DIFFERENCES OF SOIL AGROCHEMICAL PROPERTIES IN CONNECTION WITH ALTITUDE IN WINTER WHEAT

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Abstract. Investigations were carried out in 2005-2007 in Kurpnieki field on the Research and Training Farm Vecauce of the Latvia University of Agriculture. Researches were performed out in the stationary observation points. The aim of the study was to clarify relationships between unregulated factors – relative height above the sea level and soil pH_{KCl}, potassium and phosphorus content in soil – in winter wheat growing conditions. The results showed that the most important factor that effected differences in the content of potassium and phosphorus in soil arable layer was precipitation water flows caused by curvature of mezorelief. A decision for differentiation of the dose of potassium and phosphorus fertilizers could be made only after analysis of the direction of water run-off. The smallest thickness of humus horizon as well as significantly increased soil reaction pH_{KCl} were detected at the watershed in field sites with increased relative height. The winter wheat yield maps and study of the results of soil moisture show that soil moisture is the uppermost factor determining the winter wheat grain yield level.

Key words: precision agriculture, soil agrochemical properties, soil mapping, catchment, watershed.

Introduction

Topography can have a significant influence on the crop yield, thus a better understanding of the effects of topographical parameters on the crop yield is important – especially for site-specifie soil management. The spatial variability associated with the crop yield is an integrated reflection of spatial variability in soil properties and factors affecting crop growth (i.e., light, temperature, and others). In rolling landscapes, topography is the most important factor controlling soil water redistribution, organic matter, nutrients, soil textural composition, and other soil properties that affect plant growth within a field. It also affects variations in soil and canopy temperature, and humidity. Hence, topographic parameters can be regarded as composite parameters that reflect the combined influence of various yield-affecting factors and their interactions. Consequently, an understanding of how soil variability affects the spatial variability of crop yields is a necessary prerequisite to develop proper soil management and precision farming techniques. A valuable advantage of topographical data is that they are easy to obtain and relatively time-invariant compared with the measurement of more dynamic soil properties. Previous studies have revealed a clear association between the crop yield and topographical parameters (e. g., slope percentage, soil surface curvature, and elevation). In years when precipitation is low to average, the influence of the soil surface curvature on the crop yield is reflected in higher yields in concave areas of the landscape (i.e., depressions). Conversely, water logging in the depressions may result in decreased crop yields during wet years. As well, elevation, slope, and aspect have been shown to exert a significant influence on wheat yield [1].

Kitchen et al. [2] emphasized that agronomic properties like topography are not affecting yields directly, they are only measures of how water availability due to topography is affected, and this is at the root of yield variability. Quantifying the spatial impact of water availability can be done successfully using a generic geographic information system, or the third party software as demonstrated in Fridgen et al. [3], and a high resolution digital elevation model. The spatial information derived from the digital elevation model (e. g. slope) can then be used in precision farming as a base layer that does not change quickly over time, and could provide a means to delineate zones for crop input management (e. g. fertility management using variable rate technology) [4].

Topography influences soil textural, soil physical and soil chemical properties. Topography of agricultural fields can influence soil properties, biomass production, incoming solar radiation, extreme precipitation and affect yield formation. Topography can be quantified by computing the distribution of relief parameters such as elevation, slope and the topographic wetness index [5].

When analyses of the factors affecting productivity are carried out, it is understood that the necessary measures have to be taken to yield a field-level balancing, rising areas with lower yields. Following the established cards are designed for the appropriate task map to achieve the planned level of productivity in each field areas: fertilizer doses, tillage and weed control types of measures of reclamation etc. [6].

The aim of this study was to clarify relationships between unregulated factors – relative height above the sea level and soil pH_{KCl}, potassium and phosphorus content in soil – in winter wheat growing conditions.

