Hyperspectral Analysis of Soil Total Nitrogen using PLSR Method: A Review

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Abstract

Today Indian economy is directly or indirectly depend upon the agricultural product. So the development of agriculture also helps to develop the Indian economy. Agricultural development is totally depends upon the healthy soil. Soil contain multiple micronutrients from which Nitrogen is an important micronutrients. It is important building block of proteins, nucleic acids and other cellular constituents which are essential for all forms of life. Measurement of total nitrogen content is necessary to improve the crop productivity. This paper uses Analytical Spectral Device (ASD) Field Spec 4 Spectroradiometer with 350-2500 nm wavelength band to find out total nitrogen content from the soil sample. The Vis-NIR reflectance spectroscopy require less effort and it is fast technology to find out the soil nitrogen content. For collecting the soil nitrogen content from spectral data we are using PLSR which is statistical method. In short this study uses Vis-NIR reflectance spectroscopy to calculate soil Nitrogen content.

Keywords: Total Nitrogen, Reflectance Spectroscopy, ASD field spec 4, Vis-NIR, PLSR
1. INTRODUCTION

Soil is one of the natural things present on the earth. Soil is just a thin layer of surface which is made up of unconsolidated material. The interconnected ecosystem which influences every landscape has these surficial components as vital components. A soil analysis is a process by which elements such as P, K, Ca, Mg, Na, S, Mn, Cu and Zn are chemically extracted from the soil and measured for their “plant available” content within the soil sample. Amongst the various nutrients obtained from soil, six nutrients are utilized in large amounts and hence are called as macronutrients. From these, nitrogen, phosphorus and potassium are the critical macronutrients, which are known as the most commonly deficient fertilizer elements. Of the macronutrients applied in fertilizers, nitrogen is one of the most important elements in farmland soil.

Nitrogen is necessary for all known forms of life on Earth. Wide variety of chemical forms of nitrogen present in the environment including organic nitrogen, ammonium, nitrite and nitrate. Organic nitrogen have the form such as living organism, humus or the intermediate products of organic matter decomposition. The nitrogen cycle clearly shows the transformation of nitrogen from one form to another, hence the monitoring of TN plays an important role in soil restoration programs [1].

All micronutrients in the soil must be present in proper content to improve the productivity. As the Nitrogen is the key component for plant growth. Excess amount of nitrogen may cause ground water contamination if leached with excess rain fall or irrigation. So the farmer must have the proper knowledge about soil Nitrogen content present in the soil, which will be beneficial to them to improve crop production.

Therefore there is necessary to develop the effective and sensitive tool to monitor and to evaluate soil properties to better understand their potential effects on productivity. There are many traditional techniques present to analyses the soil, but these are very time consuming methods and they have some limitations when these methods are applied to regional or global scale. Therefore there is need to develop the alternative tool, which is rapid and alternatively evaluate the spatial variability of soil. The ASD fieldspec 4 Spectoradiometer is one of the tool which is used to analyses the soil total nitrogen.

This paper describes the need of nitrogen content in the soil in section 2. Section 3 defines the Literature survey. Different algorithms are described in section 4. Section 5 defines some result obtained in previous studies.

2. NEED OF NITROGEN

Among all essential nutrients for plant, nitrogen is need in large quantity. In plant tissue the nitrogen content ranges from 1 to 6%. Amino acid is the building block of protein and for creation of all amino acids nitrogen is essential component. The formation of DNA of all living things is done by nucleic acids that are created from nitrogen. Nucleic acid also holds the genetic code. Chlorophyll is a component which gives green color to plant, chlorophyll is also component of nitrogen. Photosynthesis will occur at high range if there is sufficient amount of nitrogen. So we can say that
nitrogen has more influence on tree growth, fruit productivity and its quality than any other nutrients. Nitrogen is necessary for the formation of organic compound structure and new cells.

3. LITERATURE REVIEW

Stephan Gmur, Daniel Vogt, Darlene Zabowski and L. Monika Moskal[2] states that, Classification and regression tree are statistical methods in which regression tree uses concentrations of nitrogen, carbon, carbonate and organic matter as the response variable to fit each spectral response in tree. They found the nitrogen response at 403, 470, 687, and 846 nm spectral band widths. According to author the regression tree provides rapid, inexpensive and powerful method for assessing nitrogen in 400 to 1,000 nm electromagnetic range. Regression tree is a nondestructive method used to find the nitrogen from upper soil horizons.

