ANALYSIS OF SPATIAL VARIABILITY OF KEY SOIL ATTRIBUTES IN NORTH-CENTRAL UKRAINE

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ABSTRACT

As Ukrainian agricultural production undergoes major changes, a better understanding of the diversity of land resources is needed to optimize management. Dealing with large fields (over 100 ha in size) with non-uniform growing conditions presents an opportunity for site-specific management of agricultural inputs. This publication describes our 2010 pilot study on the implementation of integrated mapping of apparent soil electrical conductivity and field topography to guide soil sampling and, ultimately, to determine spatial variability of several key soil properties, e.g., soil acidity/alkalinity and macronutrient content. Based on this study, it was noted that soil pH as well as phosphate and potassium content have different levels of spatial distribution in different fields, which cannot always be explained through soil differences revealed using EC_a maps and field topography. Prior field management history and vegetation records might help to better define areas of the field with expected differences in soil test results.

Keywords: soil mapping, electrical conductivity, soil nitrate

INTRODUCTION

As Ukrainian agricultural production regains its scale, economically sound and environmentally safe management of soil fertility becomes an important part of the production planning process. Substantial spatial variation in water holding and nutrient storage capacity have caused inconsistent yield under a uniform management strategy. A site-specific crop management approach is believed to account for inconsistent growing conditions and to increase nutrient use efficiency (Pierce and Nowak, 1999). Understanding the scale and scope of spatial variation in soils is a critical step towards the optimized management of agricultural inputs.
Druzhba-Nova is a new agricultural enterprise in North-central Ukraine that has become a pilot production facility to evaluate the potential for site-specific crop management in a large-scale and diversified crop production environment. During

the summer and fall of 2010, maps of yield, elevation, and apparent soil electrical conductivity (ECa) were obtained from over 7,000 ha of cropland. In addition, the fields were sampled according to a 5-ha grid and soil-based production zone approach (Heiniger et al., 2003). Each soil sample was analyzed for soil acidity/alkalinity, phosphorous, potassium content and other parameters.

In this publication, a subset of six neighboring fields with a total area of 811 ha has been used to illustrate the scope of soil variability that might be accounted for through site-specific crop management. The fields presented in this study were used to grow peas during the 2010 growing season.

MATERIALS AND METHODS

Situated near the village of Bohdany in the Varva District, Chernohiv Region, the six fields (Figure 1a) are comprised of primarily Chernozem soils with an overall change in elevation of 29 m. After the harvest, each field was mapped using a modified Veris 3150 (Veris Technologies, Inc., Salina, Kansas, USA) instrument and Trimble EZGuide 500 GNSS receiver (Trimble Navigation, LLC, Sunnyvale, California, USA) with an OmniStar HP (Trimble Navigation, LLC, Sunnyvale, California, USA) differential correction service. Composite soil samples have been collected from 10 x 10 m sampling areas at 0-30 cm depth using a Nietfeld 2005 soil sampler (Nietfeld Bodenprobetechnik, Badbergen, Germany).

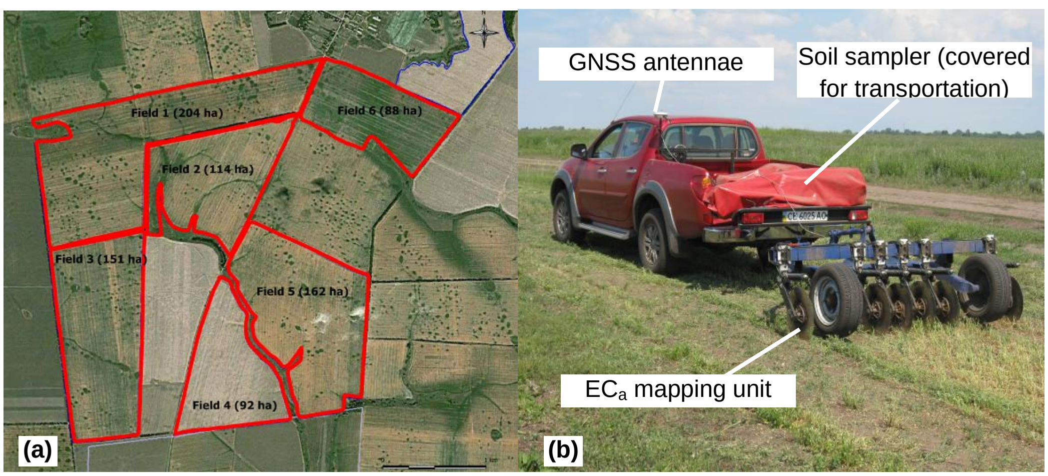

Figure 1. Example fields (a) and mobile soil mapping unit (b).