Materials and methods

Investigations were carried out in 2005-2007 in Kurpnieki field on Research and Training Farm Vecauce of the Latvia University of Agriculture. Winter wheat *Triticum aestivum* L. variety "Tarso" was grown in 2006 and 2007. Forecrop of wheat was winter rape *Brassica napus* ssp. *oleifera*. The agrotechnology used in wheat cultivation was equal in the whole field and in both trial years. 47 points (distributed as grid 50x50 m) for sampling were selected in the winter wheat field. All points were attached to their geographic coordinates. The coordinates of observation points were defined by GPS receiver Garmin IQ 3600 using AGROCOM software AgroMAP Professional that allows to find the coordinates by accuracy of ±3 m, as well as to determine the field boundaries. The information from Garmin IQ 3600 was transferred into a computer and processed by the program AgroMAP Professional. The relative height above the sea level was determined with Trimble GeoXT, and adjusted with GPS Pathfinder Office software version 4.00. The thickness of humus horizon was determined by probing. Samples for potassium, phosphorus and pH_{KC} were taken from the depth of 0.20 m using a probe. Sampling was done after harvesting on August 14, 2006, in 3 replicates in each sampling point. The samples were analyzed in a certified laboratory VSIA „Agroķīmisko pētījumu centrs", using local standard methods. The soil moisture content in percents was measured with Eijkelkamp Agrisearch Equipment instrument in soil layers 0.00-0.45 m, 3 replications, in each sampling point at two times – in autumn at winter wheat growth stage BBCH 11-12 and in spring time at growth stage BBCH 25-29. The data analysis was performed using mathematical descriptive statistics.

The meteorological conditions differed between the trial years. The observed average air temperatures were above long term in both trial years, especially in the second part of the year 2006 (Figure 1).

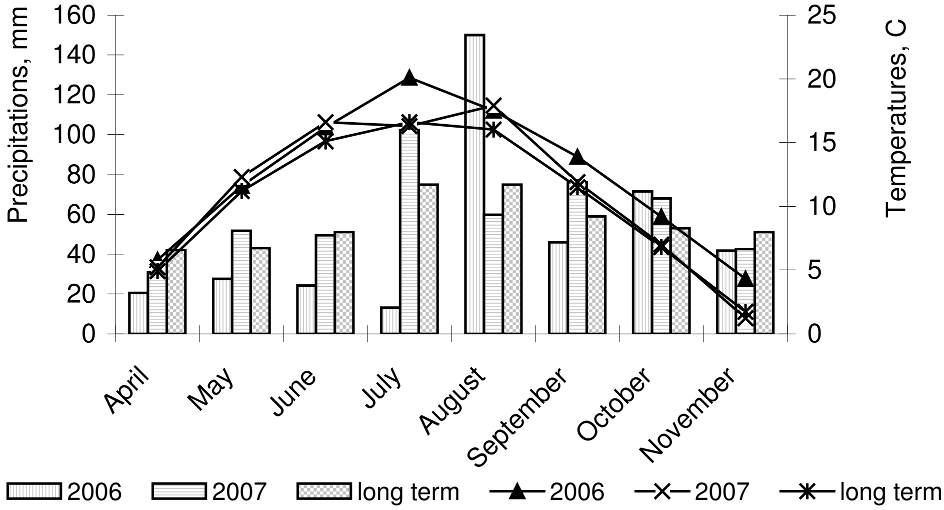

Fig. 1. **Average day and night air temperatures and precipitations in years 2006 and 2007, ˚C (according to Vecauce HMS)**

The average temperature of July 2006 was by 3.5 ˚C higher than long-term observed. Alongside with insufficient amount of precipitations it causes rapid ripening and early harvesting of winter wheat compared with long-time observed harvesting time. The sum of precipitations was low in both trial years, but during the period April-August it was lower in year 2006 compared to 2007 despite of the high amount of precipitation in August 2006 (Figure 1).

Results and discussion

It was determined that the most important factor that effected differences in the content of potassium and phosphorus in soil arable layer was precipitation water flows caused by the curvature of mezorelief. The content of potassium and phosphorus in soil was significantly lower in field sites that were characterized with possible run-off to open drainage system in average from four monitoring lines compared to GPS watershed (Figures 2 and 3). Also other scientists admit that there is significant relationship between the potassium content in soil and the relative height of the observation point [5].