Lixin Lin, Yunjia Wang, Jiyao Teng and Xiuxiu Xi [3], these author used the LCMCS Method(local correlation maximization-complementary superiority method) to establish TN prediction models. They consider the relationship between spectral reflectance (measured by an ASD FieldSpec 3 Spectroradiometer) and TN based on spectral reflectance curves of soil samples collected from subsided land. These subsided land samples were determined by synthetic aperture radar interferometry (InSAR) technology. Authors states that the LCMCS method has great potential to monitor TN in subsided lands. The subsided land caused by the extraction of natural resources including groundwater, oil and coal.

Sneha J. Bansod and Shubhadha Thakre[4], uses Near Infrared Spectroscopy to measure soil nitrogen. NIRS is the is the rapid, non-destructive analytical technique which allows the simultaneous estimation of standard soil characteristics and does not require the use of chemicals.

X M Shu, T Z Shi, Y Liu, H W Peng, W X Gao, and C Zhang [5], author uses visible near infrared spectroscopy and combine with multiple regression method have been employed to assess various soil properties quantitatively. According to author Successive projections algorithm (SPA) is an effective technique for selecting informative variables, and its application potential in estimating soil contents using visible/near infrared reflectance (Vis/NIR) spectroscopy has not been explored.

Ramdas D. Gore, Reena H. Chaudhari, and Bharti W. Gawali[6], uses a technique for classification of soil spectral signature known as Linear Discriminant Analysis(LDA). This technique classifies the chemical properties of soil spectral signature. They found soil structure of Marathwada region comes under slit clay loam. They found 75% nitrogen content in their selected soil sample.

LIU Xiang, GUO Yan, WANG Qian-long, ZHANG Jian, SHI Zhou[7], authors uses visible near infrared spectra (vis-NIR) for mapping soil available nitrogen. Soil available nitrogen (AN) is closely related to soil fertility and quality, assessing its content and mapping the spatial variability greatly satisfies precision agriculture.
Snehal N. Kulkarni, Dr. Ratnadeep R. Deshmukh [8], they use reflectance spectroscopy to determine the spectral signature of agricultural soil.

Xiaoting Peng, Tiezhu Shi, Aihong Song, Yiyun Chen and Wenxiu Gao[9], according to the author the combination of SPA and SVMR is reliable to estimate the soil organic content and also help to find the soil nitrogen. For that they use VIS/NIR of different soil types.

Rahul B. Kharat, Dr. Ratnadeep R. Deshmukh[10], found the nitrogen from the leaf of tomato plant. For that they use vegetation indices. These vegetation indices are crop reflectance indices collected from ASD field spec 4.

Shuo Li, Wenjun Ji, Songchao Chen, Jie Peng, Yin Zhou and Zhou Shi[11], according to authors the traditional methodology for nitrogen fertilizer rate (NFR) is very expensive and also time consuming so they evaluate the visible near-infrared shortwave-infrared (VIS-NIR-SWIR: 400–2500 nm) spectroscopy to determine the NFR. They use partial least squares regression (PLSR), locally weighted regression (LWR), and support vector machine discriminant analogy (SVMDA) methods to estimate the soil nitrogen.

Z. Sh, W. Ji, R. A., Vis car ra Ros s e l, S. Chen & Y. Z ho u[12], the author uses the vis-NIR spectral libraries to predict the soil properties from new spectral readings. They test the local regression method which combine the geographical subsisting with local-PLSR. They use the limited number of similar vis-NIR spectra(K-nearest neighbour).

Ramdas D. Gore, Sunil S. Nimbore, Bharti W. Gawali[13], they use the Spectroradiometer to develop the soil spectral signature. For that they use Visible Near Infrared, Short Wave Infrared and Mid-wave Infrared spectral reflectance of soil sample. According to author PCA and PLSR algorithms are widely used to extract the information of soil properties.

D. Curcio, G. Ciraolo, F. D’Asaro, M. Minacapilli[14], they use VIS/NIR (VNIR 400-1200 nm) and SWIR(1200-2500 nm) reflectance domain to predict the soil properties. According to author PLSR is classical statistical multivariate technique which uses the full reflectance spectra. They uses ASD fieldspec pro(350-2500 nm).

Changwen Du, Jianmin Zhou[15], according to authors soil properties like C, P, N are used to determine the soil fertility. They use the infrared spectroscopy as an alternate method to laboratory analysis, which is used to determine the soil properties. Most of the soil related research is depend upon the reflectance spectroscopy, and IR reflectance which is used here is quantitative. They use diffuse reflectance spectra and total attenuated reflectance spectra to analyse the soil quantitative properties.

