International Journal of Advance Research in Science and Engineering
Vol. No. 5, Issue No. 08 , August 2016
www.ijarse.com
IJARSE
ISSN 2319 - 8354

Measurement of soil attributes using NIR spectroscopy : A review

BabanKumar S. Bansod[1], RitulaThakur[2], Vikash[2],Neha Kamboj[2]

[1]CSIR- Central Scientific Instruments Organisation, Sector 30-C, Chandigarh, (India)

[2]NITTTR- National Institute of Technical Teachers Training and Research, Chandigarh, (India)

ABSTRACT

Soil fertilizer management is important to adjust the soil fertility by supplying fertilizers at optimum level to achieve maximum yield at minimum environmental risks. Precision agriculture demands to develop better cost and time efficient methodologies for analysis of soil properties. Besides conventional techniques, sometimes spectroscopy is more accurate, fast, non-destructive and inexpensive analytical technique. Diffused reflectance measurement in the NIR region (780-2500 nm) is involved in NIRS (near infrared reflectance spectroscopy) and this is highly sensitive to both inorganic and organic phases in soil. Quantitative analysis for prediction of various soil properties and components involves NIR spectra calibration against some reference value by using some prediction model (e.g. ANN (Artificial neural network) or MPLS (Modified Partial Least Square Regression)).The goal of this paper is to review the results, modelling methods, hardware and software involved to measure various attributes of soil using NIR spectroscopy.

Keywords- NIRS, Precision Agriculture, Soil properties, Spectroscopy.

I. INTRODUCTION

Measurement of soil properties by means of conventional methods is expensive, time consuming and complex when large numbers of samples are needed. Perhaps a possible substitutes to improve the conventional laboratory methods for analysis of soil properties are the spectroscopic techniques (e.g. nuclear magnetic resonance (NMR), near-infrared (NIR), mid-infrared (MIR), visible (VIS) spectroscopy and mass spectroscopy)[1]. Spectroscopic techniques preserve the integrity of the soil system due to their non-destructive nature. Near infrared reflectance spectroscopy (NIRS) having electromagnetic spectrum region from 780-2500nm wavelength is highlighted in Fig.1. Simultaneous characterisation of multiple soil attributes, in particular with infrared spectroscopy is permitted by a single spectrum. Less time consuming, in expensive and need for a little or no sample preparation are some other advantages of NIR spectroscopy over conventional techniques of soil analysis [2]. NIR spectra of soil consists of tones and combinations of fundamental bands for N-H, C-H and O -H bonds and results from stretching, twisting, scissoring or bending of different chemical bonds [3].Near-infrared (NIR) spectra is also influenced by the physical as well as the chemical properties of a material. The length of transmission of light through a sample is affected by the shape, size, arrangement and the voids between particles of the sample under observation and hence it influences the reflectance[4].