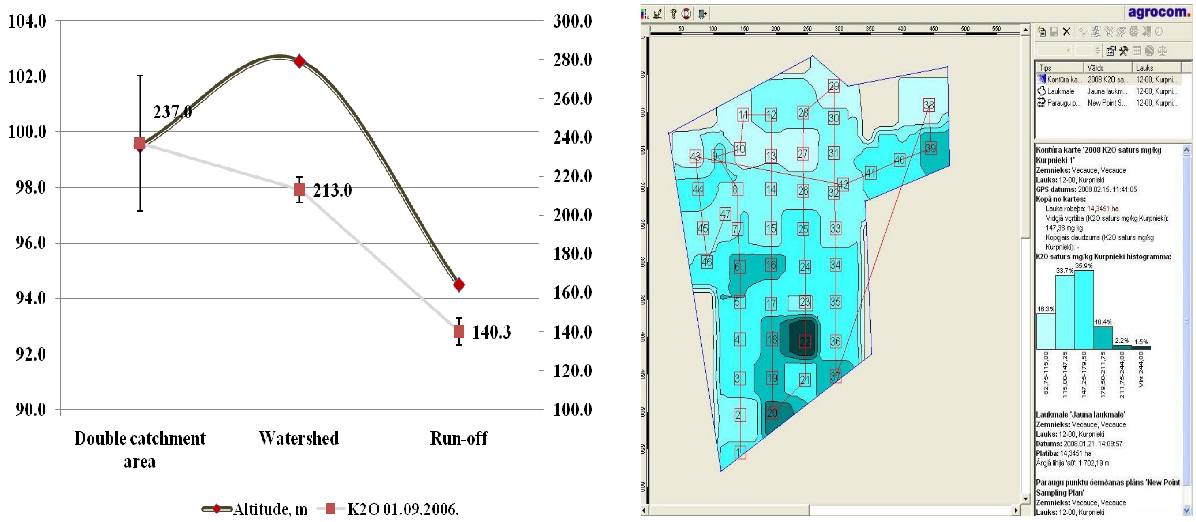

Fig. 2. **Effect of watershed and catchment area to differences of K_2O in topsoil**

The results of potassium and phosphorus content in soil do not show significant differences between the field points in the double catchment area and watershed. The soil samples were taken as a grid 50x50 m but unevenness of the soil chemical properties were more explicit in the field sites with the lowest altitude and on the watershed. To get a clear view the distance between the sampling points should be smaller that 50 m in such field areas.

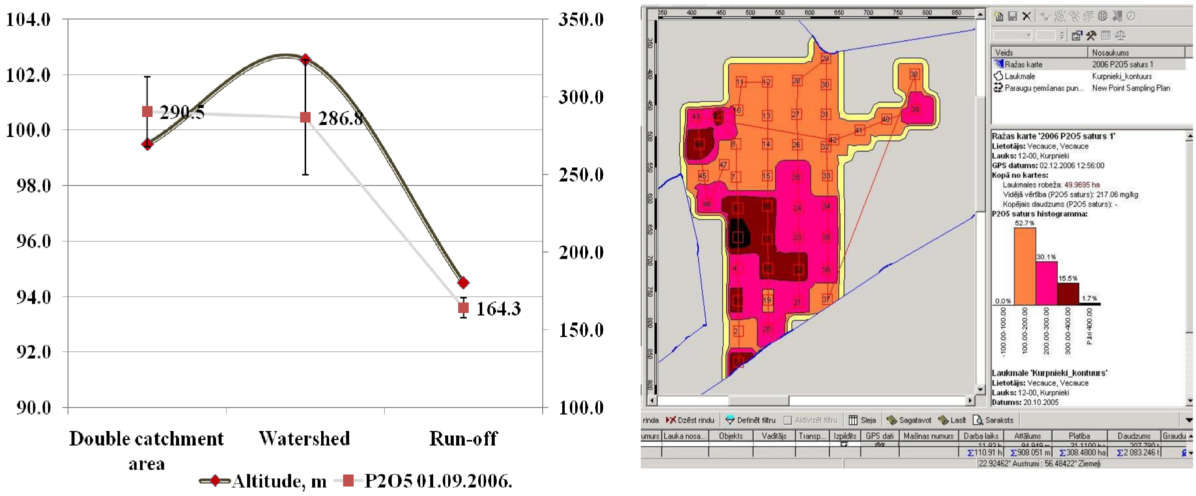

Fig. 3. **Effect of watershed and catchment area to differences of P_2O_5 in topsoil**

