International Journal of Engineering Research and General Science Volume 3, Issue 6, November-December, 2015
ISSN 2091-2730

Understanding Soil Spectral Signature Though RS and GIS Techniques

Ramdas D. Gore[1], Sunil S. Nimbhore[2], Bharti W.Gawali[3]
Department of Computer Science and Information Technology[1,2,3],
Dr. Babasaheb Ambedkar Marathwada University, Aurangabad[MH], India.
ramdasgore@yahoo.com[1], nimbhoress@gmail.com[2], bharti_rokade@yahoo.co.in[3], cont: 9423744454[1]

Abstract –This paper reports the development of the soil spectral signature using Spectroradiometer form Visible Near Infrared, Short Wave Infrared and Mid-Infrared spectral reflectance of soil. Soil properties such as amount of carbon, nitrogen, phosphorus, potassium, sand, silt, and clay contains have been determined by using hyperspectral band models, in the wavelength band of 350-2500nm. Different mathematical models such as, Principal component analysis (PCA) and partial least square regression (PLSR) have widely been used to extract information regarding soil properties. This review article analyzes the reference work from 2005 to 2015.

Keywords- Agriculture; Spectral signature; Spectroradiometer; PLSR**.**

INTRODUCTION

The resent developments in the field of Geographical information system (GIS) and Remote Sensing (RS) has opened many real life applications in various domains. GIS is a computer system for capturing, storing, manipulate, analyzing, managing, checking and displaying geospatial data on the map. It is very easy to analyze, understand patterns and its relationship. It refers location (spatial data) and characteristics (attribute data). We can compare location throughout latitude and longitude (X and Y coordinate) [1]. Remote sensing is the skill of gaining data about the Earth's surface without physical touch with it. Sensors are used to record reflected and emitted energy and also for processing, analyzing the data which will be used for further analysis. Reflection depends on the objects or Earth's surface, if the object is smooth, then the reflection will be specular reflection. If the object is rough, it will be diffused reflection [2]. The collection of information depends upon these factors. Remote sensing technology is an effective means to monitor targets. Using these both technologies, these techniques can be applied to many areas as follows.

A. Agriculture

In the agriculture area there are various applications such as crop monitoring, crop classification, crop yield estimation, crop condition assessment, crop identification/ classification, soil characteristics and management [2].

B. Forestry

In this area there are various applications such as forest cover discrimination, Agroforestry mapping, clear cut mapping, burn delineation, infrastructure mapping, forest inventory, biomass estimations, species inventory and classification and types, deforestation or forest degradation, watershed protection, coastal protection and forest health [2].

C. Geology

Geology is used to support logistics. There are geological applications such as surficial deposit/ bedrock mapping, lithological mapping, structural mapping and terrain analysis, sand and gravel exploration, mineral exploration, hydrocarbon exploration, environmental geology, geobotany, baseline infrastructure, sedimentation mapping and monitoring, event mapping and monitoring, geo-hazard mapping and planetary mapping [2].

D. Hydrology

It is the study of water on the Earth's surface. It includes applications such as wetlands mapping and monitoring, soils moisture estimation, snow pack monitoring/ delineation of extent, measuring snow thickness, determining snow-water equivalent, river and lake ice monitoring, flood mapping and monitoring, glacier dynamics monitoring, river/ delta change detection, drainage basin mapping and watershed mapping, irrigation canal leakage detection, irrigation scheduling and sea ice information (ice concentration, ice type/ age/ motion, iceberg detection and tracking, surface topography, tactical identification of leads: navigation: safe shipping routers/ rescue, ice condition (state of decay), historical ice and iceberg conditions and dynamics for planning purposes, wildlife habitat, pollution monitoring, meteorological/ global change research) [2].

E. Land use and land cover

It is used interchangeably. There are including various applications such as land use change (Rural/ Urban), land cover/ biomass mapping, natural resource management, wildlife habitat protection, baseline mapping for GIS input, urban expansion/ encroachment, routing and logistics planning for seismic/ exploration/ resource extraction activities, damage delineation (tornadoes, flooding, volcanic, seismic, fire), legal boundaries for tax and property evaluation and target detection- identification of landing strips, roads, clearings, bridges, land/ water interface [2].

