Measuring and mapping within-field soil moisture content for precision (site-specific) plant production

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Abstract: Precision (site-specific) agriculture requires within-field information. Within-field information is based on site-specifically collected data. In order to be able to make decisions site-specifically, the spatial resolution of the data has to be sufficient for mapping. Traditional (hand collected) data collection methods for soil moisture content distribution mapping are time and workforce consuming; moreover, this method does not provide enough information for reliable soil moisture content distribution maps. In this paper authors report the results of the measurements based on traditional data collection as well as a result of a new measurement instrument (Veris-3100). Both methods aimed to map the spatial distribution of soil moisture content within a 23ha agricultural land. Veris technologies instrument results soil apparent electrical conductivity (EC_a) data. In our particular research field, we have investigated the connection between this (EC_a) parameter and soil moisture content, and have found strong correlation between the two datasets. We have found that on-the-go soil properties measurement instrument provides spatially well distributed data for mapping various soil parameters, and based on the (EC_a) data, soil moisture content distribution can be mapped with much better spatial resolution than mapping based on the traditional sampling method.

Keywords: Precision agriculture, within-field soil moisture content distribution mapping

Introduction

Precision agriculture relies on site-specifically collected information. As soil moisture content directly influences yield, mapping within-field soil moisture content differences provides information for agricultural management practices (Milics, 2013). The standard method for soil moisture content measurement is based on hand collected sampling, and oven drying, however this method is time and workforce consuming. This method does not provide a spatially well distributed and sufficient amount of data for mapping the distribution of soil moisture content for large areas. For this reason, authors have investigated an alternative solution. Soil moisture measurement in precision agriculture is in the research focus in order to find an efficient way for measuring soil moisture content (Balla and Jolánkai, 2012). Soil apparent electrical conductivity is one possibility to measure indirectly soil moisture content (Milics et al., 2012, Nagy et al., 2013; Balla et al., 2013). Soil apparent electrical conductivity measurement in this particular field proved that mapping soil moisture content within-field results additional information for precision agriculture practice (Milics et al., 2017). Mapping the pattern of the agricultural fields later can be the input information for precision irrigation.

Materials and methods

Measurements were carried out in the 23ha experimental research field belonging to Széchenyi István University in the vicinity of Mosonmagyaróvár, Hungary [N47°54’20.00”; E17°15’10.00”]. The study field is an agricultural land – alluvial plain of the Leitha River – on which precision agriculture has been applied since 2001. The field cannot be characterized by one typical soil profile, as a buried riverbed (former Leitha) crosses it. The humus content in the upper 0.2 m layer is between 1.4–2.8%.

Soil sampling locations were determined based on earlier experiments (Fig. 1a). In the case of hand-collected, undisturbed core sampling, moisture content was determined by means of the gravimetric method. Six undisturbed soil samples (50 mm in height) were taken consecutively from each sampling site. The sampling depth was thus 0.3 m. Soil samples were dried to a constant weight (>24 hr) in the oven at a temperature of 105 °C. After drying, the gravimetric and volumetric moisture content was determined. Volumetric moisture contents (θ) were calculated from the known volume (100 cm^3) of the core soil sampling rings. From the same locations soil samples were collected and sent

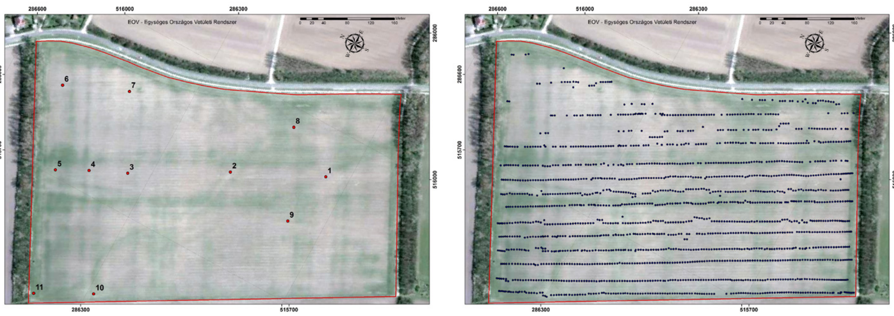

Figure 1: Location of the experimental field and the soil sampling points by hand collection (a) and on-the-go (b) methods

for laboratory analysis.