A decision for differentiation of the dose of potassium and phosphorus fertilizers could be made only after analysis of the direction of water run-off. The decision cannot be based only on a simple comparison of altitude of field points (Figures 4 and 5).

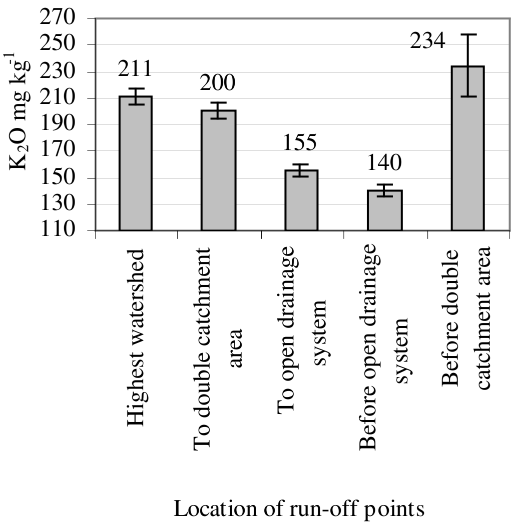

Fig. 4. **Content of potassium in topsoil in dependence on location of run-off points**

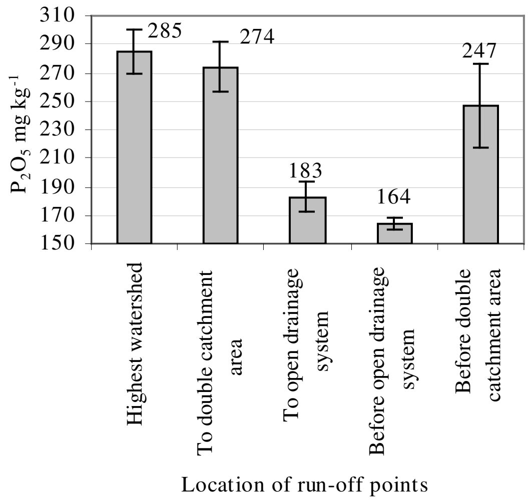

Fig. 5. **Content of phosphorus in topsoil in dependence on location of run-off points**

The watershed was characterized with the significant smallest soil moisture content in winter wheat in spring at the soil layer below topsoil. It was concluded before that the smallest content of potassium and phosphorus was detected in field sites with run-off to open drainage system, but from provision of soil moisture all preconditions were suitable for utilization of potassium and phosphorus (Figures 6 and 7).

