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Influence of soil sampling for precision fertilizing

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Abstract. The determination of the amount of nutrients in various field locations was investigated using the differential global positioning system (DGPS) and the nutrient mapping (active phosphorus, potassium and acidity) was carried out in order to use precise fertilizer rates for the crops. Two standard methods of taking soil samples are compared: the linear, in which the soil samples are taken from a 1 ha size grid in 50 m length in front of the plot centre with stated DGPS coordinates and 50 m behind the plot centre, and the circular, in which the soil samples are taken at the distance of 10–30 m from the centre point of the plot.

The paper analyses the technologies based on precision agricultural methods. The impact of two different soil sampling methods, i.e. the linear and the circular, on the nutrient mapping has been stated. The fertilization plans for the target crop yield are based on the amount of nutrients in different field locations. In precision farming, when different rates of fertilizers are applied in separate plots of the field, circular soil sampling enables saving 31–136 kg ha^{-1} of active material of phosphorus when linear method of soil sampling is used. Economy of potassium fertilizers in the case of usual farming is less, i.e. 11 kg ha^{-1} when the linear method of soil sampling is used, and 17 kg ha^{-1} of active material of potassium when circular method of soil sampling is used.

Key words: soil sampling methods, differential global positioning system, nutrient maps, precision farming

INTRODUCTION

The main goal of modern farming is to save energy, minimize labour expenditure and conserve the soil. The reduction of costs of agricultural produce and quality improvement of production are closely related with nature pollution. Member States of the EU pay special attention to sustainable farming. This has been achieved by minimizing soil cultivation and preserving its vitality, and by stopping mechanical soil erosion and weathering. One of the most significant factors of cheap and competitive farming is low production costs. The optimum yield should be achieved by minimizing soil tillage and cultivation, the environmentally-friendly application of fertilizer, herbicides, pesticides, and seed rate. All these measures taken together would provide earning power (Ludowicy et al., 2002; Zinkevičius et al., 2004; Ponitka & Pößneck, 2006).

The soil must be fertilized differently, i.e., more fertilizer should be used in soils with fewer nutrient materials suitable for crops. To achieve this, field nutrient mapping should be conducted, i.e., the field contours should be indicated and the area should be measured, all obstacles present in the field (e.g. structures, ponds, trees, etc.) should be marked. The field should be divided into small plots (e.g 1 ha size grid) and soil samples taken in each plot at preset intervals. The soil pH, active phosphorus, potassium are analysed in the laboratory. Later the soil test results are entered into the computer, which produces the nutrient maps. The precision farming system requires the following:

- a differential global positioning system which operatively provides the necessary information about the position of agricultural machinery in the field (Jürschik, 1999; Doluschitz, 2002; Ludowicy et al., 2002).
- a computer with special software.

According to the judgment of Lithuanian researchers, precision farming occurs when farmers strictly adhere to crop rotation, do not exhaust the soil, use chemicals and fertilizer in strictly precise rates, i.e., apply the exact quality and quantity of fertilizer needed for crops. The farmers work not only to get a good yield but to protect the soil from pollution, degradation, erosion, at the same time improving the quality of the produce and its compatibility in the market (Zinkevičius, 2004).

There are three soil sampling methods (Nette et al., 2000; Ludowicy et al., 2002):

- proportion grid;
- specific grid;
- objective grid.

When the proportion grid method is used in the fields or irregular form, the sizes of the plots from which samples are taken vary significantly thus the samples are distributed unevenly. When the grid is adapted to the field form and the direction of the technological track, the method is called specific grid. When the objective method is used it is obligatory to have information about the distribution of the nutrients in the soil.

Soil samples in the plot may be taken in the circles receding from the centre, or lengthwise along the diagonal. Literature reveals that when the 1 ha grid is used, both of these methods or techniques are equivalent. But in practice the proportion grid method is used more often when manual tools are used for soil sampling while the specific grid method is used when automatic devices are applied. Equal distribution of soil sampling is significant when greater (more than 1 ha) net is used (Lütticken, 1999; Ludowicy et al., 2002).

