure01:Study area

3. A.SPECTRAL SIGNATURE ACQUISITION

The soil samples were taken for spectral measurement in dark room using Analytical spectral Devices (ASD) Field Spec4 Spectroradiometer for obtaining the reflectance spectra of soil. The ASD Spectroradiometer provides the reflectance spectra at VNIR –SWIR region having wavelength range from 350-2500nm,providing the total of 2151 reflectance variables for each spectrum[16].The instrument has a high spectral resolution with 3 nm for 350-1000 nm and 10 nm for 1000>2500 nm onward with sampling interval 1.4 nm and 2nm for each range. This instrument uses a 75 W tungsten quartz halogen filament lamp as an illumination source for illuminating the soil

sample[17]. The reflected light was collected in 1 nm bandwidths between 350-2500nm with an 8º Field of View (FOV) fiber optic cable of Spectroradiometer that was kept off-nadir at a distance of 15 cm above the soil sample. The instrument was optimized and controlled laboratory readings before sample were recorded. The total of 10 spectra of each sample was recorded to minimize the noise produced by the instrument for obtaining the final spectra. We got 350 soil spectra's for 35 samples for creation of database. The RS3 spectral acquisition software was used to collect soil spectral measurements. We also used Global Position System to record the corresponding Geographical Coordinates.



region Spectral Band 1400,1900 and 2200 nm shows water absorption and hydroxyl absorption. Mineral composition calcite shows absorption bands between 1800 -2500 nm. Soil Macronutrients like Carbon, Nitrogen ,Phosphorus are important .The Spectral range 2040 -2260 nm for carbon ,1702 nm ,1870 nm and 2052 nm for nitrogen .Whereas wavelength from 2021-2025 nm 2240-2400 nm is for phosphorus.

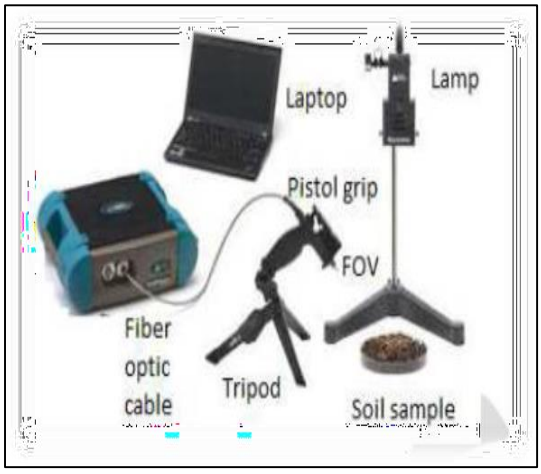


Figure02: Setup for Soil Spectral Signature Acquisition

4. SPECTRAL PREPROCESSING AND SPECTRAL CHARACTERISTICS ESTIMATION

Field Spec4 Spectroradiometer is a Non-Imaging point spectroscopy, in this we record spectra one point at a time. In Fig 03 (a): shows that spectral signature with the raw signal (DN) of all soil samples. Fig 03(b): shows raw reflectance spectra of all 35 soil samples whereas fig 04(a)shows the statistics mean

reflectance of all soil samples .we also apply some preprocessing techniques including 1st and 2nd Derivatives with derivative gap 5 is taken on raw spectra to solve break points and decrease the baseline effects to improve spectral features. In figure 05 (a) shows the Ist and IInd Derivative .For preprocessing purpose we have use ViewSpecPro software. After preprocessing each spectral signature export into text/data format for further analysis purpose .The Field Spec 4 Spectroradiometer having wavelength (350-2500 nm)consist of three detector first VNIR with carry (350-1000nm) wavelength,SWIR1 (1000 1800nm) and SWIR2 having (1800-2500 nm) wavelength. The wavelength from 350 nm to 450 nm and 2,350 to 2500 nm carry very noise. So this unwanted wavelength has no use in statistical analysis that's why we remove it from the data. The characterization of soil samples are estimated by both traditional laboratory methods and also spectrally estimated in the electromagnetic range between 400 to 2500 nm[18].The Soil characteristics were divided in the given successive in VNIR-SWIR region of electromagnetic spectrum. In VNIR

Figure 03 (a):Raw DN Spectral signatures of Soil samples.(03.b) Reflectance of Spectral Signatures of total 35 soil samples

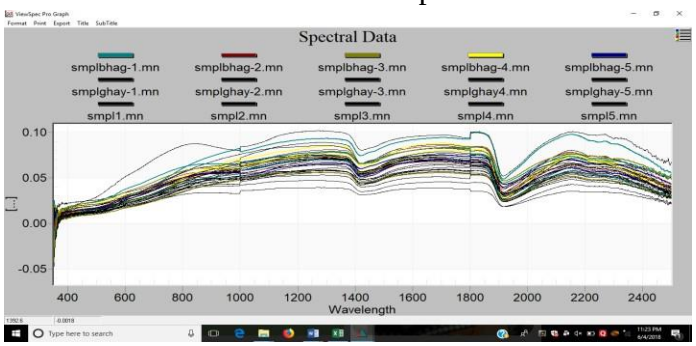


Figure04: Fig 04: Statistics mean spectral signature of all 35 soil samples with wavelength from 400-2500nm

