INVESTIGATION ON THE INDIRECT CORRELATION AND SYNERGISTIC EFFECTS OF SOIL PH AND MOISTURE CONTENT DETECTED BY REMOTE SENSING

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Remote sensing is a measuring method which applicable for soil characterization on agricultural areas. Utilization of remote sensing is particularly important in the case of agricultural farming. This method is based on the molecule- or functional groups specific absorption peaks that are measured in infrared wavelengths over 2500 nm. Due to the high levels of disturbance of the water the measurements in this range are only feasible on water-free samples. The absorption peaks of the reflectance spectra measured at 350 to 2500 nm range which is used in remote sensing are found far less specific. This is the near-IR range which can excite overtone or harmonic vibrations. The most intensive absorption between 1900-2000 nm is caused by the omnipresent water that is moisture content. The relationships between soil properties and reflectance spectra can be determined the most effectively by using partial least-squares regression (PLSR) which takes into account the entire spectrum. Several authors who applied this method found a relationship between the pH of the soil and the spectral data. Since the pH cannot cause absorbance in infrared range the detected absorption was the result of the molecular structural changes indicated by the change in the soil pH. This means the correlation between the detected absorption and the pH is indirect. In this study we attempt to investigate of this indirect correlation.

Keywords: hyperspectral technology, soil acidity, humidity

Introduction

By the spread of precision agriculture the development of analytical methods using remote sensing has become important. The optical properties of the soil surface are dependent on the soil properties and the chemical, biochemical changes occurring in the soils. These properties can be determined effectively by remote sensing.

The ASD FieldSpec ® 3 Max spectroradiometer can collect data from the soil surface on large area. It has a spectral wavelength range from 350 to 2500 nm. The information which defines mineral composition of soil is usually in the upper range of this spectrum (Kardeván et al., 2000; Kardeván, 2007).

The vast majority of Hungarian soils are acidic. In order to the appropriate amelioration and soil conservation it is important to estimate the extent of acidification (Várallyay, 2006).

During the examination the obtainment of detailed information is desirable. Beyond the conventional laboratory tests, pH(H_2O), pH(KCl), hydrolytic acidity (y1) (Buzás, 1988), the total acidity can be measured by the titration of soil suspension. The principle of this method is that pH level of the suspension is kept at constant level during the titration (Czinkota et al., 2002; Vágó et al., 2010). The precise measurement of soil acidity is especially important to calculate the lime quantity (Tolner et al., 2008).

The detection of the soil acidity is not easy because only the indirect effects of surface pH can be analyzed through reflected spectra. Furthermore, an important factor that

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must be considered is that optical effects generated by the pH change can mix with the effects of the organic or clay content (Chang et al., 2001).
In this experiment we studied the effect of moisture content, pH value and the calcium mineral to the NIR reflection spectra.

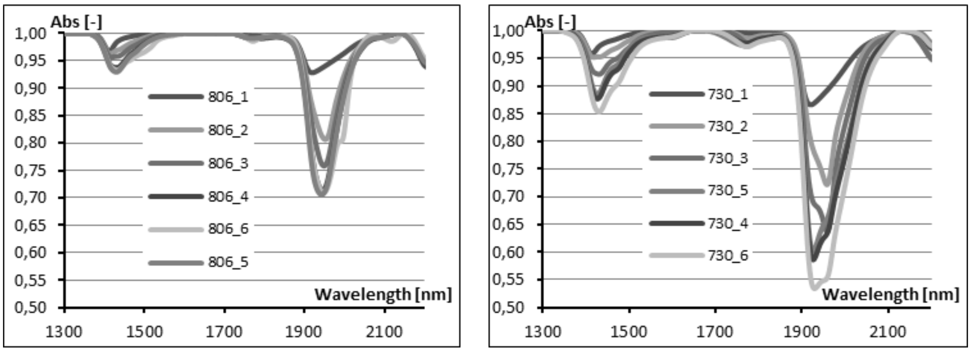
Materials and methods
Sandy soil samples from Fót, North-Central Hungary (Coords: 47.617252N, 19.189166E) were applied for the treatments. The main properties of the soil are the following: KA=28.33 (saturation percentage), lime content, $CaCO_3$% = 8.0 %, pH(H_2O) = 8.2, pH(KCl) = 7.2, humus content, H% = 1.4 %, AL-P_2O_5 = 95 ppm, AL-K_2O = 120 ppm. The treatments calculated for 100 g soil are summarized in Table 1. The treatments will hereinafter be marked with the numbers in Table 1.. All measurements were carried out in duplicates.

Table 1: Details of treatments (calculated for 100 g of soil).

No.	Treatments	Added amount of HCl
1	Control	Soil without any treatment
2	Acidification	1.46 g HCl (equivalent for 25% of $CaCO_3$ content)
3	Acidification	2.92 g HCl (equivalent for 50% of $CaCO_3$ content)
4	Acidification	4.38 g HCl (equivalent for 75% of $CaCO_3$ content)
5	Acidification	5.84 g HCl (equivalent for 100% of $CaCO_3$ content)
6	Acidification + $CaCl_2$	5.84 g HCl (equivalent for 100% of $CaCO_3$ content) + 2.22 g $CaCl_2$ (equivalent for 25% of $CaCO_3$ content)

The reflectance spectra of all samples were examined at absolute dry and air humidity equivalent state. The absolute dry samples were made through a drying process on 105 °C. The air humidity equivalent samples were in balance with the laboratory's air humidity. The dried samples reached this state in 24 hours. The spectra were collected with ASD FieldSpec ® 3 Max spectroradiometer by using ContactProbe sensor-head in three positions. Each position was measured ten times with twenty scans providing with average spectra composed from ten times twenty measurements. During the processing we performed continuum removal on reflectance spectra .