F. Ocean and coastal monitoring

It is important link in the Earth hydrological balance, CO^2 storage and weather system, there are various application such as ocean pattern identification (currents, regional circulation patterns, shears, frontal zones, internal waves, gravity waves, eddies, upwelling zones, shallow water_bathymetry), storm forecasting (wind and wave retrieval), fish stock and marine mammal assessment (water temperature monitoring, water quality, ocean productivity, phytoplankton concentration and drift, aquaculture inventory and monitoring), oil spill (mapping and predicting oil spill extend and drift, strategic support for oil spill emergency response decisions, identification of natural oil seepage areas for exploration), shipping (navigation routing, traffic density studies operational fisheries surveillance, near-shore bathymetry mapping), intertidal zone (tidal and storm effects, delineation of the land/ water interface, mapping shoreline features/ beach dynamics, coastal vegetation mapping, human activity/ impact) [2].

The objective of this paper is to report studies done in the area of soil using GIS and RS. Soil area is vital part of environmental, wildlife, human well-being and other thinks. Soils are essential products of the nature and without which there would be no life. Soils are made up of minerals, organic matter and components living organism's components. The percentage of these is important in determining the type of soils. Other factors such as climate, vegetation, the surrounding terrain, even human activities are also important in influencing formation of soil [3].

There is number of reasons, for the difference in soil in various regions. The most influential factors include the parent material, climate and terrain of the region, as well as the type of plant life, vegetation and present human influence. Soil health gives greater emphasis on soil biodiversity and ecological functions that makes soil dynamic living resources with capacity for self-organization. Soil quality is the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, to maintain water and air quality and support human health and habitation. Ecosystem depends on the soil. There are three types of soil properties classified in physical, chemical and biological.

Horizonation is soil physical property. It has layers like topsoil [0-20cm], subsoil and parent soil. Soil texture is one of the soil physical properties like sand, silt and clay. Consistence and bulk density are the soil physical properties. It is defined soil is dry, wet or moisture. Soil spectral signature can change as par the physical properties [6-8].

It is the interaction of various chemical components that takes place among soil particles like carbon, calcium, iron oxide, magnesium, nitrogen, pH, phosphorus and potash. It is very important for soil quality analysis. Soil quality is also depending on chemical properties. It is checked by the spectral signature [9, 10].

Soil samples have been studies in the laboratory for getting different properties of the soils [11]. They are scanned to get absolute reflectance corresponding to the samples. [12-14].

SOIL ANALYSIS USED SPECTRORADIOMETER

This review paper focuses on keywords such as diffuse reflectance spectroscopy, FieldSpec, soil spectral library, NIR, Mid-Infrared spectroscopy, spectrometer, and Spectroradiometer appears in its title, abstract or keywords. The work described more soil spectral library. There were a few papers that only reported pretreatment or pre-processing and classification. The hyperspectral tools are used in table 1, are presented.

TABLE 1. HYPERSPECTRAL TOOLS

Tools	Range	Reference ID
FieldSpec TM FR Spectroradiometer	350-2500 nm	[3, 31, 38, 39, 40,]
FieldSpec Pro FR spectrometer	350-2500 nm	[4, 25, 27, 30]
FieldSpec Spectroradiometer	350-2500 nm	[5, 6, 12, 20]
FT-NIR Spectrometer	700-2500 nm	[6]

FieldSpec 3 Spectroradiometer	350-2500 nm	[8]
ISCO S.R. Spectroradiometer	24 channels	[9]
AvaSpec spectrometer	200-1050 nm	[10]
Vis/NIR spectrophotometer (Tech5 Germany)	350-2500 nm	[11]
IRIS sensor and Lansat-TM (1-5, 7)	400-2500 nm	[13]
FieldSpec Pro	350-2500 nm	[15, 16]
MIR spectrum	400-4000 $cm-1$	[17]
Field Spectroradiometer	350-2500 nm	[18]
FieldSpec Pro FR (handheld)	325-1075 nm	[19]
Photoacoustic Spectroscopy (MIR spectrum)	400-4000 $cm-1$	[23]
Tensor 37 FT-IR spectrometer	400-4000 $cm-1$	[24]
NIRS	700-2500 nm	[26]
UV-VIS-NIR	350-3500 nm	[28]
BioRad FTS 175	1200-20000 nm	[28]
LI-1800 Spectroradiometer	400-1100 nm	[29]
LabSpec 2500 spectrometer	350-2500 nm	[32, 33, 34]