Sampling locations have been prescribed either in the center of each 5-ha grid cell, or adaptively following generic soil trends according to the EC_a and field elevation maps. Each sample was analyzed in a Druzhba-Nova laboratory for soil pH (DSTU, 2007), P_2O_5 (DSTU, 2005), K_2O, (DSTU, 2005), and other soil properties. The preliminary analysis involved the comparison of distributions in the measured parameters represented by grid-based and adaptive sampling locations. The potential for site-specific management of these fields has been discussed.

RESULTS AND DISCUSSION

Shown in Figure 2, elevation and EC_a maps indicate that three waterways running from the northwest to the southeast were the dominant features of the landscape. As indicated by the EC_a maps, the corresponding depression could be associated with a finer soil texture. This could be explained as the result of water erosion processes. Figure 3 illustrates both systematic and adaptive sampling schemes. From the results of the supplementary data, the total number of samples has been reduced from 164 to only 39. Figure 4 illustrates per field distributions of soil pH, phosphorous and potassium soil tests as well as the yield, shallow EC_a, and elevation that corresponded to the sampling locations. As was intended, soil sampling was prescribed using the supplementary data provided a reasonable representation of the range exposed based on the systematic sampling method.

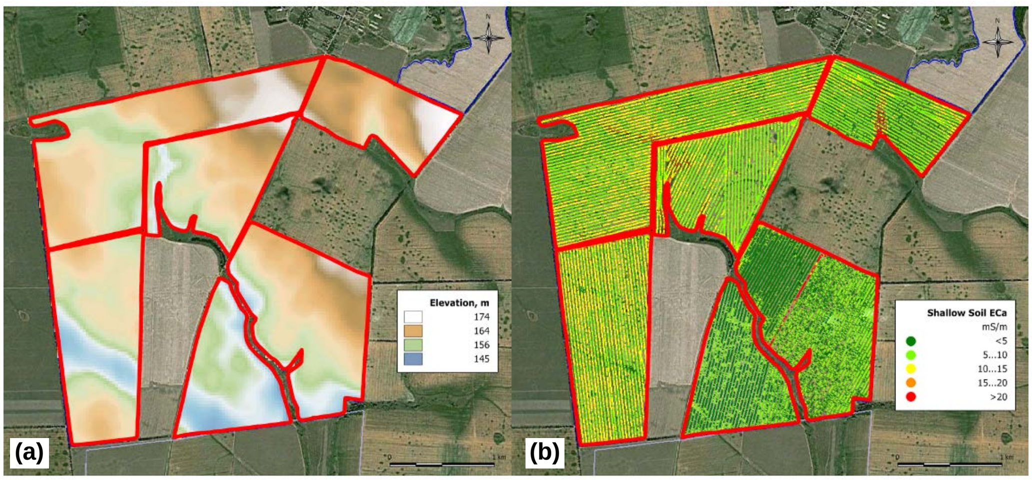

Figure 2. Field elevation (b) and shallow apparent soil electrical condivity (b) maps.

Figure 3. Soil sampling locations prescribed using systematic (a) and adaptive (b) approaches.

However, this observation could not be made relevant to yield and soil test results in each field. Thus, low yielding areas of fields 3 and 4 as well as high yielding areas in field 5 have not been sampled when distributing a relatively small number of samples according to the expected soil productivity. Similarly, targeted sampling failed to reveal the existing range of soil pH and phosphorous content in most fields. This could be attributed partially to a relatively low correlation between these soil properties and soil EC_a or field elevation (Figure 5). A potential source of inconsistencies is the management-induced differences in historical soil treatments and crop rotations. In fact, each current field is a combination of smaller fields under long-term cultivation with diversified management schemes. As a result, it is difficult to define a soil-based variable rate technology practice that would account for changing local conditions without intensive sampling. Vegetation history (sampling high and low yielding areas) will help to assure the range of expected soil test results is covered. However, a robust approach to prescribe targeted sampling is needed.