The research goal is to investigate the impact of the linear and circular soil sampling methods on nutrient mapping (active phosphorus, potassium and acidity) for the planning of precise fertilizer application in the field.

MATERIALS AND METHODS

The research object is the mechanized or push-button sample-taking technology. The comparison of the soil sampling methods was fulfilled in sod grown clover in the Test Station of Lithuanian Agricultural University. We used the four-wheel drive motorcycle "Yamaha 350 4x4" with the mounted automatic soil sampler "Wintex 1000", the receiver "Trimble AgGPS 124" with DGPS aerial (instrument accuracy ± 0.30–0.80 m) and data storage device, i.e., the laptop HP Omnibook with software "Farmplan A-Map PF" (Fig. 1).

The nutrient map was organized in the following steps:

1) creation of an accurate field map;

2) division of the field into soil sampling zones;
3) taking soil samples in the field;
4) agrochemical analysis of the soil samples;
5) creation of the nutrient map.

The accurate field plan has been prepared with a DGPS receiver. The differential global positioning system consists of 24 artificial Earth satellites and several above-ground monitoring and control stations. Each of these satellites constantly sends certain signals at accurately defined frequencies about its location in space, the exact universal time, and its identification codes. DGPS receivers record these signals and, using the input information with the help of suitable algorithms, calculate the geographic latitude, longitude, altitude of the receiver, and its movement speed and direction or course. The four-wheeled motorcycle with the mounted DGPS receiver moved through the field edges to determine the field coordinates and accurately measure the field area. The area of the test field was 3.45 ha.

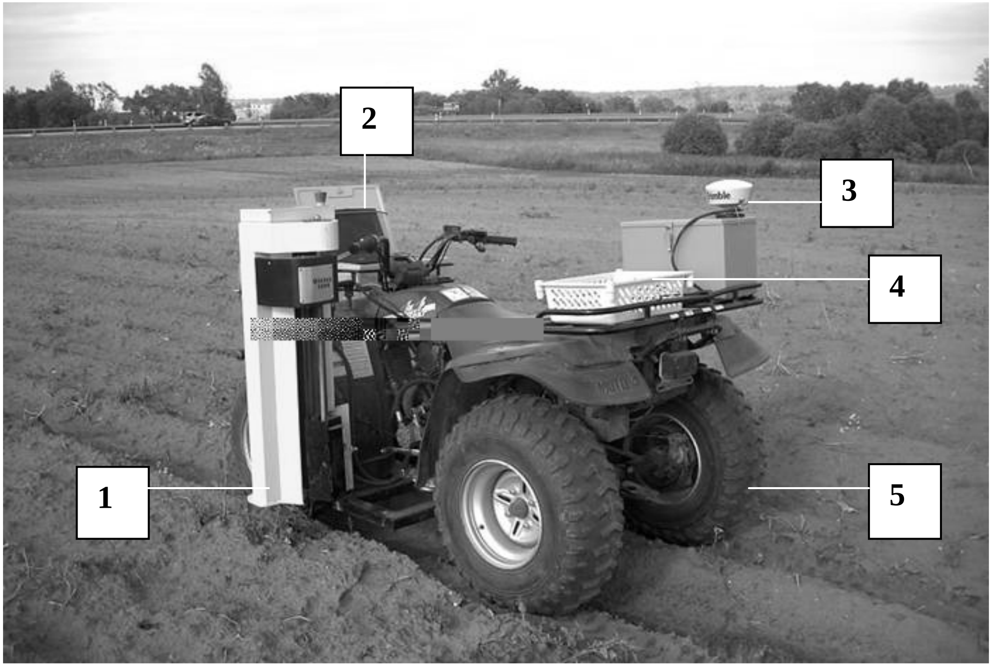

Fig. 1. Four-wheel drive ATV “Yamaha 350 4X4” equipped with device for taking test samples of soil and DGPS antenna: 1 - device for taking soil samples; 2 – computer; 3 – DGPS antenna; 4 – box for test samples; 5 - four-wheel drive ATV.