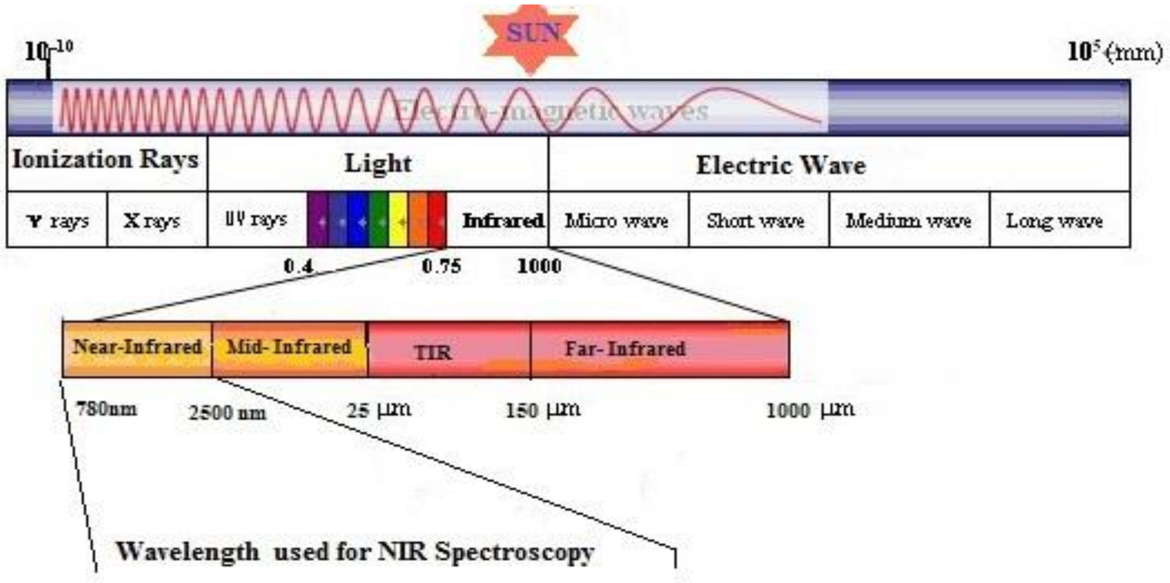

Figure 1- EM spectrum highlighting NIR portion

II. QUANTITATIVE ANALYSIS OF SOIL SPECTRA

It is impossible to interpret the NIR spectra directly. A statistical treatment is required for each NIR data[5]. A mean centring technique is used to normalize the spectral data and it can be variance scaled. 1st and 2nd derivative of spectra is computed to reveal information hidden in spectral data. Derivative filters (e.g. Savistky-Golay or Norris) can be used for smoothing the optical signal. It helps to reduce spectral noise and scattering corrections like MSC and SNV [6]. Statistical tools are implemented for spectral data analysis after pre-treatment.

Various Statistical Techniques to relate the spectral data with the soil properties

There are lot of techniques used by the researchers to relate soil attributes to spectra obtained from soil. For e.g., MRA (multiple regression analysis) was used by Ben-Dor Banin (1995)[7] to relate various properties of soil to specific bands in NIR. SMLR (stepwise multiple linear regression) was used by Shibusawa et al. (2001)[8] for estimating a number of soil properties from the NIR spectra obtained from the soil by an on-the-go field installed sensing system. MARS (Multivariate adaptive regression splines) was used by Shepherd and Walsh (2002) [9] for estimating soil properties from available soil libraries. RBFN (radial basis function network) was employed by Fidencio et al. (2002) [10] to detect OM contents of soil from the spectra obtained in near infra-red region. ANN (artificial neural network) was used by Daniel et al. (2003) [11] to evaluate soil OM, P and K from the VIS-NIR spectra. However the most widely used prediction techniques or spectral calibration technique are PCR (principal components regression) and PLSR (partial least square regression) used by Chang et al. (2001) [12] and McCarty et al. (2002) [13] respectively. BP-NN(back propagation neural network) was used by XiaofeiAn et al. (2013) [14] to estimate soil attributes from a NIR spectra.

A local methodology for calibration of NIR prediction has attracted attention recently [15] [16] [17][18]. Within spectral classes, a local calibration is predicted and defined either directly upon soil texture groups, land use or soil type or on Mahalanobis distances (statistical distance among spectra). The Mahalanobis distance of an

IJARSE
ISSN 2319 - 8354

observation $\vec{x} = (x_1, x_2, x_3, \ldots \ldots .. x_n)^T$ from a set of observations with mean $\vec{\mu} = (\mu_1, \mu_2, \mu_3, \ldots \ldots .. \mu_n)^T$ and covariance matrix S is shown by (1):

$$D_M(\vec{x}) = \sqrt{(\vec{x} - \vec{\mu})^T S^{-1} (\vec{x} - \vec{\mu})} \quad \text{………….Equation 1 [27]}$$

Assessment of the quality of NIR prediction model can be done with various indices [5].R^2(the coefficient of determination), SEP(standard error of prediction) and RPD (ratio of performance to deviation), where R^2- the coefficient of determination is as shown by (2):

$$R^2 = \frac{(\sum_{i=1}^{n} d_{xi} d_{yi})^2}{\sum_{i=1}^{n} d_{xi} \sum_{i=1}^{n} d_{yi}} \text{………….Equation 2}$$

Where,
dx is the standard deviation of x
dy is the standard deviation of y

III. INFERENCE AND DISCUSSION

NIRS (Near infra-red diffuse reflectance spectroscopy) technology is a good tool to detect various soil attributes with a considerable accuracy by using various prediction techniques. TABLE 1shows the value of R^2 obtained while measuring various soil properties by using different prediction models. The study shows that various methods of pre-processing the data are employed to enhance the robustness, reliability and performance of the prediction model. Spectroscopic analysis of soil properties in laboratory is simple, non-destructive and accurate method which does not require a complex procedure to prepare soil samples for testing. The only disadvantage is that the whole testing system consists of a very costly set-up and it is lab based only. Keeping in view the small farmers who have small and scattered land for farming and their ignorance towards bringing soil samples to laboratory for testing, there is a need to develop a cheap on-the go system based on the above said technology to detect soil macro-nutrients , so that Indian farmers can be benefitted in order to improve the crop production.

Table 1- A detailed study of prediction techniques and hardware used to detect various soil attributes by means of NIRS.

