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Visible-Near Infrared Spectroscopy's Features

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Abstract

As the spectroscopy technique is quick, simple to use, and free of chemical extractants, it has numerous advantages over traditional analytical procedures. This study uses VIS-NIR reflectance spectroscopy to measure soil total carbon (C), accessible phosphorus (P), and exchangeable potassium (K). 877 different soil samples were taken in all from different agricultural fields in Mali. To determine the chemical parameters of the soil, multivariate analysis was used on the soil spectra that were obtained. The Principle Component Regression (PCR) outperformed the Partial Least Square Regression, according to the findings (PLSR). PLSR accounts for 0.29 of the coefficient of determination (R2) for C, P, and K, respectively. Nonetheless, this work shows the VIS-NIR reflectance spectroscopy's potential for studying the chemical makeup of soils.

Keywords: Spectroscopy technique; Soil; PLSR accounts

Introduction

From a social, economic, and environmental standpoint, agriculture is a topic of significant importance for the vast majority of nations. It is essential to the economy and food security of Mali. The success of productive farming systems and a healthy environment depends on the quantification of the nutrients in the soil that are available to the plants. Chemical techniques are frequently employed in Mali to [1-11] evaluate the chemical and physical characteristics of soil. Nevertheless, these techniques call for the employment of costly, hazardous chemical extract ants that are bad for both people and the environment. In this situation, it becomes vital to look for an alternate approach to replace or scale back the current methods for analyzing the soil properties. The benefits of spectroscopic techniques are justifiable for a number of reasons. For instance, sample preparation simply entails drying and grinding, therefore the analysis is unaffected by the chemical properties of the sample. Also, the measurement is quick and a single scan can estimate a number of soil parameters. Also, the procedure is adaptable and can be used in situ or in a lab. Early in 1990, the first publications on VIS-NIR spectroscopy's potential for soil analysis appeared. Since then, numerous studies have been conducted on the application of this approach, particularly in recent decades. Classical soil characteristics such soil organic matter (SOM), clay concentration, mineralogy, chemical nutrients, structure, and microbial activity have received special attention. Total organic carbon and total soil nitrogen calibrations are thought to have the best success rates. According to prior research, the coefficients of determination for P and exchangeable K, respectively, ranged from 0.11 to 0.55 and 0.23 to 0.92. Nonetheless, spectroscopy's predictions for P and K remained incorrect. Several studies have been conducted in some African nations, such as Mali, on the development of spectroscopic technologies. Additional research looked into the possibility of using near infrared diffuse reflectance spectroscopy to determine various parameters using soil samples from all throughout Kenya's Lake Victoria basin. Nonetheless, they recommended performing more calibrations with a wider variety of soil types and evaluating different infrared diffuse reflectance-based techniques. Total organic carbon and total soil nitrogen calibrations are thought to have the best success rates. Earlier research suggested that exchangeable K has a coefficient of determination that varied from 0.23 to 0.55. Nonetheless, spectroscopy's predictions for P and K remained incorrect. The VIS-PIR spectroscopy approach is intriguing for a number of good reasons. For instance, the only steps involved in sample preparation are drying and grinding; the sample is not altered in any way by the analysis, and no [4-9] chemicals (which pose an environmental risk) are also needed. Also, the measurement is quick because it just takes a few seconds, and one scan can estimate multiple soil parameters at once. Moreover, the procedure can be applied in situ or in a lab. The Global Agroforestry Center (ICRAF) supports a network of infrared spectroscopy labs in national institutions in Africa, at the moment in Cote d'Ivoire, Kenya, Malawi, Mali, Mozambique, Nigeria, and Tanzania. In spite of all of this work, some research organisations employ the spectroscopic approach for soil analysis ineffectively. The purpose of the current work is to describe and illustrate how diffuse reflectance spectroscopy can be used to assess some soil parameters in Mali. The overall goal of this study is to compare the estimates of two regression models, Principal Component Regression (PCR) and Partial Least Squared Regression (PLSR), for the determination of total carbon (C), available phosphorus (P), and exchangeable potassium in order to assess the performance of VIS-NIR spectroscopy (K).

