Soil Parameters Assessment by Remote Sensing

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Abstract. In this paper, remote sensing measurements like apparent electrical conductivity (ECa.) are used to assess soil compaction. In an experiment comparing five tillage treatments and their effect to energy crops soil penetration resistance (SPR) was measured at the same time as ECa. ECa measurements were carried out using EM-38with dipoles at 1m apart and SPR by an electronic penetrometer. The negative correlation between the two parameters for all measurements resulted in R2= 0.73. Taking the measurements for each treatment in conventional tillage plots R2 = 0.53, chisel plough tillage 0.61, rotary tiller 0.69, disk harrow 0.55, strip-till 0.35 and no till 0.81.

Keywords: soil compaction, tillage, soil apparent electrical conductivity, soil penetration resistance

1 Introduction

Soil compaction is a major problem of soil degradation affecting soil fertility and crop yields. Soil compaction is caused in the present day agriculture mainly by heavy farm machinery. Several factors affect compaction by machinery like soil water content, machinery weight, machinery tyres (width, type and inflation pressure). Compaction is not homogeneous in all parts of the field because it depends on the traffic of each part. The compaction caused is alleviated by soil tillage. Soil deep loosening causes breaking of the soil causing the restoration of large pores and facilitates the soil functioning. Tillage practices employing deep loosening and soil inversion like conventional tillage using ploughing or minimum tillage that causes soil loosening at different depths without soil inversion can lead to higher or lower soil disturbance and loosening. Soil tillage is an energy and labour consuming practice and the intensity depends on the soil compaction. It would be of interest to find ways to assess soil compaction in order to apply variable rate tillage depth and reduce energy consumption.

Soil compaction is measured by instruments like penetrometers measuring soil penetration resistance (SPR) at different depths, by measuring dry bulk density at layers of different depths and by measuring water infiltration rate. Penetrometers are

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usually following the ASABE standardisation (ASABE 2014). The penetrometer has a cone with base diameter of 12.83 mm and cone angle of 30°. It is inserted at stable speed up to a depth usually of 50 cm. Undisturbed soil cores are taken at different depths and the dry weight of the unit of volume is estimated. Water infiltration is measured by metallic tubes filled with water and the rate of water infiltrated by the soil is measured. All methods are time and labour consuming and are difficult to be applied. An alternative method proposed in the literature to estimate soil compaction is the measurement of soil apparent electrical conductivity (ECa). This is a method that can measure soil properties on the go. This is a fast and low cost method. The sensors are based on electrical and electromagnetic, measurements (Adumchuk et al.2004). Electrical resistivity and electromagnetic induction (EM) was used to assess the soil apparent electrical conductivity (ECa). The ECa measures conductance through not only the soil solution, but also through the solid soil particles and via exchangeable cations that exist at the solid–liquid interface of clay minerals.(Colvin and Lesch 2003). This property is directly connected to soil properties like texture, water content, organic matter, salinity, ions in the soil and temperature. There are formulae to correct measurements to a basis of 25° C (Ma et al. 2011). If we exclude saline soils from the measurements and take measurements near field capacity most measured conductivity is due to soil texture. Electric resistivity instruments use flat, vertical disks to apply a voltage and measure the soil resistance by measuring the current in other similar disks (Figure 1). The distance between the disks defines the depth of the measurement. In Electromagnetic induction sensors (Figure 2) coils induce and measure the electricity. An EM transmitter coil located at one end of the instrument induces circular eddy-current loops in the soil. The magnitude of these loops is directly proportional to the ECa of the soil in the vicinity of that loop. A second coil measures the produced current which is the result of soil properties (e.g., clay content, water content, organic matter, ions). Instrument construction (distance between the dipoles), orientation and distance from the soil when measurements are taken define the depth the soil the measurements present.

Fig. 1. Electrical resistivity instrument (VERIS)

Fig. 2. Electromagnetic induction (EM) instrument.

The two instruments were used in many applications in precision agriculture combined with GPS. They provide a fast and relatively cheap way to produce maps which are presenting the variability of the field and they are correlated to yield. Many researchers have reported this connection (Kitchen et al. 2005).

The two instruments were used to assess soil compaction. Siqueira et al. (2010) have studied the correlation between ECa and SPR. They found negative correlation between SPR amd ECa measured by an inductance instrument EM38. The best correlation coefficient of r= - 0.695 was found between the Vertical position of the EM38 and the SPR at 0.30 to 0.40 m depth interval. They explain the negative correlation by the water content of the soil. High water content gives high ECa and low SPR. Jabro et al.(2006) have studied the relationship between SPR and ECa measured by a VERIS electrical resistivity instrument. They found very low negative correlation between the two.