S.No	Authors	Soil attributes measured
1	Cheng-wen Chang et al., 2001	33 various properties
2	Yong He et al., 2007	N, P, K, OM and pH
3	Joel B Sankey et al., 2008	Clay contents , SOC contents
4	H.T.Xie et al., 2010	SOC, TN
5	V.Genot et al., 2011	TOC, TN, Clay content
6	M.Todorova et al., 2011	TN, pH
7	Xiaofei An et al., 2012	TN, Moisture
8	YandanQia et al., 2012	OM, N,P,K
9	Xiuying Liang et al., 2012	Soil moisture
10	M. Rabenarivo et al., 2013	C, N

No. of samples taken	Device Used	Software used	Prediction Model used	r2 values
802	Perstrop NIR System 6500 scanning manochromator (Foss NIR Systems , Silver Spring , MD) 1300-2500nm		Principal Component Regression, Least Square method	C=0.87, N=0.85, K=0.55, P=0.40,pH=0.55
135- calibrat. 30- validation	FieldSpec Pro FR (350-2500nm)/A110070 Trademark of ASD	Unscambler 8.0 (CAMO, ASA, Norway)	Principal Component Analysis , PLS Method	N=0.93 , K=0.68,P=0.47, OM=0.93, pH=0.91
clay=234, soc=118	FieldSpec Pro FR (350-2500nm)/A110070 Trademark of ASD	Unscambler 8.5 software Package	PLSR, BRT	SOC= 0.89 , Clay Contents=0.38
239- calibrat. 78- validation	Bruker-TENSOR 37 Spectrometer (Bruker Optics GmbH, Ettlingen, Germany) 1250-2500nm	OPUS QUANT2 Software (Bruker Optics GmbH, Germany)	PLSR	SOC=0.97, TN= 0.97
1300	Foss NIR Systems 5000 Spectrophotometer (Laurel, MD, USA)		Modified Partial Least Square (MPLS) Regression method	nearly 15% error
65- calibrat. 32- validation	Perkin Elmer Spectrum one NTS, FT-NIR Spectrometer (700-2500nm)		PLS regression Method	TN=0.81, pH=0.82
36- calibrat. 12- validation	Matrix-I type of FT-NIR analyser (spectral measure range781-2779 nm)		Single Linear Regression Analysis, BP N N and SVM Method	TN= 0.89, Moisture= 0.88
40- calibrat. 14- validation	FieldSpec Pro FR (350-2500nm)/A110070 Trademark of ASD		Principal Component Analysis , LS-SVM	OM=0.87, N=0.72, P=0.84, K=0.69
116	NIR Spectrophotometer (Oceanoptics NIR-256-2.5) 900-2550nm		Single Linear Regression Analysis	0.99
150- calibrat. 56- validation	Foss NIR Systems 5000 Spectrophotometer (Silver Spring, MD, USA)	WinISI III-V.1.61 Software (Infrasoft Intl, LCC, PA, USA)	PCA, PLS Method	C= 0.97, N= 0.93

REFERENCES

[1] Janik,L.J.,Merry, R.H., Skejemstad, J.O., Can mid infra-red diffuse reflectance analysis replace soil extractions?Australian Journal of Experimental Agriculture, 38(7), 1998, 681-696.

[2] R. A. ViscarraRossel, D. J. J. Walvoort and A. B. McBratney, Visible near infrared, mid infrared or combined diffuse reflectance spectroscopy for simultaneous assessment of various soil properties, Geoderma, vol. 131, 2006, 59-75.

[3] Ludwig, B. &Khanna, P. K., Use of near infrared spectroscopy to determine inorganic and organic carbon fractions in soil and litter, Lewis publ., Chapter 25, 2001, 361-370.

[4] Wetzel, D. L., Near-infrared reflectance analysis, sleeper among spectroscopic techniques, Analytical Chemistry 55,12, 1983, 1165-1176.

[5] Fearn, T., Assessing calibrations: SEP, RPD, RER and R^2, NIR news, 13(6), 2002, 12-14.

[6] L.Cecillon and J. –J. Brun, Near-infrared reflectance spectroscopy(NIRS): a practical tool for the assessment of soil carbon and nitrogen budget, Greenhouse-gas budget of soils under changing climate and land use(Burnout), cost 639, 2006-2010, 103-110.

[7] Ben-Dor, E., Banin A., Near-Infrared analysis as a rapid method to simultaneously evaluate several soil properties, Soil sci. soc.Am. J., 59, 1995, 364-372.

[8] Shibusawa, S., ImadeAnom, S.W., Sato, S., Sasao, A., Hirako, S., Soil mapping using the real-time soil spectrophotometer, ThirdEuropean Conference on Precision Agriculture, vol. 1, Agro Montpellier, 2001, 497-508.

[9] Shepherd, K.D., Walsh, M.G., Deelopment of reflectance spectral libraries for characterization of soil properties, Soil sci. soc.Am. J., 66, 2002, 988-998.