R.A. Viscarra Rossel, T, D.J.J. Walvoort, A.B. McBratney, L.J. Janik, J.O. Skjemstad[16], authors use the diffuse reflectance spectroscopy, which is good alternative to traditional soil analysis method. They use the VIS,NIR,MIR ryes to analyse the soil properties. They use PLSR algorithm to calculate the soil properties in VIS,NIR,MIR. More accurate prediction is obtain using MIR.
Hyen Chung Chun, Suk Young Hong[17], author uses the Korean soil to predict the soil organic matter using Vis-NIR spectroscopy. They use ASD fieldspec pro to take soil reflectance spectra. They use PLSR and regression rules model to calculate soil OM. They develop the good prediction model for Soil OM in Korean soil.

Antonio P. Leone, Raphael A. Viscarra-Rossel, Pietro Amenta3 and Andrea Buondonno[18], they selected the southern Italy area to calculate the soil properties. They use the PLSR algo and Vis-NIR spectra to analyze the soil properties. By using Vis-NIR they predict physical and chemical properties such as sand, slit, clay, organic carbon, total Nitrogen etc.

Fikrat Feyziyev, Maharram Babayev, Simone Prior2, Giovanni L’Abate[19], according to the authors the Vis-NIR is very effective, rapid soil analysis process and also it is not hazardous to environment. They determine the soil properties of the soil sample collected in Mugan Plain. They use the PLSR model to monitor total carbonate and soil electrical conductivity.

Harm Bartholomeusa, Michael Schaeplman, Lammert Kooistra, Antoine Stevens, Willem Hoogmoed, Otto Spaargaren[20], the author concentrate on soil organic carbon. Like lignin and cellulose SOC is also a biochemical constituents. They make use of remote sensing spectral indices to calculate the SOC from soil sample. Estimation of SOC with remote sensing is mostly based on the overall decrease in reflectance in the reflective part of the spectrum.

4. ALGORITHMS
The next section describes the different methods and algorithms used to determine the soil total nitrogen content.

a) Principle component Regression (PCR):

The basic idea of PCR is calculate principle components and use of them as predictor in linear regression model. PCR is two stage processes. 1) PCR minimizes the number of independent components. These components required to describe the variation between the spectra and entire spectrum. It is method of data reduction. it enables the thousand spectral points to be reduce to few principal components and these PCs describe spectral variance across all the samples. 2) These components are regressed against known property data and then calibration model.

b) Partial List Square (PLS): The difference between PCR and PLS is that PLS uses known property data and spectral data both during the calculation of principle components. The advantage of PLS is reducing the noise and detecting unknown samples which are not represented by calibration model. It also reduces the Wavelength section.
c) **Wavelet Analysis**: The limitations of Fourier transform are overcome by Wavelet analysis. Wavelet analysis uses the scaled and shifted version of base function known as mother wavelet. These mother wavelet are also local and finite. They make the ideal waves for approximating signal with sharp peaks and discontinuities. It is important to select the proper mother wavelet which represent the general shape of signal.

**d) Artificial neural network modelling:**

Artificial neural network is a method which use non-parametric attempt to model of the human brain. ANNS provides the method characterize synthetic neurons to solve complex problems in the same manner as the human brain does.

**e) Linear Discriminant analyses (LDA):** Using LDA, within-class scatter to between class scatter ratios can be minimize. LDA is simple and mathematically robust algorithm. To define the scatter of samples around the respective class center, the within-class scatter matrix is used.

5. **RESULT AND DISCUSSION**

Stephan Gmur, Daniel Vogt, they use the regression tree to find out the Nitrogen, carbon, carbonate and organic matter from the given soil sample. They collect the soil samples from different horizons of Washington and Oregon cites. They use filed spec Spectroradiometer to measure their spectral signature. The statistic result obtained from the fitted tree for nitrogen is $R^2 = 0.91$ (p < 0.01) at 403, 470, 687, and 846 nm spectral band widths. For carbonate $R^2 = 0.95$ (p<0.01), total carbon $R^2 = 0.93$ (p<0.01), organic matter $R^2 = 0.98$ (p < 0.01).

Author Lixin Lin, Yunjia Wang uses LCMCS method to find out the total nitrogen from subsided land. They collect total 1655 samples and observe their reflectance spectra using ASD fieldspec 3. They got the calibration ($R^2 = 0.90$, RMSEC = 0.269 and MREC = 1.446) and validation ($R^2 = 0.885$, RMSEV = 0.898 and MREV = 5.921).

6. **CONCLUSION**

In this paper we have discussed different soil minerals, among which Nitrogen is very essential for crop production. So we analyze different method’s which are used for detecting the Soil Nitrogen. We compare all these methods, and concluded that PLSR method is best suitable for calculating soil Total Nitrogen. In this study we are using spectroscopy which has vast application in different field like dairy industry, meat industry, etc. In spectroscopy the characterization of martial is depend upon the obtained reflectance. That’s why we are using spectroscopy to analyze the soil nitrogen content.
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8. REFERENCES