A. FieldSpec spectroradiometer

Soil samples are collect from the ASD FieldSpec sensor. It is scanned and absolute reflectance of samples is recorded for 350-2500 nm 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 (350-1000nm) @ 350-1000 nm and 2 nm (1000-2500nm) @ 1000- 2500 nm. The total number of 2151 data points per spectrum using a FieldSpec, FieldSpec Pro and FieldSpec FR Spectroradiometer (Analytical Spectral Devices Inc., Boulder, Colorado, USA). It uses air-dry soil samples and halogen lamp light source is held inside it. Reflectance records, though the samples with constant angle at distance from sensor and after 3-5 successive readings, each average of ten successive reflectance spectra. The sample can be rotated 90 and 360 degrees and placed on petri plates. The spectral reflectance of soil samples was measured in VNIR and SWIR region [15-19].

It can be see in table 1, that wavelength ranges from 350 to2500 nm is widely used for soil analysis. It's got the 22 article. It has the capacity to take 350-2500 nm spectral range like FieldSpec TM FR, FieldSpec Pro FR, FieldSpec, FieldSpec 3, FieldSpec Pro, Vis/NIR and LabSpec 2500 Spectroradiometer. The spectral bands were omitted bands like, 350-420, 970-1010, and 2460-2500 nm [20]. Its input is 1.5m permanent fiber optic cable and it having 25 degree, 8 degree and 1 degree FOV. Fiber optic cable is flexible and it can move. It is shown in fig 1. It is a very flexible instrument. We can carry it, collect spectrum and save it on laptop through it. It can use in lab and on the field. It requires same accessories like pistol grip tripod, lamp, reference panels, backpack, battery, AC power supply and laptop. The laptop is requires communicate to instrument through Ethernet wired interface or Wi-Fi Ethernet interface.

Fig. 1 FieldSpec Spectroradiometer

It has some software like RS3, ViewSpec Pro, Indico Pro and third party software. RS3 software is used for data collection. Rs3 software is us File is saved as .asd extension. We can set 25 degrees, 8 degree and 1 degree FOV. ViewSpec Pro software is used for data analysis. It is useful for process data. It shows spectral signature between 350-2500 nm. 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), shows the latitude and longitude of the field location (GPS) and it can use ArcGIS tools for it [21].

TABLE 2. TECHNIQUES FROM LITERATURE SURVEY

Preprocessing	**Feature extraction**	**Feature classification**	**Statistic method**	**References ID**
1st Derivatives, Savitzky-Golay filter	N (Nitrogen)	PLSR, LWB, SVMDA, PCA	RPD, Cohen's kappa coefficient, min. max, mean, SD, CV	[4]
2nd Derivatives, MSC, SNV, Savitzky-Golay filter	Db, MC, Clay, silt, Sand	SMLR	RMSE, Correlation coefficient, coefficient of multiple determinations(R^2)	[5]
1st Derivatives , MSC, Savitzky-Golay filter	Zn, Cu, Pb, Cr, Ni. (Heavy Metals)	PLSR	RMSE, cross-validation, RPD, min, max, mean, SD, RMSE_cv, RPD_cv, pre	[6]
MNF, Spectral mixture analysis, pixel purity index	CaSo_4, CaCo_3, Gypsum, OM, CEC	Gaussian Model, FWHM	RMSE	[7]
CCD detector	N, P, K	LIBS	RSD	[10]
MA, MSC, SNV, DT, BC, 1st & 2nd derivatives	Sandy, clay, loam clay, semi clay	PCA	Min, max, mean, SD	[11]
1st Derivatives, Savitzky-Golay filter	C, N, SO4, PH, P-Olsen, P, CEC, K, Ca, Mg, Na, Bulk dencity	PCA, PLSR	Min, max, mean, SD, RMSE, RMSECV, RMSEP, RPD, REP	[12]
Nearest neighbor method, normalization	OM, sand, silt, Aluminum, clay, Ca, Mg, K, CEC	NDVI	average, min, max, SD, Cov varia	[13]
Log 1/R, 1st derivatives	CaCO3, SOM, Ca, K, Mg, Na, CEC, pH, EC, clay, silt, sand	PLSR, MARS	RMSEP, RPD, RER, SD,	[15]
Normalization, baseline-corrections, smoothing, 1st derivatives	C, N, P,k, S, Ca, clay	PLSR, ANN,PCA, PCR, beer-Lamber law, back-propagation Algo	RSME,cross-validation, RPD, ME.	[17]
Log(1/T), SNV		LS-SVM, PCA	RBF, Eigenvalues & eigenvectors	[19]
1st derivatives	Nitrogen	NDVI	RMSE, correlation coeffient, ABD	[20]
Base line correction, Savitzky-Golay filter	Clay, CaCO3, Organic matter	NN(Non-linear classifiers)		[23]
1st & 2nd derivatives, SNV, Savitzky-Golay filter	OC, CEC, Clay, TC, Ca, TN, sand, Mg, pH, K, TP, silt, ESP, NH4, Na, P, EC, NO3-N	PLSR,PCA	RMSE, ME, SDE, RPD, Mahalonobis statistic	[24]
1st derivatives	Clay, SOC	PLSR, BRT, CART LM, GLS, GNLS	MSD, RMSD, Bias, SB, NU, LC, SEP	[25]
1st derivatives, XRD	Clay sand, C, CEC, IC, SOC, Fed, pH	PLSR, BRT, PCA	Kappa coefficient, Cross-Validation, MSD, RMSD, Bias, SB, NU, LC,	[27]
	pH, LR, OC, clay, silt,	PLSR	Covariance, cross- validated, ME,	[28]

