The Egyptian Journal of Remote Sensing and Space Sciences xxx (2017) xxx–xxx

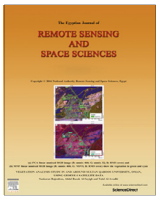
HOSTED BY

ELSEVIER

Contents lists available at ScienceDirect

The Egyptian Journal of Remote Sensing and Space Sciences

journal homepage: www.sciencedirect.com



Review Article

Application of near-infrared reflectance for quantitative assessment of soil properties

E.S. Mohamed *, A.M. Saleh, A.B. Belal, Abd_Allah Gad

National Authority for Remote Sensing and Space Sciences (NARSS), Cairo, Egypt

ARTICLE INFO

Article history:
Received 24 July 2016
Revised 31 January 2017
Accepted 1 February 2017
Available online xxxx

Keywords:
Near infrared spectroscopy
Soil salinity
Soil moisture
Soil organic carbon
Soil surface features and soil contamination

ABSTRACT

Beginning with a discussion of reflectance spectroscopy, this article attempts to provide a review on fundamental concepts of reflectance spectroscopic techniques. Their applications as well as exploring the role of Near-infrared reflectance spectroscopy that would be used for monitoring and mapping soil characteristics. This technique began to be used in the second half of the 20th century for industrial purposes. Moreover, this article explores the potentiality of predicting soil properties based on spectroscopic measurements .Quantitative prediction of soil properties such as; salinity, organic carbon, soil moisture and heavy metals can be conducted using various calibration models – such models were developed depending on the measured soil laboratory analyses data and soil reflectance spectra thereby resampled to satellite images - to predict soil properties. The most common used models are stepwise multiple linear regression (SMLR), partial least squares regression (PLSR), multivariate adaptive regression splines (MARS), principal component regression (PCR) and artificial neural networks (ANN). Those methods are required to quickly and accurately measure soil characteristics at field to improve soil management and conservation at local and regional scales. Visable-Near Infra Red (VIS-NIR) has been recommended as a quick tool for mapping soil properties. Furthermore, VIS-NIR reflection spectroscopy reduces the cost and time, therefore has a wonderful ability and potential use as a rapid soil analysis for both precision soil management and assessing soil quality.

Contents

Peer review under responsibility of National Authority for Remote Sensing and Space Sciences.

* Corresponding author.
E-mail addresses: Salama55_55@yahoo.com, Salama55@mail.ru (E.S. Mohamed).

http://dx.doi.org/10.1016/j.ejrs.2017.02.001
1110-9823/

Please cite this article in press as: Mohamed, E.S., et al.. Egypt. J. Remote Sensing Space Sci. (2017), http://dx.doi.org/10.1016/j.ejrs.2017.02.001

1. Introduction

Soil is described as a heterogeneous system, their mechanisms and processes are complex and difficult to be fully understood. Numerous traditional methods are used in an endeavour to describe the relationship between different soil properties such physical, chemical and principal soil components. Consequently, simple and accurate soil testing procedures are required in field and laboratory. Near-infrared reflectance spectroscopy (NIRS) is a nondestructive systematic strategy for characterizing and identifying soil properties. Those techniques have been used since the 1960 to estimate moisture, protein, and oil in agricultural products (Ben-Gera and Norris, 1968). During last three decades, numerous studies illustrated that the spectral reflectance property of soil samples in laboratory conditions, as well as field investigation of soils' characteristics, can be assessed where remote photography materials occupy an increasingly significant place in the organization of soil cover monitoring (Mohamed, 2013; Mohamed et al., 2015; Saleh et al., 2015; Savin, 1993). Recently, this technique is widely used in several fields as an amazing tool for evaluating such agriculture, food, polymer .pharmaceuticals and petrochemicals. Moreover, the technique, NIR method can be applied to predict soil properties as additional (to laboratory analysis) or initial assessment of soil quality (Demattê and da Silva Terra, 2014; Mateusz Kania and Piotr gruba, 2016). Near-infrared reflectance spectroscopy (NIRS) has been used to predict several soil properties such soil organic carbon, soil moisture content, soil contemenation, soil salinity, etc. Soil electrical conductivity can be detected using visible, near infrared, or short-wave infrared spectral bands from optical sensors to be promising for the detection of surface soil salinity. The intensive of reflectance is related to concentration of soluble salts in salt-affected soils (Dwivedi and Rao, 1992; Khan et al., 2005; Nield et al., 2007; Abdi et al., 2016). Many authors suggested that, infrared and red channels are applicable methods to monitor soil characteristics such iron oxides and soil moisture are considered (Samsonova and Meshalkina, 2011; Sonia et al., 2012 and Niederberger et al., 2015). Near infrared (NIR) and mid-infrared (MIR) ranges are promising technologies considered as a quantitative ones that gives good results for heavy metals concentration as there is a high correlation between pollutants and their spectral indicators. Reflectance spectroscopy techniques have been used for retrieving and mapping the distribution of heavy metals such as Pb at high accuracy (Samsonova and Meshalkina, 2011). Many of regression models are used to estimate quantitative and qualitative analyses of the various soil elements, based on investigating the correlation between each element properties and the observance for each selected wavelength. However, the most widespread regression models are partial least square regression (PLSR), multivariate adaptive regression splines (MARS), ordinal logistic regression, stepwise multiple linear regression (SIMR), artificial neural networks (ANN), locally weighted regression (LWR) and principal components regression (PCR) (Chang et al., 2001; Ciurczack, 2001; Nawar et al., 2014; Fikrat et al., 2016; Zheng et al., 2016).