The soil electrical conductivity EC_a was measured by a Veris Soil EC-3100 (Salina, KS, USA) instrument. The most important parts of the Veris-3100 meter are the Coulter-Electrode blades (6 pcs) with 430 mm diameters, which are electrically insulated from the frame. The Coulter-Electrode Blades are arranged symmetrically. The device measures the bulk apparent electrical conductivity of the soil at depths of 0–0.3 m and 0–0.9 m at the same time. In this study only data from the depth of 0–0.3 m was used, as the reference soil samples were also collected from this depth. Soil data collection was in much denser locations (Fig. 1b). Measurements were carried out in 28th of October 2016.

All measured data was integrated to ArcMap 10.0 software. For mapping, kriging interpolation method was used.

Results and discussion

Soil moisture content map based on the data of measurement of hand collected and oven dried samples showed some differences in the field; however, the map did not show the assumed pattern that was expected based on earlier experiments (Fig. 3a).
Measured soil moisture content data, laboratory reference data and on-the-go collected EC_a values were analysed by linear regression. In 2016 we have found strong correlation between EC_a and gravimetric soil moisture content (w), and EC_a and volumetric soil moisture content: R^2=0.8972 and 0.8251, respectively (Tab. 1). Other results based on laboratory analyses also showed strong correlation with EC_a.

Based on the equation derived from the linear correlation regression (Fig. 2), all EC_a values were converted to soil moisture content values.

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Table 1: Correlation matrix of selected soil properties

	ECa	w	θ	K_A	OM	Mg	Zn	Cu
ECa	1	0.8972	0.8251	0.9672	0.8505	0.8834	-0.5577	0.8811
w		1	0.9099	0.9348	0.7684	0.9917	-0.5407	0.965
θ			1	0.8369	0.6991	0.8801	-0.4247	0.8675
K_A				1	0.8061	0.92	-0.6403	0.8726
OM					1	0.7949	-0.3771	0.834
Mg						1	-0.5004	0.9673
Zn							1	0.4387
Cu								1

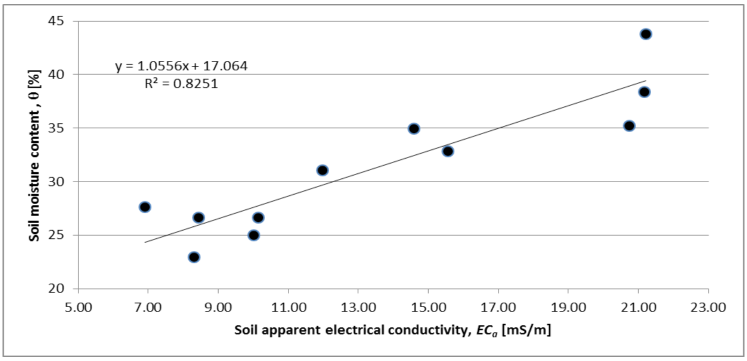

Figure 2: Results of the linear regression analysis between ECa and soil moisture content (θ)

Soil moisture distribution map was created by means of applying agricultural GIS mapping tools (Fig. 3b). As it is clearly visible on the map, the pattern of soil moisture content

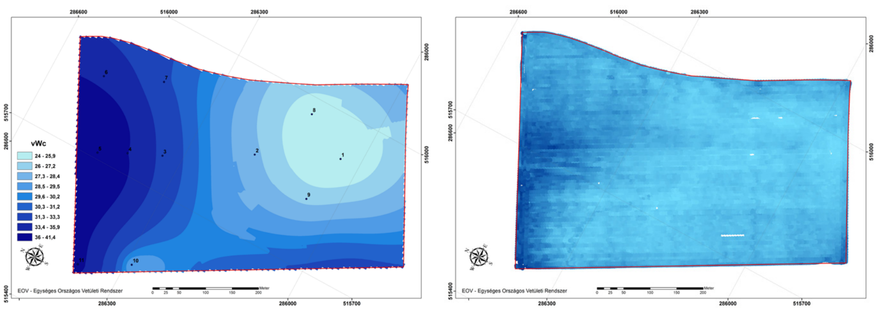

Figure 3: Location of the experimental field and the soil sampling points

differs from the map created from hand collected and spatially less well distributed data.

Conclusions

In precision agriculture having accurate information about the habitat is the basic prerequisite of all agricultural activities, as plants growing conditions are influenced by genetic, ecological and production technology factors together, which can change and vary considerably even within one agricultural field. Manual soil moisture content measuring does not provide spatially well distributes and dense data for mapping within field differences. It can be replaced by Veris Soil EC-3100 mapping of the soil apparent electrical conductivity (ECa). Further research is needed to define how the connection between soil moisture content and soil apparent electrical conductivity changes in the case of the different soil types, physical characters and salinity of the soils.

We state that soil moisture content map can be created from the measured soil apparent electrical conductivity values.

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