The Application of Infrared Spectroscopy as A Rapid and Innovative Technology for Soil Quality Properties Prediction

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Abstract
A major function of soil is to provide fundamental natural resources for the survival of plants, animals, and the human race. The maintenance of soil quality is critical for ensuring the sustainability of the environment and it depends on the balances of soil structure and nutrient composition. To determine soil quality, several methods were already widely used in which most of them were based on solvent extraction followed by other laboratory procedures. However, these methods often require laborious and complicated processing for samples. Infrared reflectance spectroscopy can be considered as a rapid, innovative and non-destructive method for determining soil properties. The objective of this study is to apply infrared technology in classifying soils based on their land-use and to predict related soil quality properties based on its infrared reflectance. Soil infrared spectrum was acquired in the wavelength range from 1000 to 2500 nm for rice-field (with a total of 30 points) and ground-field soils (31 points). Principal component analysis (PCA) with non-iterative partial least square (NIPALS) was applied to analyze soils spectral data. The result showed that two principal components (PC1=97% ad PC2 = 3%) based on infrared reflectance data were successfully able to recognize and distinguish soils based on their land-use. Furthermore, the wavelength ranges of 950 – 1128 were related to soil nitrogen content whilst 1460 nm and 1920 nm were associated with soil moisture content. Soil organic matter can be predicted in the wavelength range of 1230 – 1315 nm, 1580 – 1680 nm, and 2095 – 2200 nm. This may conclude that infrared technology was feasible to use as a rapid, innovative and non-destructive method in soils quality properties classification and evaluation.

Keywords: infrared; non-invasive; soil; technology; evaluation

INTRODUCTION
Soil is the main medium where plants can growth and provide fundamental natural resources for the survival of plants, animals, and the human race. The maintenance of soil quality is critical for ensuring the sustainability of the environment and it depends on the balances of soil structure and nutrient composition. Significantly, plants can grow optimally in a healthy soil, heavy metals free and fertile. Soil chemical properties related to the amount of nutrients required by plants, the amount needed will vary each growth phase [1,2,3].

During the last two decades, infrared (IR) spectroscopy has been widely employed as an effective tool for the analysis of soil properties. Compared with traditional wet chemistry analysis, IR analysis is rapid, cost effective, non-destructive, requires minimal sample preparation and can be used in situ. More importantly, it permits a quantitative assessment of several properties from a single measurement. This technique mainly measures overtones and
combinations of fundamental vibrational bands for O-H, N-H and C-H bonds from the mid-infrared region. Numerous studies for the measurement of soil nitrogen (N) and organic carbon (OC) have been reported using this technique [4,5,6].

The IR Spectroscopy is a technique or method which uses infrared radiation of the electromagnetic spectrum to analyze the chemical composition of organic matter. It provides information through spectra signatures and patterns, regarding with the intrinsic organic bonds of the molecules and thus the primary chemical constituents of the object can be determined [7,8]. The term spectroscopy is the study of electromagnetic radiation as a function of wavelength, which has been reflected, absorbed or transmitted from a solid, liquid or gas material. Spectroscopy generates a unique spectral pattern of the material monitored. Each biological object has its own special optical properties, which means it has a different spectra pattern or signatures indicated its chemical compositions. The spectral patterns of different matter are defined by their reflectance or absorbance as a function of wavelength. These special signatures were then used to describe and predict the chemical constituents of biological matter [9].

Therefore, the main objective of this study is to apply infrared technology in classifying soils based on their land-use, and to predict related soil quality properties based on its infrared reflectance. Classification model was established using the principal component analysis (PCA) and related wavelengths were analyzed using PCA loading plot.

MATERIALS AND METHODS

Samples and instrument preparation
Material used in this present study were rice-field and ground field soils obtained in Aceh Besar District, Nanggroe Aceh Darussalam Province. IPTEK infrared instrument was used to acquire diffuse reflectance spectra of soil samples and saved the spectral data.

Infrared spectra acquisition
In this study, infrared spectra data of all soil samples were acquired in form of diffuse reflectance spectral data. Sample measurement with integrating sphere was chosen as a basic measurement and background spectra correction was performed every hour automatically. Diffuse reflectance spectra in wavelength range of 1000 – 2500 nm with the increment of 0.2 nm resolution were acquired 64 times and averaged.

Spectra data correction
Spectra data pre-processing was performed prior to PCA classification models development. Spectra smoothing was applied as spectra data correction method.

PCA classification models
Infrared soil spectra data acquired from the NIR instrument were analyzed through principal component analysis (PCA). It employs a mathematical procedure that transforms a set of possibly correlated response variables into a new set of non-correlated variables, called principal components. non-iterative partial least square (NIPALS) was also coupled to PCA in analyzing soils spectral data.

RESULTS AND DISCUSSION

Soil classification
The PCA result as shown in Fig.1 shows a significantly cluster based on soil land-use. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible. PCA is used as a tool for screening, extracting, compressing and discriminating samples based on their similarities or dissimilarities of multivariate data. The first PC (PC1) accounted 97% of all spectra data while remaining 3% was explained by the second component (PC2).
The differentiation of showed PCA classification is probably due to nutrient content of related soil land-use. Soil spectral features in the infrared wavebands are highly correlated to the vibration modes of functional groups like the chemical bond of H and C, N, and O. These bonds are subject to vibrational energy changes in which two vibration patterns exist in these bonds including stretch vibration and bend vibration. The nitrogen (N) content in the soil is a macroelement that plays an important role in soil nutrition along with Phosphorus (P) and Kalium (K).

![Fig. 1: PCA soil classification based on their land-use derived from infrared spectra data.](image1)

The N content of soil was observed at around 950 – 1128 nm, whilst 1460 nm and 1920 nm were associated with soil moisture content. Soil organic matter can be predicted in wavelength range of 1230 – 1315 nm, 1580 – 1680 nm, and 2095 – 2200 nm as shown in Fig.2.

![Fig. 2: Related wavelengths of specific soils nutrient content based on loading plot of PCA](image2)

**CONCLUSIONS**
Achieved present study shows that infrared technology was feasible to use as a rapid, innovative and non-destructive method in soils quality properties classification and evaluation based on their land-use. The important nutrient content such N and organic carbon can be predicted using specified relevant infrared wavelengths. Further, this technology can be used to monitor soils condition and pollution from hazardous material.

**REFERENCES**