The field was split into *soil sampling zones*. These plots can be from 0.5 to 1.0 ha in size. Their centre has fixed DGPS coordinates. During the experiment the field was divided into soil sampling zones using a 100 x 100 m grid.

Soil sampling in the field. One cumulative soil sample is made of three sample replications from the plot of a specific size and is compiled by collecting the samples from ten different places. The cumulative soil sample was collected using the following two methods (Fig. 2):

1) circular: soil samples taken at the distance of 10–30 m from centre point of the plot with the determined DGPS coordinates;
2) linear: soil samples taken from diagonals of 1 ha size plots in 50 m length or segment in front of the plot centre with stated DGPS coordinates and 50 m behind the plot centre.

Agrochemical analysis of the soil samples was conducted in the Agrochemical Laboratory of the Test Station of Lithuanian Agricultural University. The soil acidity was determined with potentiometer and active phosphorus and potassium using A – L methods.

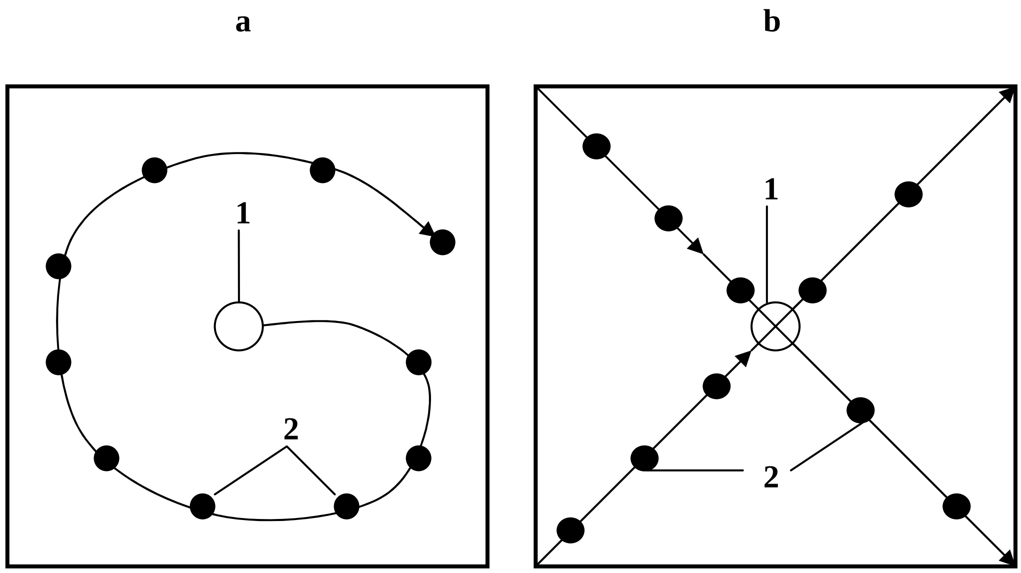

Fig. 2. The schemes of the soil sampling within the confines of 100x100 m: a – circle method; b – linear method; 1 – the centre of the plot with the determined DGPS coordinates; 2 – the points of the soil sampling, → the soil sampling aggregate's movement trajectory

In order to produce *the nutrient maps* the soil test results of every sample were entered into the computer program "Farmplan A-Map PF" that processes the data using "Punctual kriging" statistical method. This is a statistical method used to estimate the value at a point from known sampled points. The nutrient maps of active phosphorus, potassium and soil acidity were prepared.

RESULTS AND DISCUSSION

It has been concluded that the soil sampling method is important for the nutrient mapping, i.e., whether they are taken in circles around the plot centre in the field or at diagonals in from and behind the plot centre.

