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Geophysical Applications in Agriculture in the World and Initial Results of the GPR Method in Vietnam

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Abstract

Geophysical methods are very popular in Vietnam and have been applied for several decades in different deep earth investigations such as geological mapping, mineral resource searching and especially oil and gas exploration. In the World, they have proven to be great tools in agriculture as well for soil characterization and monitoring thanks to their notable advantages including rapid data acquisition, large data coverage, high data density, and non-destructive and inexpensive survey implementation. However, in Viet Nam, the applications of geophysical methods in agriculture have received little attention probably due to the lack of suitable equipment and data processing techniques. This article gives an overview of popular geophysical methods being applied in agriculture in several countries to characterize and monitor soil properties such as moisture, salinity, density, texture, structure, porosity, etc. The main uses of each method are summarized, and relevant publications are given for reading recommendations with the aim to suggest similar applications in Viet Nam. According to the summary, Ground Penetrating Radar (GPR) and Electromagnetic Induction (EMI) are the most versatile with minimum field crew for data acquisition. They should be prioritized to try in Vietnamese agriculture. Since EMI equipment is not currently available in Vietnam, only a GPR test survey was implemented in the Agricultural Academy experimental field by the authors of Hanoi University of Mining and Geology. The preliminary result shows that the biggest challenge is to find reliable techniques to accurately infer soil properties from measured geophysical parameters, which have no explicit relationship with soil properties. Noise suppression is another problem that needs to be addressed to ensure sufficient data quality.

Introduction

Geophysical methods, traditional tools for studying deep earth properties, in recent years, have been actively applied in agriculture to utilize their significant strengths, such as quick measurement, easy deployment, high data density and low operational cost. With the help of geophysical methods, maps of soil properties in vast areas can be created and updated regularly to assist land management, plantation optimization and farm planning. Several techniques for geophysical data analysis have been established and widely applied to determine soil properties (Besson et al., 2013; Blanchy et al., 2020; De Benedetto et al., 2012; Donohue et al., 2013; Jadoon et al., 2015; Grote et al., 2010; Huang et al., 2016; Keller et al., 2017; Moghadas et al., 2019; Wong et al., 2009). In Vietnam, however, soil properties are still solely measured by sample analyses in laboratories which are time-consuming, expensive, and hence leading to sparse data points. Apparently, little attention has been given to geophysical applications in agriculture in spite of their effectiveness. Nguyen et al. (2008) and Trinh et al. (2012) are probably the only two articles found on the Vietnamese public domain that tried to use an electrical method to predict the high salinity of underground water in a northern Vietnam coastal plain area. With that background, this article gives an overview of the most common geophysical methods being applied in agriculture all over the World and describes a preliminary experiment implemented at the Agricultural Academy testing ground aiming to evaluate the potential application of these methods in Vietnamese agriculture.

Geophysical methods applied in agriculture

A. Ground Penetrating Radar method

- Ground Penetrating Radar(GPR) emits electromagnetic wave via an antenna-transmitter and receives them by an antenna- receiver. The velocity of the wave can be calculated by a formula:

$$V = \frac{1}{1+\frac{\varepsilon\mu}{2}\sqrt{1+\left(\frac{\sigma^2}{\varepsilon\omega}\right)}} \quad (1)$$

where μ is the magnetic permeability; σ is the electrical conductivity; ε is the dielectric constant; and ω is the angular frequency.

- GPR method can be used to determine the petrographic composition and thickness of the soil layers (Ditzler et al., 2017) (Figure 1).
- GPR method is particularly useful for rapid estimation of water content in shallow soil layers over large areas (Lesmes et al., 1999; Grote et al., 2003; Huisman et al., 2003; Galagedara et al., 2005).