Materials and Procedures

Illustration Collect

The soil lab "Laboratoire Sol-Eau-Plante" in Mali performed soil preparation and sampling. The soil samples were taken at depths ranging from 0 to 10 cm. The geographical details of each sampling site are displayed in Figure 1.

Soil reference data measurements

Standard laboratory procedures were used in the soil laboratory, Laboratoire Sol-Eau-Plante (LSEP), to measure soil reference data. Prior to being crushed and sieved to 2 mm, soil samples were air dried. The modified Anne method, which involves oxidising soil carbon with potassium dichromate, was used to measure the total carbon using an

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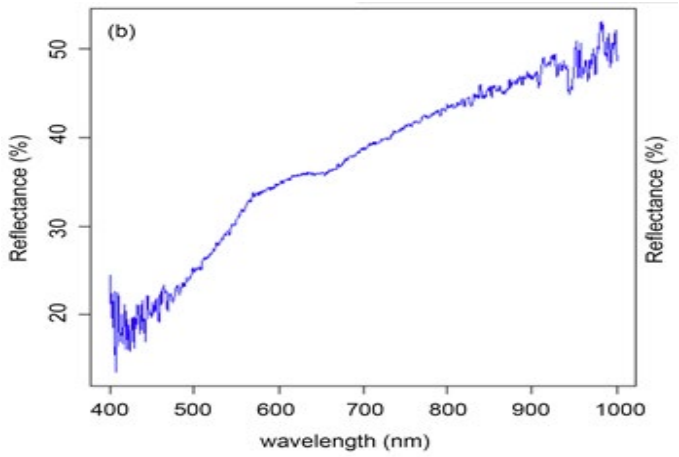

Figure 1: Diagram of the spectroscopic apparatus for spectrum capture and scanning soil samples.

automatic titrator. A mixed solution of 0.1 M HCl and 0.03 M NH4F was used to extract the soil's usable phosphorus, and an ultraviolet (UV) spectrophotometer or a colorimeter was used to measure the results. The soil was leached with a 1 M ammonium acetate solution at pH 7 to extract the exchangeable K. Using a flame photometer, it was directly measured in the ammonium acetate percolate.

Results and Discussion

Technique for Selecting Samples

The 877 soil samples were divided into two sub-samples, which made up the calibration and validation sets. The choice was chosen so that both the calibration and Figure 1 validation sets included data from each sample site. The calibration sample set (587 samples) is made up of around two-thirds of the samples from each sampling site, while the validation sample set is made up of the remaining one-third of the samples (290 samples).

Measurements in the spectrum

The Laboratory of Optics, Spectroscopy and Atmospheric Sciences performed the spectral measurements and associated processing (LOSSA). These observations involve logging the reflectance of the soil from 342 to 1060 nm in wavelength. Prior to air drying, soil samples were crushed to pass a 2-mm filter. The spectral measurements were carried out using a Miniature Fiber Optic Spectrometer that operates in the UV-VIS-NIR spectral range (BLUE-Wave Miniature Fiber Optic Spectrometers for UV-VIS-NIR & OEM, StellarNet Inc.). The Spectra Wiz software is installed on a PC that the spectrometer is linked to in [3-6] order to manage the data acquisition.

Treatment of spectra before

The raw spectral data go through several pretreatments before being used. Pre-processing spectra most frequently entails subjecting the raw data to one or more mathematical adjustments designed to make them appropriate for modelling.

Conclusion

This work provides evidence for the usefulness of VIS-NIR diffuse reflectance spectroscopy in soil research. This type of analysis holds great promise for the study of soils because it is quick, simple to measure, chemical-free, and even allows for in-field measurements. The PLSR estimation outperforms the PCR model's prediction, according to the results. VIS-NIR spectroscopy over 400–1000 nm has poor performance for determining some soil parameters, according to the independent validation.

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Competing Interests

The authors say they have no competing interests.

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