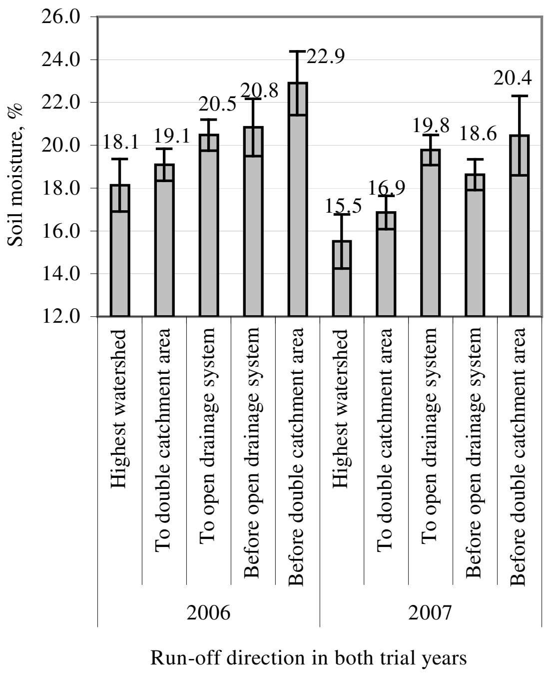

Fig. 6. **Soil moisture at the depth of 0.20-0.25 m**

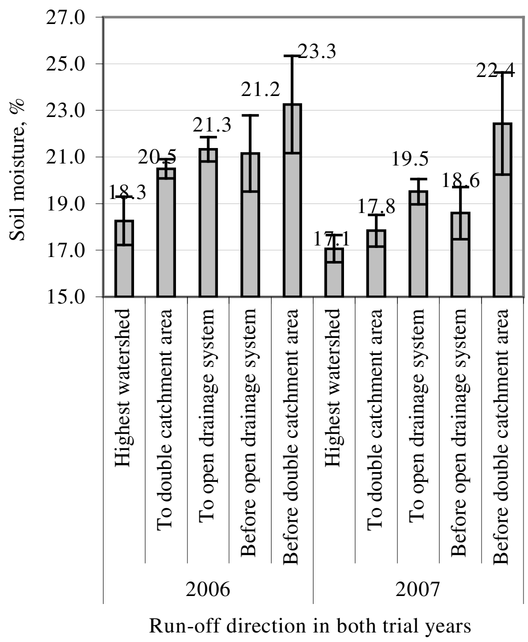

Fig. 7. **Soil moisture at the depth of 0.40-0.45 m**

The smallest thickness of humus horizon as well as significantly increased soil reaction pH_{KCl} were detected at the watershed in field sites with increased relative height (Figures 8 and 9). It may indicate on erosion processes in these field sites. The obtained results may be used for diversification of soil liming in field excluding it on the watersheds.

Winter wheat yield maps and study of the results of soil moisture show that soil moisture is the uppermost factor determining the winter wheat grain yield level. Significantly higher winter wheat yields were harvested in field sites with significantly higher soil moisture in spring at the soil layer below topsoil (Figures 6, 7, 10 and 11).

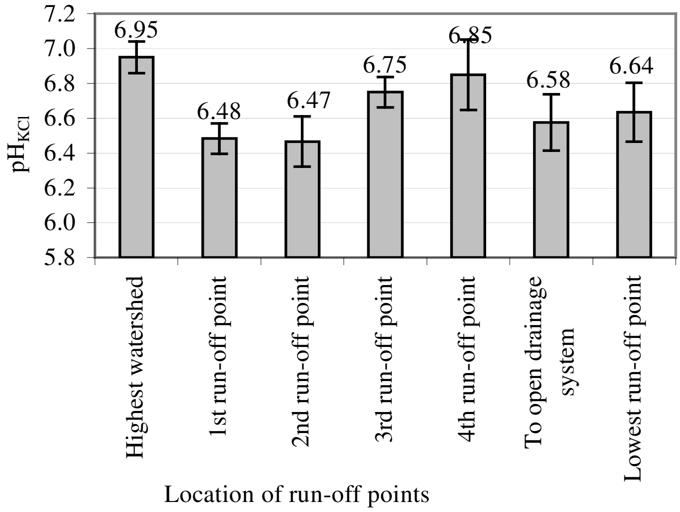

Fig. 8. **Soil reaction pH $_{KCl}$ in topsoil in dependence on location of run-off points**

Fig. 9. **Aero-photo of "Kurpnieki" field of winter wheat in 2005 (photo by J. Repsons)**

The yield maps show great spatial winter wheat yield level variability from 2.0 up to 9.0 t·ha^{-1} (Figure 11). In other trials in chernozems (Krasnojarsk region) unevenness in microrelief caused differences in grain yield up to 2.6 times [7]. Differences in grain yield in our trial are bigger because of explicit unevenness in mezorelief.