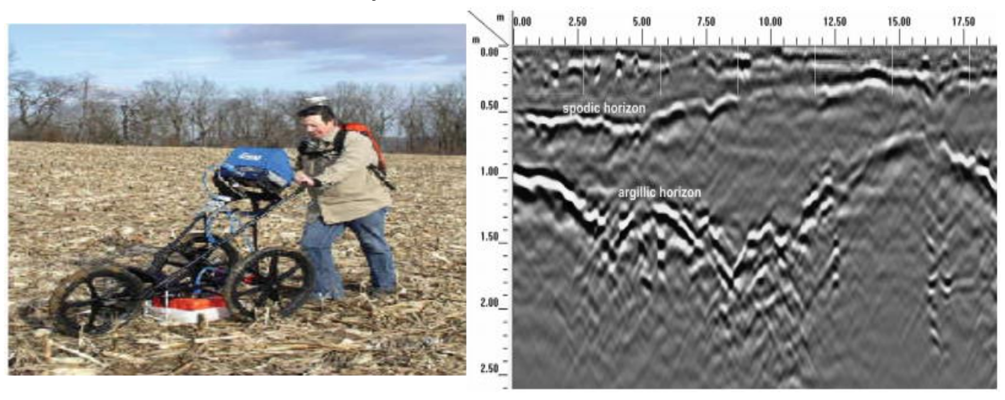

Figure 1: GPR survey in the field can be carried out by one man with handy equipment. After the data processing, radargram section can reflect the sand and clay layers (Ditzler et al., 2017).

B. Electromagnetic induction method

- Electromagnetic induction (EMI) method measures vertical or horizontal components of an EM field forming in the soil by induction in response to a prescribed EM field. Electrical resistivity of the soil affect the measured voltages or EM induction. The field measurement by EMI method can also be carried out by one man with handy equipment (Figure 2).

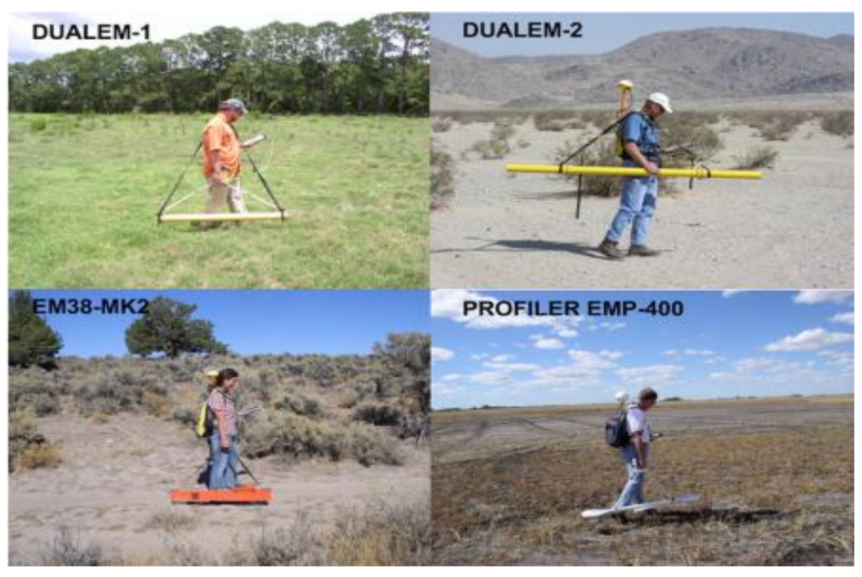

Figure 2: EMI equipments are easy to move and compact (Doolittle and Brevik, 2014)

- The EMI equipment measures apparent conductivity (ECa), which reflects the conductive property of the soil vertically at specified depths (Figure 3). The conductivity of the soil depends on the dissolved ion content, the amount and type of clay in the soil, the water composition, and the temperature and phase of soil water. The ECa value increases with increasing salt concentration, water or clay content and temperature, the method can also be used to determine the changes in some agar compositions (Allred et al., 2010).