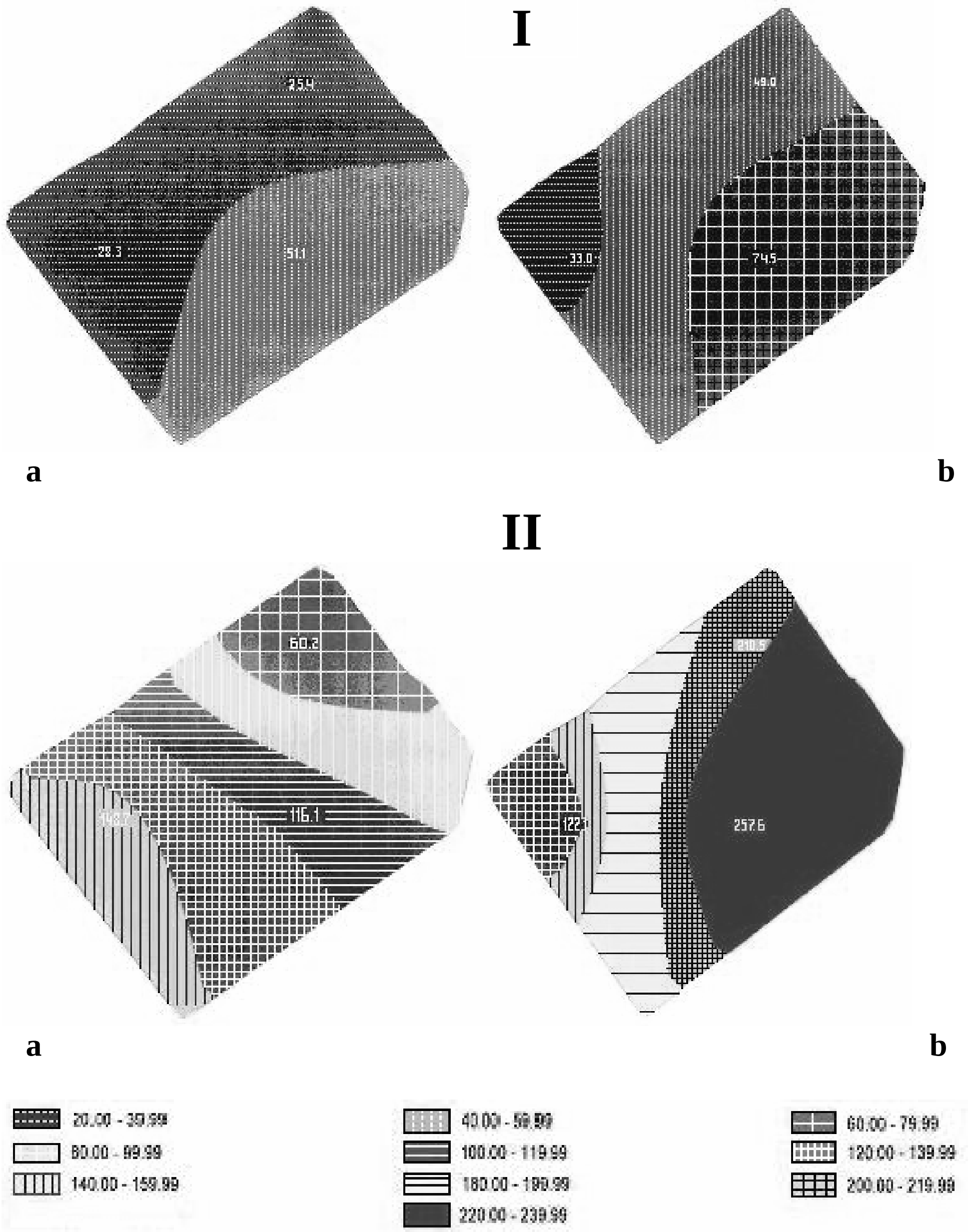

Fig. 3. The trends of active potassium (K_2O mg kg^{-1}) and phosphorus (P_2O_5 mg kg^{-1}) exchange in an experimental plot (Experimental station of LUA): I – the trends of active potassium (K_2O mg kg^{-1}); II – the trends of active phosphorus (P_2O_5 mg kg^{-1}); – the soil samples were taken by a circle method; b – the samples were taken by linear method.