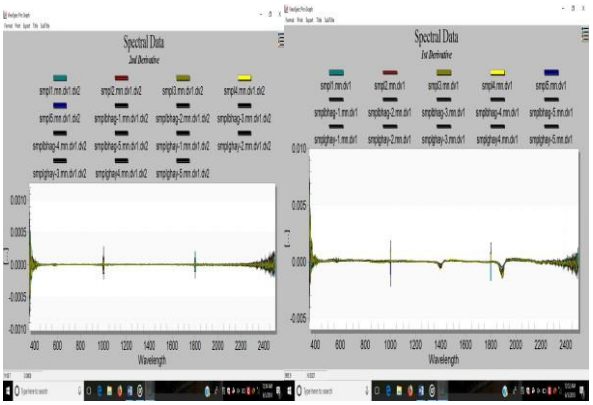


Figure 05(a,b): Ist and IInd Derivative

5. QUANTITATIVE MEASUEMENT OF SPECTRAL DATA

Table I. Shows quantitative measurement of soil spectral characteristics which is recorded by Field Spec4 Spectroradiometer and it consist of Soil characteristics, Average(Mean) ,Minimum value, Maximum Value ,Median and Std. Deviation. In figure 06 shows the Multiple axes Line plot for Water, Nitrogen, Carbon, and Phosphorus of below table for 35 soil samples.

TABLE I. STATISTICS OF SPECTRAL ANALYSIS OF SOIL SAMPLES

Sr.No	Soil Characteristics	Mean	Min	Max	Median	Std.Dev
1	Soil Moisture	0.055	0.029	0.164	0.052	0.021
2	Nitrogen	0.064	0.033	0.192	0.060	0.025
3	Carbon	0.065	0.033	0.184	0.061	0.024
4	Phosphorus	0.055	0.030	0.171	0.052	0.023

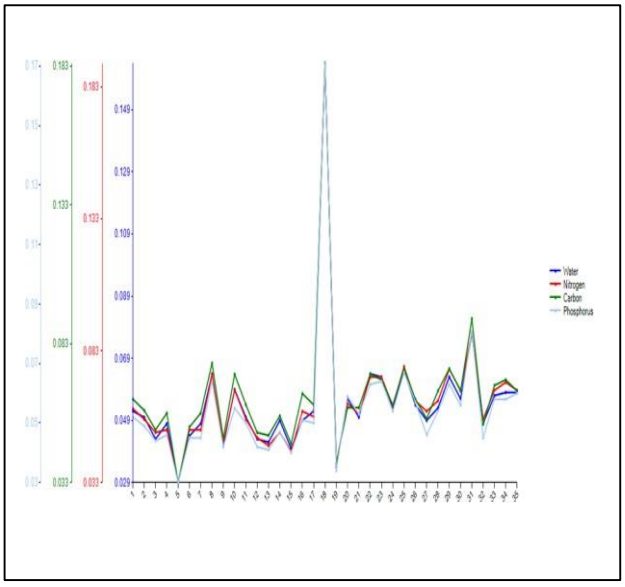


Figure06: Multiple axes Line plot for Moisture, Nitrogen, Carbon, and Phosphorus of all soil samples

6. RESULTS AND DISCUSSION

Partial Least Square Regression

Partial Least Squares Regression (PLSR), also sometimes referred to as Projection to Latent Structures or just PLS, models both the X- and Y-matrices simultaneously to find the latent (or hidden) variables in X that will best predict the latent variables in Y. In PLS loadings Moisture, Phosphorus and Nitrogen has a positive loading, it means that all samples of soil water, phosphorus and nitrogen with positive scores have higher than average values for that variable. All samples with negative scores have lower than average values for that variable .conversely soil carbon has a negative loading, it means just the opposite. All samples with positive scores have lower than average values for that variable. All samples with negative scores have higher than average values for that variable[20].