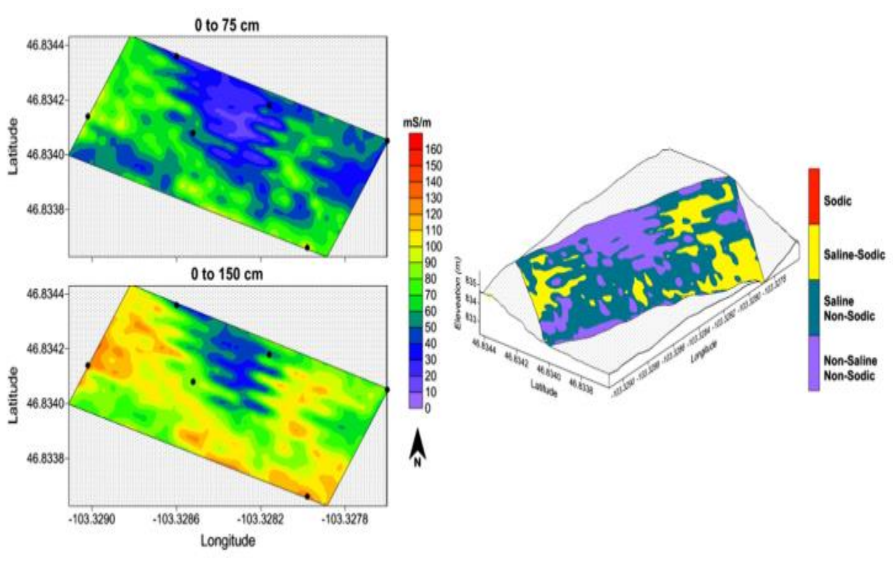

Figure 3: ECa measurements for 2 different depths (on the left), classification according to the salt content of southwestern North Dakota on the right (Corwin, 2008).

C. Resistivity method

- Resistivity is related to some important soil properties such as porosity, moisture content, structure and architecture of soil (Samouëlian et al., 2005). Therefore, the resistivity method has been widely used in research and applications in soil science (Figure 4).

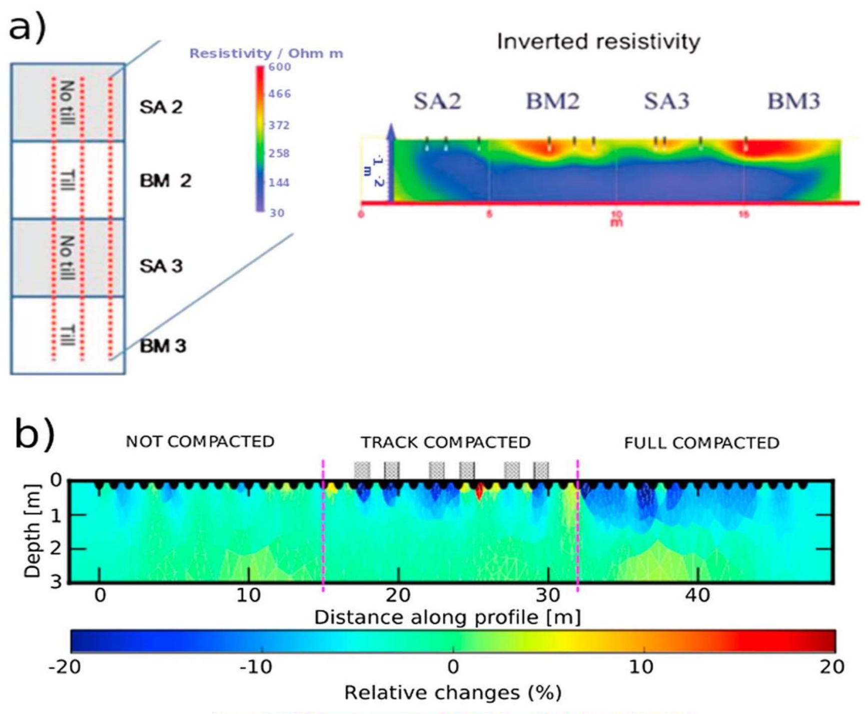

Figure 4: The change in soil salinity obtained from the resistivity measurement method. (Romero- Ruiz et al., 2018)

D. Gamma method

- Radioactive gamma rays have good penetrating ability, in the soil environment can pass through about 30 cm (Mahmood et al., 2013; Van Egmond et al., 2018).
- In soil survey, gamma spectra equipment was attached to a vehicle moving in the field (Figure 5).

Figure 5. Equipment can be mounted on a vehicle for fast and convenient measurement

E. Seismic method

- Seismic provides parameters such as the thickness of soil, soil porosity, sand and clay composition, can provide parameters that other methods could not determine such as the change of soil structure under the tillage process (Figure 6).

