CORRELATION OF SELECTED SOIL TYPES AGROTECHNICAL PROPERTIES WITH CORRESPONDING GPR RESPONSE

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Introduction

Soil must provide the opportunity to create a system of transporting water, air and minerals to the roots of plants. Such a system consists in infiltrating water into deeper soil layers, from where all due necessary capillary properties components are carried into the plant's root system. Infiltration into the ground requires the existence of relatively large pores connected with each other to ensure efficient water drainage. On the other hand, components with smaller granulation allow building a capillary transport system essential in the proper nutrition of plants. Accordingly, recognizing the distribution of porosity of the ground (which is directly associated with the volumetric water content) and distribution of soil compaction is vast problem for achieve optimal yields.

It should be noted that the change in the agrotechnical properties of the soil is closely related to the volume fraction of water in the soil structure or its mineralization. This relationship may be the basis for the project of using the GPR (Ground Penetrating Radar) method to study the quality of agricultural soils, in particular, changes in soils properties as a result of agrotechnical or anthropogenic environmental changes. First of all, the electrical permittivity of a medium composed of various components can be described (Schon 1996) by the formula:

$$\varepsilon^* = (\sum_k \nu_k \sqrt{\varepsilon_k})^2 \tag{1}$$

where: ν_k - the volume fraction of the k-th component with permittivity ε_k, in a unit volume of soil, so that:

$$\sum_k \nu_k = 1 \tag{2}$$

Electrical permittivity tests are best carried out using a GPR method, in which an electromagnetic wave of frequencies 10^8-10^9Hz is used. Considering dependence (Carcione, Schoenberg 2000):

$$\varepsilon(\omega) = \frac{\varepsilon_s}{K}\sum_{k=1}^{K}\frac{1+i\omega\tau_{E_k}}{1+i\omega\tau_{D_k}} \tag{3}$$

where: K - the number of Debey's polarizing effects, τ_{Ek} - Debey's relaxation time, τ_{Dk} - time of relaxation of the electric flux and ε_s - static electrical permittivity. For a suitably selected frequency band, the electrical permeability determined from radar measurements is proportional to ε_s.

Because of the generally high value of ε_s for water its role in formula (1) is decisive and changes in the volume of water (that is, soil water saturation) and the value of water permittivity fully approximates the changes in ground electric permittivity.

The value of water permittivity $\varepsilon_w(\omega)$ for electromagnetic field with frequency ω can be expressed using the formula (Carcione, Schoenberg 2000):

$$\varepsilon_w(\omega) = \varepsilon_w^\infty + \frac{\varepsilon_w^0 - \varepsilon_w^\infty}{1-(i\omega\tau_w)^q} + \frac{i\gamma_w}{\omega} \tag{4}$$

where: ε_w^0 and ε_w^{oo} they are permittivities for low and high frequencies of electromagnetic field, τ_w - Debey's relaxation time, q – constant and γ_w - electrical conductivity. This formula shows that in addition to water saturation, the electrical conductivity of water plays an important role in the response of the ground to extortion in the form of passing radar waves.

With parameter γ_w the damping factor b is associated:

$$b = \frac{\omega\sqrt{\varepsilon^*}}{\sqrt{2}}\sqrt{\sqrt{1+(\frac{\gamma}{\varepsilon^*\omega})^2}-1} \tag{5}$$

The coefficient b is to some extent a measure of water mineralization.
Change in agricultural properties of soil in the form dangerous for plants changes in the distribution of pores caused by soil loading by agricultural machines, the occurrence of large solid rock inclusions, or the disturbance of groundwater levels can be identified by GPR methods. On the other hand, by using GPR method, it is possible to identify changes in groundwater mineralization resulting from the impact of landfills of various types of waste near the cultivated agricultural fields.
Commonly used methods to estimate porosity and compaction are based on laboratory tests and penetrometer (PR) measurements, which are time consuming and gives us sparse information. GPR (Ground Penetrating Radar) method is noninvasive, fast and provides us with very dense information about the electrical features of the soil.

Samples and methods

This work presents results of GPR field and laboratory soil tests from three test fields. First considered GPR measurements were carried out in the test field of the University of Agriculture in Krakow by using ProEX GPR unit. Soil in this area can be considered as sandy loam. During measurements we used 800 MHz shielded antennae. GPR measurements were conducted in standard common offset mode in three parallel lines which were perpendicular to tracks of tractor (Ursus 1012 with cultivator). To get more compaction, tractor's journeys took place in ten parallel lines with increasing number of passings (from one to ten). In the places where the GPR measurement lines and the tractor tracks crossed, soil samples were collected in cylinders, with a volume of 250 cm^3. For each sample density and volumetric water content was established.
Second set of GPR data was collected in area of Kryspinów on peat and sandy soil. Measurements were conducted in Short-Offset and Wide-Offset mode. In addition, soil water content determinations were performed using the gravimetric method. Third GPR measurements were conducted in Short-Offset mode on anthropogenic soil in area of AGH University Campus. The measurements were made for dry (after long period without rain), wet (day after strong rainfall) and medium wet soil (three days after rainfall). In addition, soil water content determinations were performed. The GPR data processing was performed using the ReflexW program. Analyzes of these data were made using Matlab and ReflexW programs.

Results

As the results of the research, we obtained a correlation between different types of soils in terms of their agriculture quality and electrical parameters determined on the basis of registered GPR data for individual types of soil. These relationships vary depending on the type of considered soil. It was also possible to determine the distribution of electrical parameters within individual soil profiles.

Conclusions

On the basis of the analysis of the results of GPR measurements, it is possible to classify the investigated soils. This is possible due to the correlation of the electrical parameters of the different types of soil, such as velocity and attenuation coefficient of electromagnetic wave, with the agrotechnical properties of those soils.
It should be noted that the change in agrotechnical properties of soil is closely related to the volume fraction of water in the soil structure or its mineralization. This relationship and the results obtained in this paper can be the basis for the project of using the GPR method to study the quality of agricultural land, in particular changes in soil properties as a result of agrotechnical work or anthropogenic environmental changes.

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