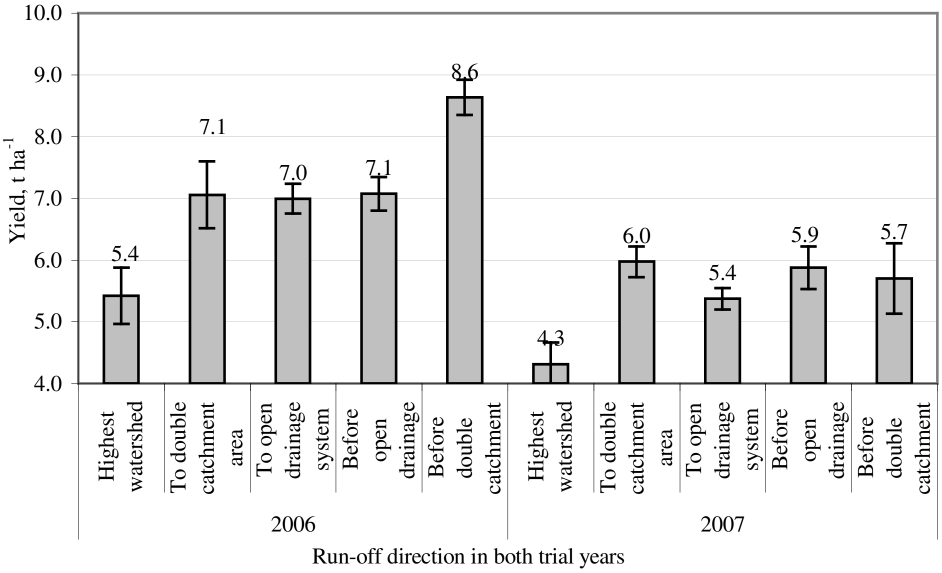

Fig. 10. **Winter wheat grain yield, t·ha $^{-1}$, in dependence on location of run-off points**

The yield maps as well as the placement of the stationary observation points showed that the observation point grid in the interval 25x25 m could be preferable although it would increase expenses for all analysis as well as expenditure of time for sampling.

Decreased doses of potassium and phosphorus may be recommended for watersheds and double catchment areas in field if making a cartogram for differentiation of fertilization. In field areas with run-off to open drainage system it is recommended to use liquid fertilization during vegetation period in forms for easy plant uptake.

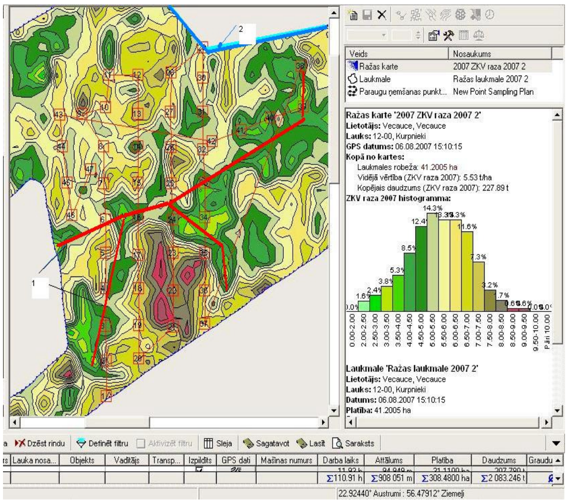

Fig. 11. **Winter wheat grain yield map of "Kurpnieki" field in 2007**

Conclusions

1. The most important factor that effects differences in the content of potassium and phosphorus in the soil arable layer was precipitation water flows caused by the curvature of mezorelief.
2. A decision for differentiation of the dose of potassium and phosphorus fertilizers could be made only after analysis of the direction of water run-off.
3. Decreased doses of potassium and phosphorus may be recommended for watersheds and double catchment areas in field if making a cartogram for differentiation of fertilization.
4. The smallest thickness of humus horizon as well as significantly increased soil reaction pH_{KCl} was detected at the watershed in field sites with increased relative height. The obtained results may be used for diversification of soil liming in field excluding it on the watersheds.
5. The winter wheat yield maps and the study of results of the soil moisture show that soil moisture is the uppermost factor determining the winter wheat grain yield level.

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