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A PATH FOR HORIZING YOUR INNOVATIVE WORK

SOIL NITROGEN DETECTION USING NEAR INFRARED SPECTROSCOPY

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Abstract: Spectroscopy is a rapid, simple, non-destructive and analytical technique, which has been increasingly used for agricultural and food analysis processes. Soil nitrogen, being an important macronutrient of the soil, measurement of total Nitrogen (TN) content can be used as an index of crop productivity. Near Infrared (NIR) spectroscopy can accurately predict the soil nitrogen content by evaluating reflected Near Infra-red rays intensity. The designed Nitrogen estimation model resulted in correlation coefficient (R^2) of 0.82. The need of expensive and bulky spectrometers is eliminated by use of light-emitting diode (LED) as a Near Infra-red light source, making the system cost effective and portable.

Keywords: Spectroscopy, Near Infrared (NIR), Total Nitrogen (TN), Spectrometers, LED

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INTRODUCTION

Near Infrared reflectance spectroscopy (NIRS) is the rapid, non-destructive analytical technique which can estimate standard soil characteristics without using chemicals. It is a spectro-photometric method that deals with the interactions of near infrared radiation with the sample under investigation. It is based on the absorption of electromagnetic radiation at wavelengths in the range of 780-2500 nm. Each constituent of a complex organic mixture has unique absorption properties in the NIR region (780-2500 nm) due to stretching and bending vibrations of molecular bonds between elements (Morra *et al* 1991).

To generate a soil spectrum, radiation containing all relevant frequencies in the particular range is directed to the sample. Depending on the constituents present in the soil the radiation will cause individual molecular bonds to vibrate, either by bending or stretching and they will absorb light to various degrees with a specific energy quantum corresponding to the difference between two energy levels. As the energy quantum is directly related to frequency and inversely related to wavelength, the resulting absorption spectrum produces a characteristic shape that can be used for analytical purposes (Miller *et al* 2001).

The wavelength at which the absorption takes place (*i.e*. the size of the energy quantum) depends also on the chemical matrix and environmental factors such as neighbouring functional groups and temperature, allowing for the detection of a range of molecules which may contain the same type of bonds (Stenberg B., Raphael A. *et al* 2010).

This property of Spectroscopy, to characterize material according to the reflectance, has been used in many areas, such as the food industry, petrochemical industry, and in agriculture. The study shows that prediction of residual nitrate or nitrogen content is possible by spectroscopy. NIRS technology has been applied in many areas, such as the food industry, petrochemical industry, and in agriculture, because of its testing speed, low cost and non-destructive as well as real-time testing (Xiaofei A., Minzan L. *et al* 2013).

Amongst the various nutrients obtained from soil, Nitrogen, Phosphorus and Potassium are the critical macronutrients. From these, Nitrogen is one of the most important elements in farmland soil. It has more influence on the tree growth, appearance, fruit production and fruit quality than any other element. Nitrogen is essential in the formation of new cells and organic compounds in their structure. Thus, Nitrogen content analysis will definitely help in crop production.

SOIL SAMPLE PREPARATION

Soil moisture content and soil particle size are the main factors influencing the measurement accuracy in addition to soil colour. Similarly, spectra pre-processing, sample preparation, size of calibration area, spectrophotometer wavelength range and type of detectors and calibration methods also affect calibration accuracy. Before scanning soil samples, a preparation procedure need to be defined. Following is the sample preparation steps necessary before soil spectroscopic analysis.

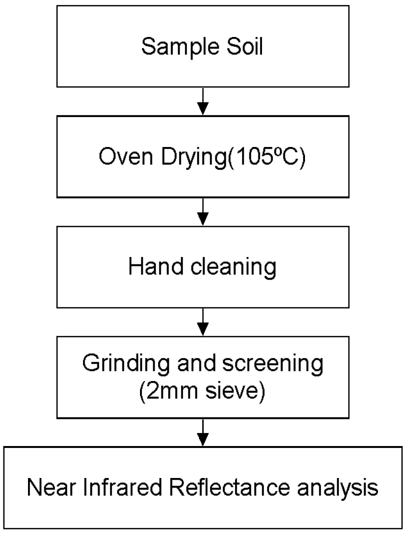

Figure 1. Sample preparation steps

Based on the studies, it was decided to work with 2mm crushed and sieved soil samples. (Valerie G., Gilles C. *et al* 2011)