Without reference to the method of taking soil sampling the amount of active potassium (K_2O mg kg^{-1}) in different field places was varied. When the circular technique was used for soil sampling the amount of the active potassium in the first plot was 28.3±1.3 mg kg^{-1} of the soil, in the second plot, 51.1±1.7 mg, and in the third, only 25.4±1.1 mg, accordingly (Fig. 3, I, a).

Meanwhile in the samples taken linearly the amount of active potassium was greater, amounting to 33.0±1.5 mg kg^{-1} in the first plot, in the second 74.5±2.0 mg, and in the third, 49.0±1.5 mg, respectively (Fig 3, I, b).

On the basis of these investigation results and the recommendations of the Lithuanian Agricultural Institute, when a plan of the field fertilization is made using the soil samples taken with the help of the circular method the recommended fertilizer rates in individual field plots are similar. For example, in the first plot 126 kg ha^{-1}, in the second plot 121 kg ha^{-1} and in the third plot 132 kg ha^{-1} of potassium (active material) should be applied in the soil in order to achieve the target yield of 5.5 t ha^{-1} of winter wheat. But when the linear soil sampling method is used the recommended rates of the individual field plots would be different if compared with those mentioned above. For the same planned yield of winter wheat 132 kg ha^{-1} of potassium (active material), in the second plot 121 kg ha^{-1} and the third plot 132 kg ha^{-1}, should be used. Thus in precision farming it is possible to save from 11 kg ha^{-1} of potassium material (the soil samples are taken linearly) to 17 kg ha^{-1} of potassium active material (using the circular soil sampling method) when different fertilizer rates are used for individual field plots.

The greatest difference was noticed in active phosphorus (P_2O mg kg^{-1}): when the samples were taken using the circular method in the first plot the amount of active phosphorus was 148.7±3.2 mg kg^{-1} of soil, in the second - 116.1±2.7 mg, and in the third plot - 60.2±1.8 mg (Fig. 3, II, a). Meanwhile in the samples taken linearly the amount of active phosphorus was reverse. In the first plot it amounted to 122.1±2 mg kg^{-1} of soil, in the second, to 257.6±3.4 mg, and in the third, to 210.5±2.9 mg, respectively (Fig. 3, II b). According to these soil test results and the recommendations of Lithuanian Agricultural Institute when the plan of the field fertilization was made, e.g., in the first plot 60 kg ha^{-1}, in the second plot 63 kg ha^{-1} and in the third plot 77 kg ha^{-1} of phosphorus (active material) should be applied to achieve the target yield of 5.5 t ha^{-1} of winter wheat. But when the linear soil sampling method is used the recommended rates for the individual field plots would be different.

For the same planned yield of winter wheat, 63 kg ha^{-1} of phosphorus (active material), in the second and the third plot only 16 kg ha^{-1}, respectively, should be used. In this case if compared with the usual fertilizer application rate that is equa **b** ' kg ha^{-1} phosphorus economy is significantly greater. When the soil samples are t sing the circular method it is possible to save from 31 kg ha^{-1} phosphorus active material as compared to 136 kg ha^{-1} when the linear soil sampling method is used.

The soil acidity (pH) from the soil samples taken differently varied insignificantly, from 6.9 to 7.06 in individual field plots.

CONCLUSIONS

1. The method of taking soil samples, i.e whether they are taken in the field around the chosen point or in a straight segment before and behind the point, is vital in producing soil structure maps.
2. In precision farming, in order to achieve the target yield of 5.5 t ha^{-1} of winter wheat, when different rates of fertilizers are applied in separate plots of the field, economy of phosphorus fertilizers in the case of usual farming is less: circular soil sampling enables saving 31 kg ha^{-1} and the linear method of soil sampling enables saving 136 kg ha^{-1}.
3. In order to achieve the target yield of 5.5 t ha^{-1} of winter wheat, economy of potassium in the case of usual farming is less, i.e. 11 kg ha^{-1} when the linear method of soil sampling is used, and 17 kg ha^{-1} of active material of potassium when the circular method of soil sampling is used.

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