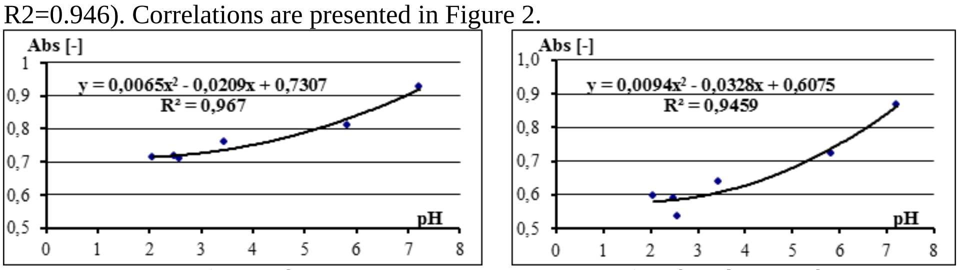
Results and discussion
Potash fertilizing plays important role in the acidification of soils (Loch et al., 2006). When the roots take up the potassium ion, equivalent amount of hydrogen is released at the same time. This hyperspectral spectrum sections can be seen on Figure 1. Spectral sections can be seen on the left side for the dried soil samples (105°C), and on the right side for soil samples with moisture content equivalent to the humidity of the laboratory (air dried).



A) Dry soil *B) Air humidity equivalent*

Figure 1.: Continuum removed spectra of soil samples

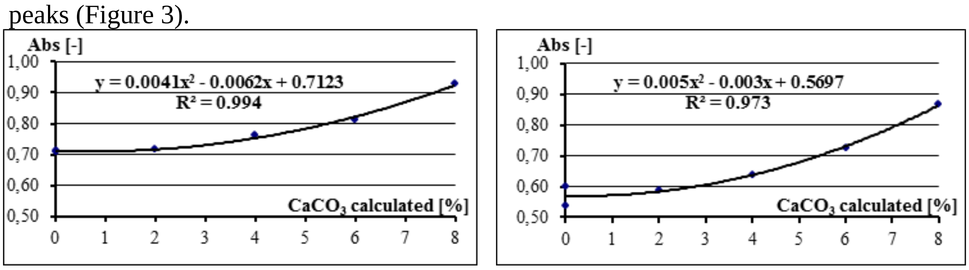
Between 1900 and 2000 nm typical water characteristic adsorption peaks were found which were dependent on the definite treatment. We applied approximately proportional heights to the area under the peaks in order to get quantification. We examined the correlation between the pH and the absorption peak height generated by the treatments. We found close quadratic correlation in case of both moisture contents (R2=0.967, R2=0.946). Correlations are presented in Figure 2.



A) Dry soil *B) Air humidity equivalent*

Figure 2.: Correlation between the absorption maxima (1900-2000 nm) of treated samples and their pH value

The question may arise rightfully if this correlation can be attributed clearly to pH. According to our results we examined the correlation with some other factors too. Acidic treatment resulted in a decrease in $CaCO_3$ content of soil samples. We also found a very close correlation between this calculated data and the height of the absorption peaks (Figure 3).



A) Dry *B) Air humidity equivalent*

Figure 3.: Correlation between the absorption maxima (1900-2000 nm) of treated samples and their Calculated $CaCO_3$ content

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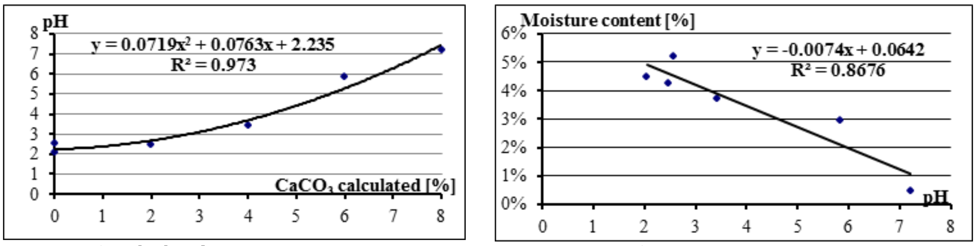
It is well known that lime content and pH of the soils have a strong correlation which was detected on our samples too (Figure 4, A). Since $CaCl_2$ is formed during the acidic treatment there is a correlation between the pH and moisture content of soil samples also resulted by the dehydrating effect of $CaCl_2$ (Figure 4, B).



A) Calculated $CaCO_3$ content - pH *B) Moisture content - pH*

Figure 4. A) Correlation between pH and the calculated $CaCO_3$, and B) between the soil sample moisture content and pH

Conclusions

The detected correlation between soil pH and the absorption maxima (1900-2000 nm) was probably the result of the synergistic effect of more parameters that are linked to pH and NIR absorption. In order to clarify and validate the correlation obtained increased number of samples is needed and repetition of the experiment is suggested.

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