During the last three years experiments studying soil tillage systems under different crop rotations were carried out in the University of Thessaly Farm at Velestino, Central Greece. During the experiment soil compaction was measured using a soil penetrometer and soil apparent electrical conductivity using an EM38. The results of these experiments are presented in the present paper.

2 Material and Methods

The tillage treatments were:

1. Conventional tillage (CT) using ploughing at 25-30 cm and 2-3 passes of a disk harrow at 7-9 cm or a light cultivator at 6-8 cm for seedbed preparation.
2. Reduced tillage (HC) using a heavy cultivator at a depth of 20-25 cm at 30-35 cm and 2 passes of a disk harrow or a light cultivator for seedbed preparation.
3. Reduced tillage (RC) with one pass of a rotary cultivator at 10-15 cm for primary tillage, and a second pass with rotary cultivator or one or two passes of a disk harrow or a light cultivator before planting.
4. Reduced tillage (DH) Primary and secondary tillage with a disk harrow at 6-8 cm for the winter crops and strip tillage for spring crops. For winter crops one or two passes for residue management and weed destruction and one or two passes for seedbed preparation before planting the crop. A strip tillage machine developed in the laboratory (lit) of farm mechanisation was used for spring crops.
5. No-tillage (NT). Direct planting using a no till pneumatic drilling for winter crops and a planting machine for spring row crops.. The plots were split in two parts. In one part all residues were removed and added to the other plot. That way one plot had double mulching material.

The following soil properties were measured: 1. Soil penetration resistance by using a Bush penetrometer with a 12.8 mm base diameter and 30^o angle. The instrument was able to record soil penetration resistance every 1 cm depth. The measurements were made in each experimental plot. Five measurements were made and the mean values for each depth were used 2. Soil apparent electrical conductivity by using an EM 38. Measurements were made by moving the instrument along the plot. Two modes of operation was used. The horizontal (H) measuring the ECa at 0-75 m depth and the vertical (V) measuring the ECa at 0-1.5 m depth. As the Horizontal mode is more sensitive to the surface layers of the soil the Horizontal mode was used for the present measurements. Three groups of measurements were taken. From 25/6/2011 till 6/7/2011 five measurements were taken, from 25/2/2013 till 2/4/2013 six measurements were taken and from 21/6/2013 till 26/7/2013 twelve measurements were taken. Date analysis were made using Excel 2013 and SPSS.

3 Results and Discussion

Figure 3a shows the correlations of all data. An exponential curve is fitted with a high correlation coefficient of 0.73. Figure 3b shows the same data with a linear curve fitted with $R^2 = 0.69$. Figures 4 show the curve fitting of the tillage treatments of the experiment. In all cases the correlation is negative i.e that higher ECa is connected to lower SPR. The basic soil parameter that can explain this is the effect of soil water content has in the two measured parameters. ECa is larger with higher water content as electrons are moving freely through water and SPR is lower with higher water content. The same conclusions were drawn by Siqueira et al. (2010).

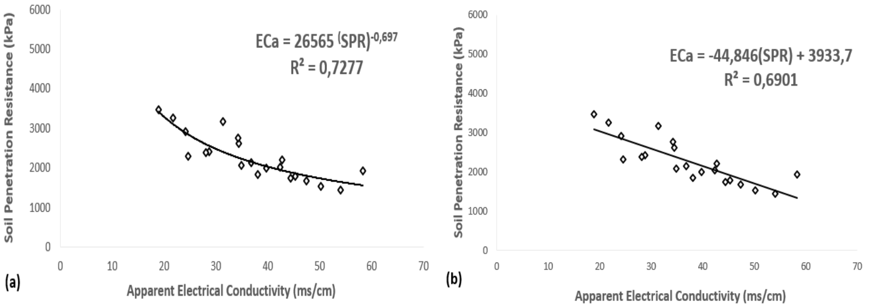

Fig. 3. a) Power regression model between SPR and ECa for all data taken and b) Linear regression model between SPR and ECa for all data.