	sand, CEC, Ca, Al, NO3_N, P Cpl, K, EC		RMSE	
1st derivatives	Clay, CaCO3, Oganic C (OC) , Inorganic C (IC)	PLSR, PCR, MARS, PCA	MSD, RMSD, Bias, SB, NU, LC, SEP	[30]
1st derivatives, Savitzky-Golay filter, normalization	C, N	PLRS, MLR	SD, SE, RMSE, Cross-Validation	[31]
1st derivatives	C	PLSR	RSQ,SECV, SEP, RPD	[32]
1st derivatives, Savitzky-Golay filter	SOC	PLS1	RSQ, SECV, SEP, RPD	[33]
1st derivatives, Savitzky-Golay filter	CSC,	PLS1 (PLSR)	RSQ, SECV, SEP, RPD	[34]
1st derivatives, Savitzky-Golay filter, MSC	clay, silt, sand, pH, C, N, Ca, Mg, K	PLSR	Mean, SE, RMSEP	[38]
1st derivatives, Savitzky-Golay filter	C, N	PLSR	RMSE, Bias	[39]
1st derivatives, Savitzky-Golay filter	Clay, silt, pH, SOC, N, Ca, Mg, K, P, CEC	PLSR, PCA	Min, Max, Median, Mean, SE, RMSEP, RMSEC	[40]

A. Techniques for soil analysis

Table 2 portraits the techniques implemented in literature. The techniques can be grouped in following categories

a. Derivatives

In table 2, 1st derivatives are widely used for Pre-processing. It is measures of the slope of the spectral curve at every point. The slop of the curve is not affected by baseline offsets in the spectral signature. It is an effective method for removing baseline offsets [22-26]

b. Principle Component Analysis (PCA)

It is multivariate techniques that analyze a data set in which observations are described by many inter correlated quantitative dependent variables. PCA is extracting the important information from the data and represent it as a set of new orthogonal variable, to show the pattern of correspondence of the observations and of the variables as points on the map. It constantly uses a projection method that can find the directions in space along which data point is the largest between the distances. It is called Principal Components (PCs). PCA is the backbone of the modern data analysis. It reduces the dimensionality of the data, filter some of the noise data, decrease redundancy in the data, compress it and prepare the data for further analysis purpose using other methods [27-30].

c. Smoothing

It is used for removing noise form the data set and allowing important patterns of in the data set. Data smoothing can do in a different ways like moving average, Savitzky-Golay filter and Gaussian filtering. Savitzky-Golay filter is better than the simply averaging data points is to perform a least squares fits polynomial data set to successive curve segment and then replace the first values with further regular variations. The Savitzky - Golay filter is continually used to remove spectral noise picks when chemical information can keep it [31-33].