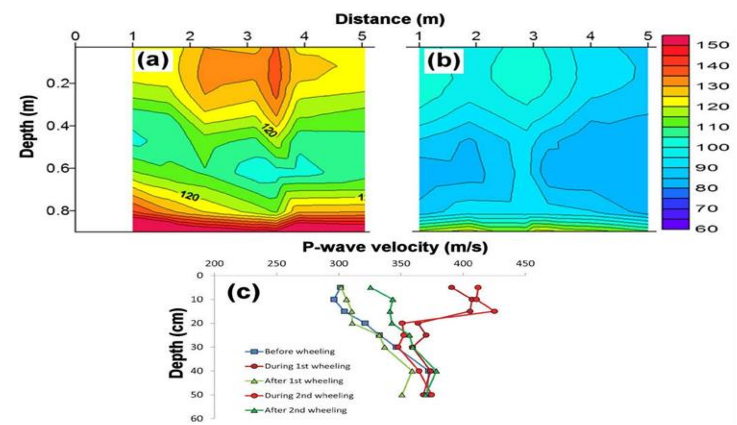

Figure 6: Sensitivity of seismic measurements to soil compaction and loading: Parts of S wave from Multichannel analysis of seismic waves inferred from the compressed region (a) and the undistorted region (b), note the lower; and (c) P wave velocity with depth measured in the rolling experiment marks changes in the load and after the wheel passes (Keller et al., 2013)

Experimental application of geophysical methods for soil property prediction in Vietnam

- A GPR survey line was carried out in the Agricultural Academy experimental field (Figure 7a). Three boundaries can be interpreted as coloured lines in Figure 7(b).
- The first boundary is sub-horizontal and has a depth of about 30 cm, the shallowest part of the boundary is about 25 cm while the deepest part is about 35 cm.

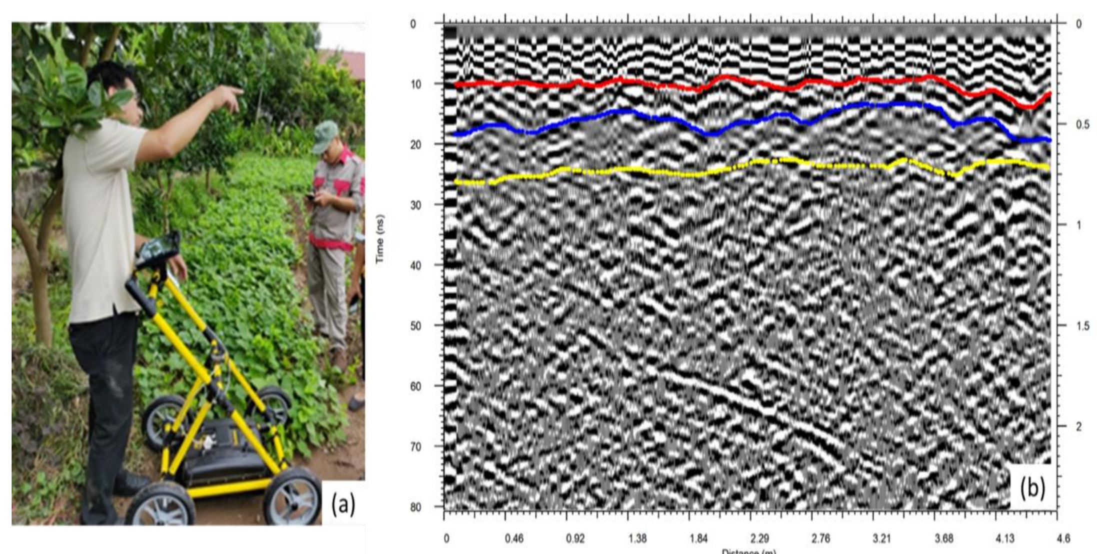

Figure 7. A trial application of GPR to predict subsurface soil layers implemented in the experimental field of the Agricultural Academy using Geoscaner equipment (a) and the resulting cross-section with interpretation (b).

Summary and conclusion

- The review has demonstrated that geophysical methods are useful tools for soil characterization and monitoring. They have proven effective in soil property studies thanks to several advantages, including rapid data acquisition, high data density, large data coverage with inexpensive implementation and most importantly they are nondestructive methods.
- The main challenge is that soil properties cannot be directly indicated by measured geophysical parameters, instead, they are inferred from them by sophisticated data analysis and data modelling techniques, that are not readily available in Vietnam. This is probably the main reason why geophysical methods have not been applied for agricultural purposes in the country so far.
- A preliminary experiment of the GPR method reveals that the data can be useful but needs a lot of processing effort to reduce the amount of contaminated noise. A combination of varied suitable geophysical methods and the use of industry 4.0 technologies can be a solution to provide more reliable information about soil properties.