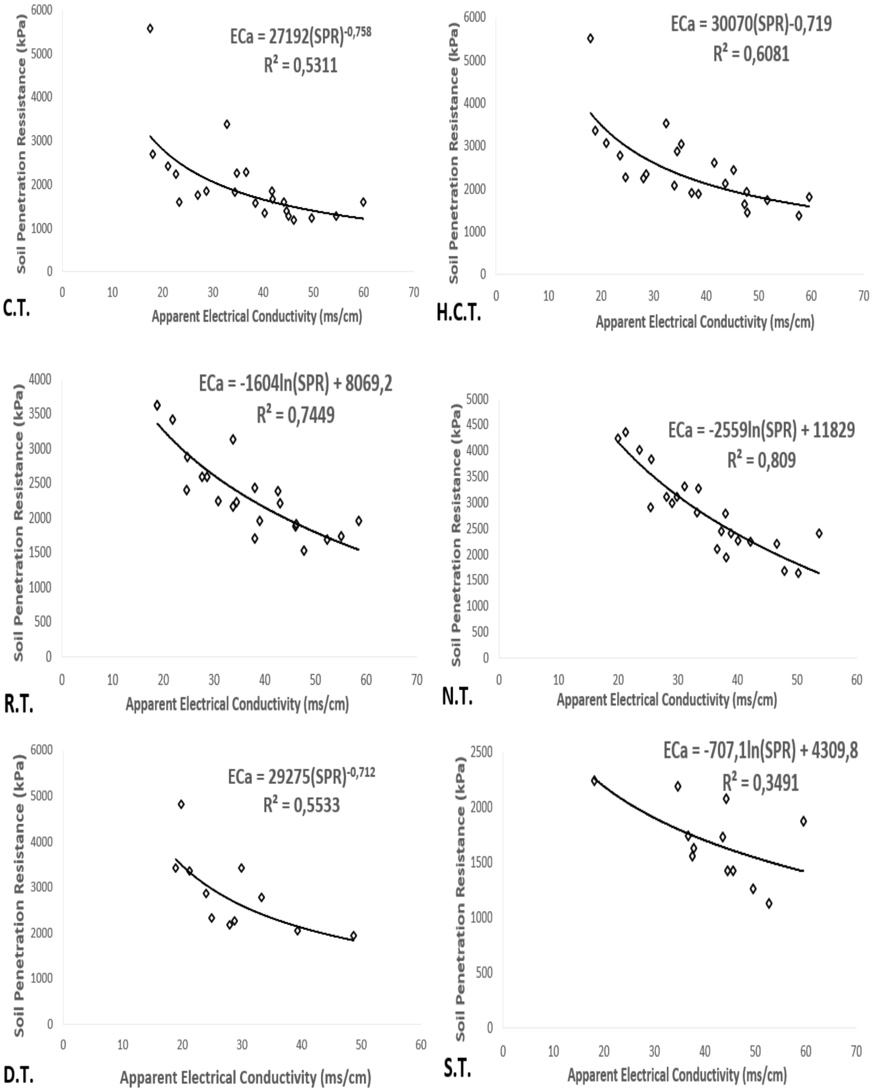

Fig. 4. Curve fitting for conventional tillage (CT), Heavy cultivator tillage (HCT), rotary cultivator tillage (RT), no-tillage (NT), disk harrow tillage (DT) and strip tillage (ST) treatments.

Table 1. Models connecting ECa and SPR

Tillage treatment	Regression curve	R^2
All field data	$EC_a = 26565 \times SPR^{-0,6972}$	0,73
Conventional tillage	$EC_a = 27192 \times SPR^{-0,758}$	0,53
Heavy cultivator	$EC_a = 30070 \times SPR^{-0,719}$	0,61
Rotary cultivator	$EC_a = -1604 \times \ln(SPR) + 8069,2$	0,74
Disk Harrow	$EC_a = 29275 \times SPR.^{-0,712}$	0,55
Strip tillage	$EC_a = -707,1 \times \ln(SPR) + 4309,8$	0,35
No Till	$EC_a = -2559 \times \ln(SPR) + 11829$	0,81

Table 1 shows the regression curves fitted to the data and the respective correlation coefficients. Strip tillage presents the lower correlation coefficient. This effect was expected as strip tillage is not homogeneous in all the area of the plot. Soil loosening is taking place only on the rows i.e. every 0.75 m while the rest of the soil remains undisturbed. Conventional and disk harrow treatments have the lower coefficients. But generally the other coefficients indicate high correlation and that RCa is a possible indicator of soil compaction.

If the results will be verified and the measurement of ECa at different depths can be achieved through the adjustment of the distance between the dipoles then the method can be used to assess soil compaction at different soil depths. This can be the basis to develop a variable rate (depth) tillage (soil disturbance) system or precision tillage system that can contribute to the reduction of energy consumption for tillage and help at improving energy productivity in agriculture.

4 Conclusions

From the results presented in this paper it can be concluded that:

- Different tillage treatments cause different residual compaction to the soil.
- ECa is negatively correlated to soil compaction measured by soil penetration resistance.
- ECa can be used to predict soil compaction at least under the conditions of the present experiment
- Correlation coefficients were higher in no till, heavy and rotary cultivator. Low correlation was found in stripe tillage and disc harrow due to the lower homogeneity of the tillage.

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