d. Baseline

It is two transformations. One is offset and another is linear baseline correction. Offset is variable to subtract to all selected variables. The result of offset baseline is minimum value is set and the rest is positive values. Linear baseline is the slope of baseline into the horizontal baseline. It is to point out two variables which will define the new baseline [34-36].

e. Partial Least Square Regression [PLSR]

PLSR is widely used for spectral calibration and prediction. It is a method for relating two data matrices two variable (x, y) though a linear multivariate model, it is widely used in reflectance spectroscopy data analysis and chemometrics and common used for quantitative spectral analysis. It decomposes both variable and finds new component [37]. It is used to construct predictive models when there many predictor variables that is highly collinear. It can use to construct a linear predictive model for the sample amount based on the spectrum. Each spectrum is comprised of measurements in different frequencies. PLS Factors are computed as a certain linear combination of spectral range and the responses are predicted linearly based on these extracted factors. It uses in chemistry and engineering. It gives richer results than the old multiple regression approach methods [38]. It developed a generalization of multiple linear regression (MLR) and analyze data with strongly collinear, noisy, multiple variables and simultaneously model several response variables. PLSR is a way to estimate parameters in the scientific model, which basically is linear and it's like any scientific model, conceptual, technical, numerical, statistical, and so on. Cross-validation (CV) is a practical and correct way to test this predictive significance [39]. It is standard in PLSR analysis. The collected data set with preserved time order and it allocates into two parts, one is training set and the second one is prediction set. Only forward prediction applied process insight initial PLSR modeling and inspection of cross-correlation indicate that some samples of the variables is warranted to catch process dynamics.

CONCLUSION

Spectroradiometer is widely used in agriculture application (Remote Sensing). VNIR, SWIR and Mid-Infrared is used in it. It appears to be very promising techniques for rapid analysis of soil samples. The main limitation of the Spectroradiometer approach is that it requires standard parameters of instrument setups and on the field work. Soil content is usually described by soil properties such as nutrient levels, soil organic matters, minerals, etc. spectral analysis is very important when FieldSpec Spectroradiometer is used in the evaluation of soil properties. PLSR is important techniques to reach this goal. Some soil samples and soil variance also needs in a good multivariate calibration of soil properties. We can make soil spectral library with including at least thousands of soil samples. It should be collected which will be useful for future design.

ACKNOWLEDGEMENT

The authors would like to thank, Dr. Suresh Mehlotra, Geospatial Technology (SAP-II) and SCM_RL (System Communication & Machine learning research laborotry) for provide infrastructure and Information

REFERENCES:

[1] Sujit choudhary, Deepankar chakrabarti and Suchandra Choudhury,"An introduction to Geographic Information Technology", I K International publishing House Pvt.Ltd, Nov 2008.
[2] [Onlineavailable]https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/resource/tutor/fundam/pdf/fundamentals_e.pdf
[3] [Online available] http://www.isric.org/sites/default/files/ICRAF-ISRICSoilVNIRSpectralLibrary.pdf
[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, OPEN ACCESS, 7, pp. 7029-7043, May 2015.
[5] Gholizadeh, M. S. M. Amin, L. Boruvka and M. M. Saberioon, "Models for estimating the physical properties of paddy soil using visible and near infrared reflectance spectroscopy", Springer Science +Business Media New York, Journal of Applied Spectroscopy, vol. 81, No. 3, pp. 534-540, July 2014.
[6] M. Todorova, A. M. Mouazen, H. Lange and S. Astanassova, "Potential of near-infrared spectroscopy for measurement of heavy metals in soil as affected by calibration set size", Springer, Water Air Soil Pollut, vol. 225, No.8, 2036, pp. 1-19, July 2014.
[7] M. Saleh, A. B. Belal and S. M. Arafat, "Identification and mapping of some soil types using field spectrometry and spectral mixture analyses: a case study of North Sinai, Egypt", Springer, Arabian J Geosciences, vol. 6, No. 6, pp. 1799-1806, Dec 2011.
[8] Francesca Garfagnoli, Gianluca Martelloni, Andrea Ciampalini, Luca Innocenti and Sandro Moretti, "Two GUIs-based analysis tool for spectroradiometer data pre-processing", Springer, Eath Science Informatics, vol. 6, No. 4, pp. 227-240, July 2013.
[9] K. Khadse, "Spectral reflectance characteristics for the soils on baseltic terrain of central Indian plateau", J Indian Soc Reomte Sens (Journal of the Indian Society of Remote Sensing), Springer, vol. 40, No. 4, pp. 717-724, Dec 2011.
[10] Zejian Lei, Mingyin Yao, Muhua Liu, Qiulian Li and Hanping Mao, "Comparision 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, vol. 1, pp. 363-366, 2011.
[11] Haiqing Yang, Boyan Kuang, Abdul M. Mouazen, "Affect of different preprocessing methods on principal component analysis for soil classification", IEEE, *ICMTMA*, vol. 1, pp. 355-358, Jan 2011
[12] Bambang Hari Kusumo, Mike J. Hedley, Carolyn B. Hedley and Mike P. Tuohy, "Measuring carbon dynamics in field soils using soil spectral reflectance: prediction of maize root density, soil organic carbon and nitrogen content", Springer, Plant Soil, vol.338, No. 1, pp. 233-245, Jan 2011.
[13] Jose A. M. Dematte, Peterson R. Fiorio and Suzana R. Araujo, "Variation of routine soil analysis when compared with hyperspectral narrow band sensing method", Remote Sensing, Open Access, vol. 2, No. 8, PP.1998-2016, Aug 2010.
[14] Volkan Bilgili, H. M. van Es, F. Akbas, A. Durak and W.D. Hively, "visible/near infrared reflectance spectroscopy for assessment of soil properies in a semi-arid area of turkey", ELSEVIER, Journal of Arid Environments, vol. 74, No.2, pp. 229-238, Feb 2010.
[15] 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, vol. 34, No. 3, May/June 2010.
[16] Changwen Du and Jianmin Zhou, "Evaluation of soil fertility using infrared spectroscopy: a review", Springer, vol. 7, No.2, pp. 97-113, Jun 2009.
[17] I. Belyaev, Yu. V. Belyaev, L. V. katkovskii and i. M. Tsikman, "Estimation and analysis of the parameters of a field spectroradiometer covering the spectral range 350-2500 nm", Springer Science + Business Media, Journal of Applied Spectroscopy, vol. 76, No. 4, pp. 577-584, 2009.
[18] Li, Z., Yu, J. and He, Y., "use of nir spectroscopy and LS-SVM model for the discrimination of varieties of soil", Boston:Springer, IFIP international Federation for Information Processing, vo. 293, Computer and Computing Technologies in Agriculture II, vol. 1, pp. 97-105, 2009.
[19] Jian Wu, Yaolin Liu, Dan Chen, Jing Wang, Xu Chai, "Quantitative Mapping of Soil Nitrogen Content Using Field Spectrometer and Hyperspectral Remote Sensing", IEEE, *ESIAT*, vol. 2, pp. 379-382, Jul 2009.