SYSTEM DESIGN

The detector consists of an optical unit and a control unit. The optical unit includes six near-infrared sources (LED), a medium (optical fiber) for carrying light and a detector. The control unit consists of an amplifier circuit, a filter circuit, an analog-to-digital converter (A/D) circuit, an LCD display. The optical signal at each wavelength is transferred from the LEDs to the surface of the target soil. The reflected light from the soil surface is acquired

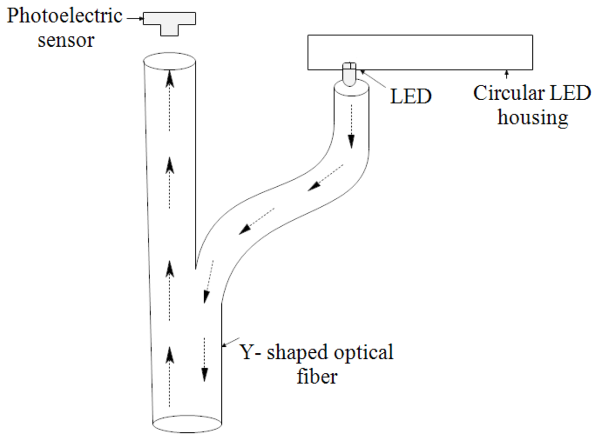

Figure 2. System design

and transferred to the photoelectric sensor, through which the optical signal is converted to an electrical signal. Subsequently, the electrical signal is amplified to achieve adequate voltage level and amplified signal thus obtained is then digitized using ADC, and the absorbance at each wavelength is calculated. Calibration of the result is done for estimation of Nitrogen content of the soil from the device output and known to achieve optimal accuracy. Finally, the calculated soil TN content is displayed on the LCD display.

RESULTS AND DISCUSSIONS

Absorbance is selected as the spectral parameter. A standard whiteboard is taken as reference, which is needed to obtain the absorbance of the soil samples. The output voltage V_i is obtained from the reflected rays due to the standard whiteboard. Then, the output voltage V_o corresponding to the required soil sample. The reflectance R_i and absorbance A_i of every soil sample can be calculated according to equations (1) and (2) (Xiaofei A., Minzan L. *et al* 2013).

$$R_i = \frac{V_o}{V_i} \times 100\% \qquad (1)$$

$$A_i = \log\left(\frac{1}{R_i}\right) \qquad (2)$$

Where, i indicates 1550, 1300, 1200, 1100, 1050 and 940 nm; V_i is the standard whiteboard output voltage at i; V_0 is the soil sample output voltage at i; R_i is the reflectance at i and A_i is the absorbance at i.

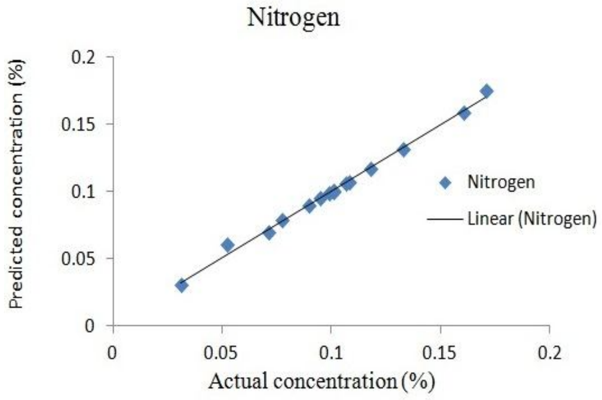

Figure 3. Calibration curve of Nitrogen

From the result, accurate predictions of nitrogen were obtained. The regression coefficient R^2 obtained for the device is 0.82. Thus, the device can be used for determination of Nitrogen content of the soil. Results show that, prediction accuracy has increased due to pre-sample preparation procedure.

CONCLUSION

Nitrogen being the key component for plant growth, the knowledge about soil Nitrogen content will be beneficial for farmers to improve crop production. Spectroscopy technique has been successfully used for soil Nitrogen contents with R^2 equal to 0.82.

The accomplishments reviewed in this paper, have led to the modified model consisting of six LEDs corresponding to wavelengths 1550, 1300, 1200, 1100, 1050 and 940 nm, as a NIR light source. Thus, a portable and cost effective TN detector model is developed, eliminating the need of expensive and bulky spectrometers.

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