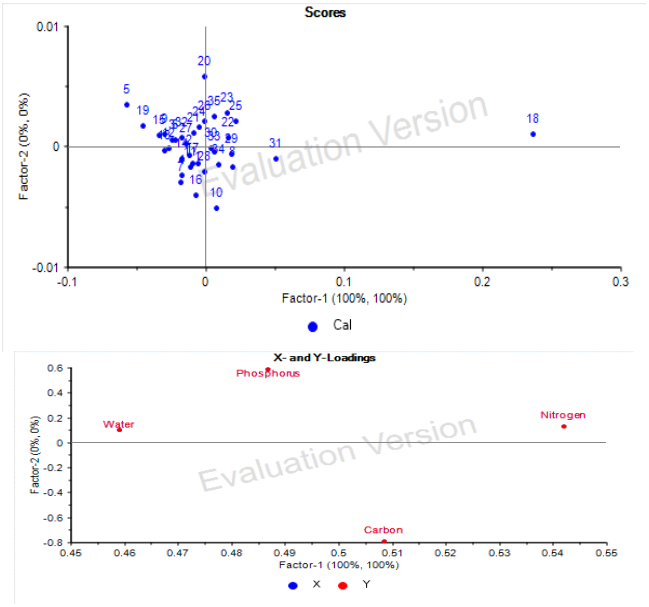
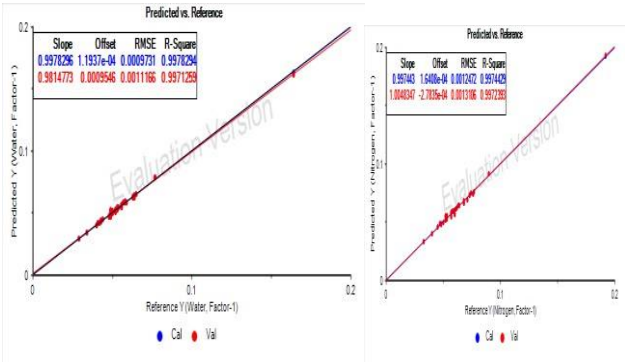


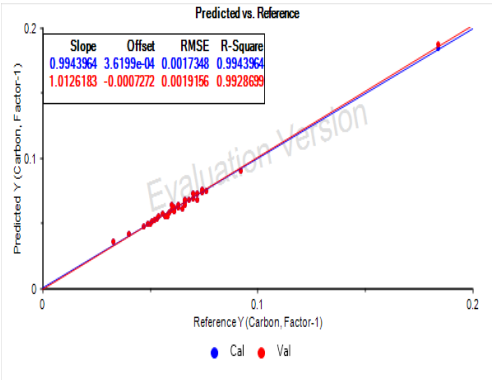
Figure 07: Interpretation of Partial Least Square Regression (with Score ,Weighted Regression Coefficients) for all soil samples.

7. A.PREDICTED VS REFERENCE PLOT FOR SOIL CHARACTERISTICS

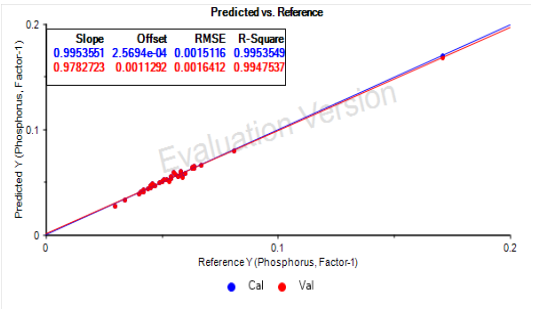
The selected predicted Y-value from the model is plotted against the reference Y-value[21].This is a good way to check the quality of the regression model. If the model gives a good fit, the plot will show points close to a straight line through the origin and with slope close to 1. Generally all the y-variables should be studied and give good results. The below fig shows the statistics of a predicted vs. reference plot with regression and target lines .It includes Slope ,Offset RMSE and R- Square. The given predicted vs reference plot shows that the given model gives good fit according to their slope value which is close to 1 which is given in statistical table.



(a) (b)



(c)



(d)

Figure 08:Predicted vs Reference plot using PLSR for Water(a),Nitrogen(b),Carbon(c) and Phosphorus contents(d).

8. CONCLUSION

The economy of India is based on agriculture which is a source of income for most of the people in India .This study assessed the effectiveness of Field Spec4 Spectroradiometer (VNIR-SWIR) reflectance spectroscopy is a very rapid and in- situ, nondestructive technology used to checking the soil macronutrients for improving soil quality as well as increasing agriculture productivity of study area

Vaijapur, Aurangabad
,Maharashtra. The data which is recorded by Spectroradiometer it gives noise in our soil spectra. We have apply preprocessing techniques like 1st and 2nd Derivative on soil spectral data. It gives good results So according to this study spectral preprocessing of ASD soil data is crucial to compare the soil parameters in better way. The wavelength 400-1000 nm1702,1870,2052nm, 2021-2025 nm , 2040-2260nm and 2240-2400nm gives high reflectance peak in soil spectral signature. At the end of the conclusion, the statistical assessment and classification techniques are gives good results in assessing and classifying soil macro parameters and also helps to improving agriculture sector.

9. ACKNOWLEDGMENT

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