[20] Isa Yunusa, Rhys Whitley, Melanie Zeppel, Derek Eamus, "Simulation of Evapotranspiration and Vadose Zone Hydrology Using Limited Soil Data: A Comparison of Four Computer Models", IEEE, *ICECS*, pp. 152-155, Dec 2009.
[21] Lianqinq Xue, Dan Li, Shuo Huang, Chunlin Wu, "Spatial variability analysis on soil nitrogen and phosphorus experiment based on geostatisics", IEEE, *ETTANDGRS*, vol. 2, pp. 237-240, Dec 2008.
[22] Linker, R., "Soil classification via mid-infrared spectroscopy", Boston:Springer, , IFIP international Federation for Information Processing, vo. 259, Computer and Computing Technologies in Agriculture, vol. 2, pp. 1137-1146, 2008.
[23] Rossel RAV, Jeon YS, Odeh IOA, McBratney AB, "Using a legacy soil sample to develop a mid-IR spectral library", CSIRO, *Soil Research*, vol. 46, No.1, pp. 1–16, Feb 2008.
[24] Davin J. Brown, "Using a global VNIR soil-spectral library for local soil characterization and landscape modeling in a 2nd-order Uganda watershed", ELSEVIER, SiecnceDirect Geoderma, Vol. 140, No. 4, pp. 444-453, Aug 2007.
[25] R.J. Gehl and C. W. Rice, "Emerging technologies for in situ measurement of soil carbon", Springer, Climatic Change, vol. 80, No.1, pp. 43-54, Jan 2007.
[26] David J. Brown, Keith D. Shepherd, Markus G. Walsh, M. Dewayne Mays and Thomas G. Reinsch, "Global soil characterization with VNIR diffuse reflectance spectroscopy", ELSEVIER, Geoderma, vol. 132, No.3-4, pp. 273-290, Jun 2006.
[27] R. A. Viscarra Rossel, D. J. J. Walvoort, A. B. McBratey, L. J. Janik and J. O. Skjemstad, "Visible , near infrared, mid infrared or co bined diffuse reflectance spectroscopy for simultaneous assessment of various soil properties", ELSVIER, Geoderma, vol. 131, No. 1-2, pp. 59-75, Mar 2006.
[28] R. N. Sahoo, M. Bhavanarayana, B. C. Panda, C. N. Arika and R. kaur, "Total information content as an index of soil moisture", Springer, Journal of the Indian Society of Remote Sensing, vol. 33, No. 1, pp. 17-23, Mar 2005.
[29] David J. Brown, Ross S. Bricklemyer and Perry R. Miller, "Validation requirements of diffuse reflectance soil characterization models with acase study of VNIR soil C prediction in Montana", ELSVIER, Geoderma, vol. 129, No. 3-4, pp. 251-267, Dec 2005.
[30] K. D. Shepherd, B. Vanlauwe, C. N. Gachengo and C. A. Palm, "Decomposition and mineralization of organic residues predicted using near infrared spectroscopy", Springer, Plant and Soil, vol. 277, No.1, pp. 315-333, Dec 2005.
[31] Dan Shiley and SummitCAL Solutions Team, "283-7 Measurement of soil mineralogy using Near-Infrared reflectance spectroscopy", ASD Inc., Boulder, Co 80301, pp. 1-2, 2011.
[32] Michaela Kastanek, Applications Coordinator and George Greenwood, Senior Market Manager, "Analysis of soil organic Carbon in soil samples using an ASD NIR spectrometer", Remote Sensing, ASD Inc., a PANanalytical company Boulder, Colorado, 80301, USA, pp. 1-5, Oct 2013.
[33] Donald Campbell, Daniel Shiley and Brian Curtiss, "Measurement of soil mineralogy and CEC Using Near-Infrared reflectance spectroscopy", Remote Sensing, ASD Inc., a PANanalytical company Boulder, Colorado, 80301, USA, pp. 1-2, Nov 2013.
[34] A. Shvetsov, V.M. Demkin, D. A. Karashtin, N. K. Skalyga and L. I. Fedoseev, "Microwave spectroradiometer complex for remote study of the stratosphere thermal structure", Srpinger science+Business media, Radiophysics and quantum electronics, vol. 52, No. 8, PP. 603-608, 2009.
[35] Liu Jun-ang, Guo Liang, Hao Yan and Zhi-hui, "Ecological distribution of soil microorganism and activity characteristic of soil Enzymes in camellia oleifera stands", IEEE, International conference on chllenges in Environmental science and computer engineering, vol. 1, pp. 479-482, 2010.
[36] Vincent de Paul Obade, Rattan Lal and Jiquan Chen, " Remote sensing of soil and water quality in agroecosystems", Springer, water air soil pollution, vol. 224, No. 9, pp. 1-27, Aug 2013.
[37] Alex O. Awiti, Markus G. Walsh, Keith D. Shepherd and Jenesio Kiyamario, "Soil condition classification using spectroscopy: A proposition for assessment of soil condition along a topical forest- cropland chronosequence", ELSEVIER, Geoderma, vol. 143, No.1-2, pp. 73-84, Jan 2008.
[38] Patrick Kiiti Mutuo, Keith D. Shepherd, Alain Albrecht and Georg Cadisch, "Prediction of carbon mineralization rates from different soil physical fractions using diffuse reflectance spectroscopy", ELSEVIER, Soiil Biology & Biochemistry, vol. 38, No.7, pp. 1658-1664, July 2006.
[39] Tor-G. Vagen, Keith D. Shepherd and Markus G. Walsh, "Sensing Landscape level change in soil fertility following deforestation and conversion in the highlands of Madagascar using Vis-NIR spectroscopy", ELSEVIER, Geoderma, vol. 133, No.3-4 , pp. 281-294, Aug 2006.