[10] Fidencio, P.H., Poppi, R.J., De Andrade, J.C., Cartella, H., Determination of organic matter in soil using near infrared spectroscopy and partial least square regression, Commun. Soil Sci. Plant Anal., 33(9-10), 2002, 1607-1615.

[11] Daniel, K.W., Tripathi, N.K., Honda, K., Artificial neural network analysis of laboratory and in situ spectra for the estimation of macroneutrients in soil of Lop Buri (Thailand), Australian Journal of soil Research, 41, 2003, 47-59.

[12] Chang, C.-W., Laird, D.A., Mausbach, M.J., Hurburgh Jr., C.R., Near-infrared reflectance spectroscopy-principal components regression analysis of soil properties, Soil Science Society of America Journal, 65, 2001, 480-490.

[13] McCarty, G.W., Reeves III, J.B., Reeves V.B., Follett, R.F., Kimble, J.M., Mid-infrared and near-infrared diffuse reflectance spectroscopy for soil carbon measurement, Soil Science Society of America Journal, 66, 2002, 640-646.

[14]XiaofeiAn, Minzan Li andLihuaZheng, Estimation of soil total nitrogen and soil moisture based on NIRS technology,IFIP AICT, 369, 2012, 639-647.

[15] Brunet, D., Barthes, B., Chotte, J.L. & Feller, C., Determination of carbon and nitrogen contents in Alfisols, Oxisols and Ultisols from Africa and Brazil using NIRS analysis: Effects of sample grinding and set heterogeneity, Geoderma, 139 (1-2), 2007, 106-117.

[16]Dardenne, P., Sinnaeve, G. &Baeten, V., Multivariate calibration and chemometrics for near-infrared spectroscopy: which method?, Journal of Near Infrared Spectroscopy 8, 2000, 229-237.

[17] Genot, V., Colinet, G., Dardenne, P., Bah, B., Legrain, X. & Bock, L., Etude de la performance de la spectroscopieprocheinfrarouge pour la mesure de caracteristiques du sol necessaires au counseil de fumure, Actes des 9emes journeesNationales de l'Etude des Sols, AFES, Angers France, 2007, 379-380.

[18] vanWaes, C., Mestdagh, I., Lootens, P. &Carlier, I., Posibilities of near infrared reflectance spectroscopy for the prediction of organic carbon concentration in grassland soils, Journal of Agricultural Science 143, 2005, 487-492.

[19] He,Y., Song, H.Y., Annia, G.P., A new approach to predict N,P,K and OM content in a loamy mixed soil by using near infrared reflectance spectroscopy, Lecture Notes in Computer science, 3644, 2005, 859-867.

[20] Yong He, Min Huang, Annia Garcia, Antihus Hernandez, Haiyan Song, Prediction of soil macronutrients content using near-infrared spectroscopy, Computers and Electronics in Agriculture, 58, 2007, 144-153.

[21] M.Rabernarivo, L. Chapuis-Lardy, D. Brunet, JL. Chotte, L. Rabeharisoa, B.G. Barthes, Using Near infrared reflectance spectroscopy for the determination of organic and biological properties in Malagasy soils, NIR Proceedings, Agriculture and environment, La Grande-Motte, France, 2013, 236-239.

[22] H. T. Xie1, X. M. Yang, C. F. Drury, J. Y. Yang, and X. D. Zhang, Predicting soil organic carbon and total nitrogen using mid- and near-infrared spectra for Brookston clay loam soil in Southwestern Ontario, Canada, Can. Journal for Soil Sci. 91, 2011, 53-63

[23] M.T odorova, S.Atanassova, H.Lange, D.Pavlov, Estimation of total N, total P, pH and electrical conductivity in soil by near-infrared reflectance spectroscopy, AGRICULTURAL SCIENCE AND TECHNOLOGY, 3(1),2011, 50 – 54.

[24] YandanQiao, Shujuan Zhang, Near-infrared spectroscopy technology for Soil nutrients detection based on LS-SVM, 5th IFIP CCTA, Advances in information and communication Technology, 2011, 325-335..

[25] Xiuying Liang, Xiaoyu Li, Tingwu Lei, A new NIR technology for Rapid Determination of Soil Moisture Content, International conference on Systems and Informatics, 2012, 16-20.

[26] Madari, B.E., Reeves, J.B., III, Machado, P.L.O.A., Guimaraes, C.M., Torres, E. and McCarty, G.W., Mid and near –infrared spectroscopic assessment of soil compositional parameters and structural indices in two Ferralsols, Geoderma, 136, 2006, 245-259.

[27] De Maesschalck Roy, Jouan-Rimbaud Delphine, Massart Desire L, The Mahalanobis distance, Chemometrics and Intelligent Laboratory Systems, 50, 2000, 1-18.