Computers and Electronics in Agriculture 127 (2016) 615–624

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Original papers

Application of an original soil tillage resistance sensor in spatial prediction of selected soil properties

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ARTICLE INFO

Article history:
Received 22 January 2016
Received in revised form 5 July 2016
Accepted 23 July 2016

Keywords:
Mapping
Soil properties
Tillage
Geostatistics
On-the-go measurement
Draft measurement

ABSTRACT

Horizontal and vertical variability of soil properties, temporal dynamics, and the complexity of monitoring and prediction processes are the limiting factors for full implementation of all the postulates of site specific crop management. The aim of this research was to prove the possibilities for utilization of original soil tillage resistance measuring device in spatial assessment of some physical properties of soil.

The tillage resistance measurement and soil evaluation were performed in 2012 on a field of 0.78 ha, with calcic chernozem type of soil. The year before, the field was divided into three equal plots where three types of tillage were applied (moldboard plowing, disc harrowing and chisel plowing) in order to increase spatial soil differences and to ensure more reliable testing. Soil physical properties were observed at 30 points that were arranged on the nodes of a rectangular grid all over the field along with their geopositioning. Soil tillage resistance was measured in real time and space, during 30 passes that were made on the entire field by a standard tractor and plow.

The tillage management applied in 2011 resulted in the differences of some soil parameters. Significant differences between the field plots arose with respect to cone index, moisture content and soil tillage resistance. However, no differences arose regarding the texture (sand, silt + clay content) and bulk density. The correlation analysis showed a high positive correlation between soil resistance and cone index ($R = 0.82$) and a negative correlation between soil resistance and moisture content ($R = -0.41$). Fitting of variograms in the modeling of spatial correlation gave the highest prediction error for cone index (13.9%), then for tillage resistance (9.32%), sand content (3.95%), moisture content (3.34%), bulk density (2.4%), and finally clay + silt content (2.2%). The generated maps showed that the soil compaction, moisture and tillage resistance had certain orientations with respect to the field plots.

1. Introduction

Modern methods in crop production aim to achieve maximum productivity per unit of input and used surface area with minimal negative consequences on the sustainability of a biosystem. In order to realize that, all production steps need to be equally optimized on all parts of the field taking into consideration the specific requirements of the produced crop (Hemmat et al., 2008). It is not an easy task according to heterogeneity of soil that is described in numerous studies (Adamchuk et al., 2001; Lapen et al., 2002; Hanquet et al., 2004; Hemmat et al., 2008). Spatial variability of soil is in relation to the type of soil, topography and applied in-field management. The tendency of enlarging the fields by simply erasing the previous borders that used to divide naturally different types of soil contributes to the increased in-field variability (Oliver, 2010). The concept of "fertilization of plants instead of soil", i.e., banding of fertilizers in the crop row, additionally increases variations in the nutrient content of soil (Hu et al., 2014). Therefore, in order to implement site-specific soil management, a sufficient amount of valid information about spatial variability is necessary for good decision making regarding every part of the field (Jabro et al., 2010; Hanquet et al., 2004). The quality of information depends on the applied method of data collection. Most of the standard methods used in the determination of soil conditions are spatially discontinuous, time consuming, and expensive, and they provide little accurate data (Oliver and Webster, 2014). The current trend in the advancement of systems for field data collection is the development of "on-the-go" measurement systems which are equipped with various sensors for proximal detection (Adamchuk et al., 2004). Considering the fact that those

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http://dx.doi.org/10.1016/j.compag.2016.07.027
0168-1699/

methods do not offer high accuracy data, proximal measurement systems are used for fast collection of vast geodata. In their research a great number of authors use the systems for measurement of soil mechanical resistance in order to assess the variabilities in soil physical conditions (Rockström et al., 1999; Gaston et al., 2001; Raper et al., 2005; Chung et al., 2006; Topakci et al., 2010). Van Bergeijk et al. (2001) indicated that soil tillage resistance could provide information about the locations of different types of soil. Lapen et al. (2002) concluded that if there is a relation between tillage resistance and soil compaction in the field, then the map of soil resistance can be used for the mapping of soil compaction. Understanding and modeling the variabilities in soil properties has less significance for precision agriculture unless they have some correlation with key parameters such as the soil moisture, soil type, and soil fertility. The maps of tillage resistance can be used as a criterion to locate the critical areas which require special treatments of site-specific management (Hanquet et al., 2004).

The objective of this research was to test the possibility of applying a new measuring system in spatial assessment of some soil physical properties like texture, bulk density, moisture content and cone index as a step further in the device development. The research is basically the extension of the development process of a system for soil resistance measurement according to the principles of precision agriculture (Kostić et al., 2014).