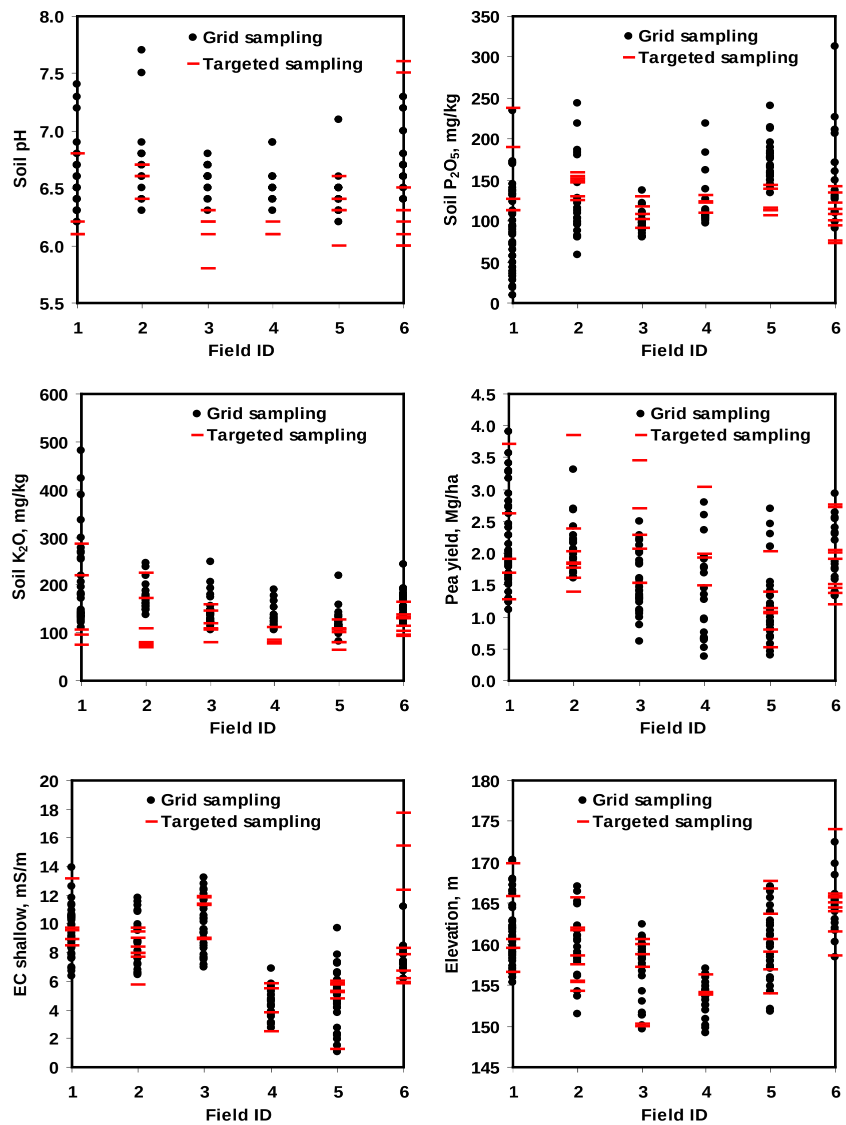

Figure 4. Per field distributions of soil test values, yield, EC_a and elevation that correspond to grid and targeted sampling.

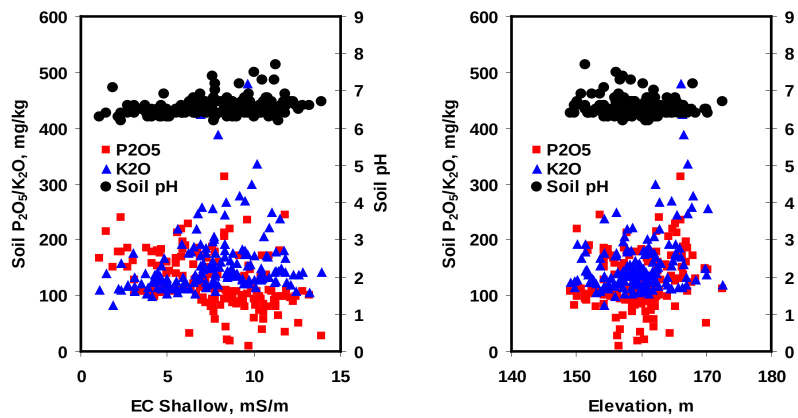

Figure 5. Relationships between soil test results and (a) EC_a and (b) elevation.

Site-specific field management can be implemented on a field-by-field basis, or at a subfield scale. Although targeted sampling can be used to assure coverage of different growing environments with as few soil samples as possible, this example shows that there is no guarantee that low or high soil test results correspond to unique landscape positions. Therefore, a sampling randomization process is still required for a field-by-field differentiation of soil treatments.

As shown in Figure 4, the six fields have a relatively high variation in soil test results that may justify variable rate technology. Field 1 is an example of a field where a significant portion of the field reveals acute phosphorous deficiency (below 25 mg/kg). Although the subjectively-guided method to prescribe targeted sampling locations used in this study did not provide the full range of soil test results, an optimized algorithm that would consider the field area represented by different values of soil EC_a, elevation, and vegetation history, may be appropriate.

In addition, the main benefits of soil EC_a and field elevation maps can be gained through optimized nitrogen and seed measurement as a result of the expected difference in water availability throughout the growing season. After an extremely dry 2010 season, many fields with fall harvesting crops have shown a significant yield reduction in the areas with low EC_a and at higher elevations.

CONCLUSIONS

Sites-specific crop management in large-scale agricultural production can be justified due to a substantial variation of essential soil parameters within one agricultural field. The six fields shown as examples demonstrate spatial field variation due to landscape position and previous land management. However, maps of soil EC and field topography to prescribe targeted soil sampling locations for a reduced number of samples did not present the entire range of soil test results. A more involved study is needed to consider vegetation data and optimize the sampling protocol that is based on supplementary data. Relatively large numbers of samples may still be the only feasible solution for soil nutrients, while high-resolution data may help optimize the use of nitrogen fertilizer resulting from differences in water storage capacity.

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