2. Spectroscopy definitions and history of spectroscopy

Spectroscopy is the science that studies the interaction between matter and its electromagnetic radiation (Crouch and Skoog, 2007). Reflectance spectroscopy is the study of light as a function of wavelength that has been reflected or scattered from a solid, liquid, or gas. This concept was expanded greatly to include any interaction with radiative energy as a function of its wavelength or frequency. Spectroscopic data is often represented by aspectrum, a plot of the response of interest as a function of wavelength or frequency (Herrmann and Onkelinx, 1986; Clark, 1999).

The history of spectroscopy began in the 17th century with Isaac Newton's discovery of the with Isaac Newton's discovery of the light nature and color basics. He introduced the word "spectrum" at first application to describe the rainbow of colors combination to form white light. During the early 1800s, Joseph von Fraunhofer made experimental advances with dispersive spectrometers that enabled spectroscopy to become a more precise and quantitative scientific technique. Since then, spectroscopy has played and continues to play a significant role in chemistry, physics and astronomy (Brand, 1995). As far as the development of instrumentation and its breakthrough for industrial applications in the second half of the 20th century were concerned, NIR proceeded in technology jumps (Fig. 1). In this respect, credit has largely to be given to researchers in the field of agricultural science. At the same time, with few exceptions, comparatively low priority has been given to NIR spectroscopy in the chemical industry (Siesler et al., 2002). This technique recently has been developed into essential methods for scientific research and industrial quality control in a different applications such chemistry, environmental analysis, agriculture and as well as life sciences.

3. Near-infrared reflectance spectroscopy

The fundamental principle of VisNIR is based on the differences in molecular characteristics, where spectral signatures of different materials are categorized based on their reflectance and absorbance spectra. The change in signatures is referred to vibrational extending and bending of atoms that arrange molecules and crystals. Most soil components are usually observed in the mid-infrared region vibrations (2500–25,000 nm), with overtones and combinations found in the near-infrared region (400–2500 nm) (Clark, 1999; Shepherd and Walsh, 2002). The electromagnetic (EM) spectrum ranges from gamma (γ) rays, at the shortest wavelengths, to radio-waves, at the longest wavelengths (Fig. 2). Most common sensing systems operate in one or several of the visible, infrared (IR) and microwave portions of the spectrum. Sensor data covering those wavelengths are readily available from both satellite and airborne platforms (NASA, 2014). The energy of infrared light corresponds to the energy required to cause molecular vibrations. Moreover, the far-IR region ($A = 4 \times l0^4 - 10^6$ nm) harmonize to molecular variations and the mid-IR ($A = 2500 - 4 \times l0^4$ nm) corresponds to fundamental molecular vibrations, such as stretching, bending, wagging, and scissoring. The energy of near-IR light corresponds to overtones and combination bands of fundamental molecular vibrations from the mid-IR. (Drago, 1992; Workman, 1996). Vibrational spectroscopy is depending on interactions between the molecules and electronic field components of incident light in the mid- and near-IR region. Such interactions result in absorption of light by molecules when the energy of incident light (Ep) is equal to the energy difference (AE) between the quantized energy levels of different vibrational states of the molecule (Fig. 3). Their relationship can be expressed as:

$$Ep = hv = hc/A. = AE, \quad (1)$$

where:

v is the frequency of incident light,
c is velocity of light,
A is the wavelength, and
h is Plank's constant

The energy difference, AE, is specified by chemical bonds of functional groups in the molecules. A molecule must undergo a