2. Materials and methods

2.1. Field preparation

Preparations for the experiment commenced in 2011. The chosen field is located in the northern part of the Republic of Serbia (45°26′09″N, 19°37′47″E) on calcic chernozem type of soil. The soil structure and stability of soil aggregates ensures good permeability of this soil. The total porosity of this type of soil is about 50% including about 20% of macropores and 30% of micropores. Topographically, the field is completely flat without rolls and inclinations, 220 m long with an area of 0.78 ha. It is used in the traditional crop rotation of wheat-maize-soybean with plowing as primary tillage. This region has an average annual precipitation of 611 mm, with 341 mm of precipitation in the vegetation period. In order to increase the spatial differences in soil properties and to provide proper soil conditions for evaluation of measuring equipment some preliminary works were done. In October 2011, the field was divided into three equal plots (Fig. 1) where different tillage systems were performed (plowing, disc harrowing and chisel plowing).

Depth of disking was ranged from 10 to 15 cm (DH plot), depth of plowing was around 25 cm (MP plot), and chisel plowing was performed at 18–20 cm (CP plot). In November 2012, physical conditions of soil were estimated according to the standard scientific methods with georeferencing sampling locations. The next day, entire field was tilled by mouldboard plow with simultaneous on-the-go tillage resistance measurement.

Trimble Juno SB with the modular system PathFinder ProXT (accuracy 0.5–1 m) was used for the in-field navigation during the measurement and sampling. Regular grid sampling pattern was applied in 12 m × 20 m grid cells, which is a standard procedure in precision agriculture because it is efficient in data processing and mapping (Viscarra-Rossel and McBratney, 1998).

2.2. Evaluation of soil properties

The physical condition of soil was assessed directly, by measuring the level of compaction, and indirectly, based on the samples.

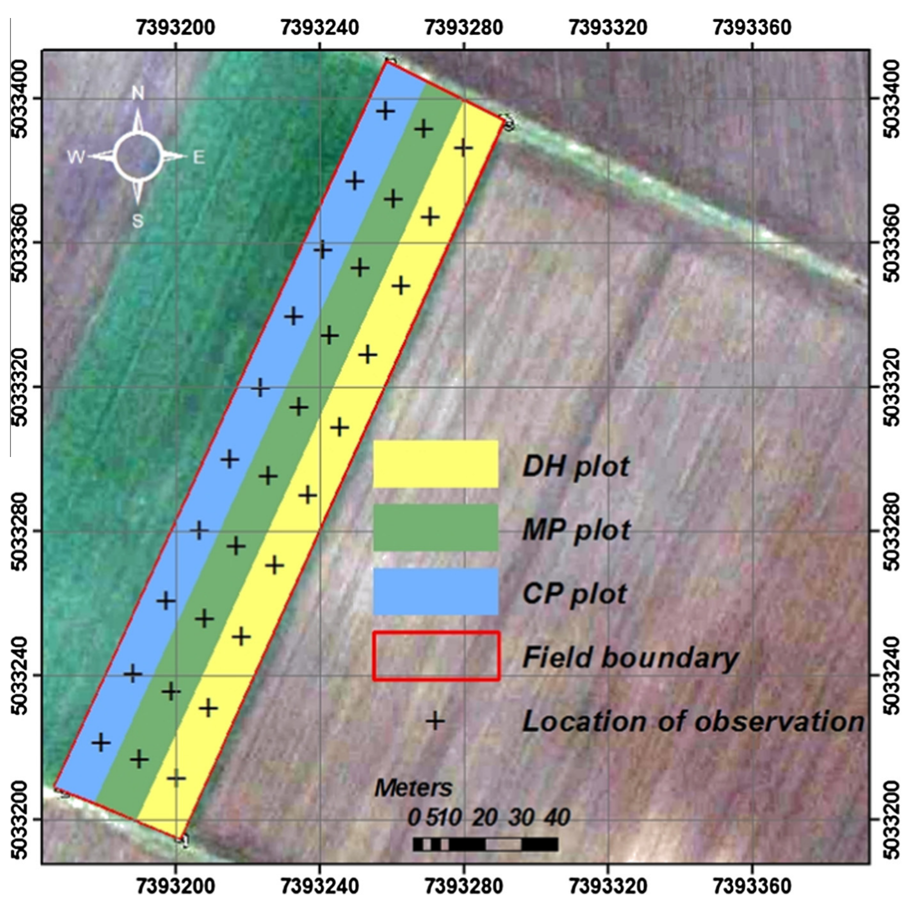

Fig. 1. Disposition of the plots in the field.