Agronomy Research **8** (Special Issue II), 403–408, 2010

Interconnection of altitude of stationary GPS observation points and soil moisture with formation of winter wheat grain yield

G. Dinaburga, D. Lapins, A. Berzins, J. Kopmanis and A. Plume

Institute of Soil and Plant Science, Latvia University of Agriculture, Liela iela 2, Jelgava, LV-3001, Latvia; e-mail: Gundega.Dinaburga@llu.lv

Abstract. Field trials were carried out at the Research and Study farm "Vecauce" of the Latvian University of Agriculture during the years 2006–07 to investigate factors influencing the formation of the winter wheat grain yield. Researches have been carried out in stationary observation points. Results show tight negative correlation between the altitude of observation points and soil moisture. The correlation is significant $P < 0.05$ in both trial years but coherence is tighter in the year with reduced precipitation, as observed in April–July 2006. Significant negative correlation was established between altitude and winter wheat grain yield. In year 2006, when lack of precipitation was observed, this coherence is with increased probability $P < 0.01$. Soil moisture at the depth of 40−45 cm was below optimum – 25% – in both trial years and also in both stationary observation levels with average altitude 95 and 102 m above sea level. It was also significantly lower in the highest points of the terrain. Significantly higher grain yield of winter wheat was obtained in field points with an average altitude 95 m above sea level. This coherence is also more explicit in the year with less precipitation, as in 2006. Analysis of correlation established that soil moisture at the depth of 40−45 cm has significant positive impact on the winter wheat grain yield and on the flag leaf area.

Key words: precision field management, winter wheat, surface altitude

INTRODUCTION

The elements of precision agriculture have been appearing on Latvian farms in recent years: first in use, equipment to form grain harvesting yield charts. In the next stage, the application of the yield chart is correlated with the investigation into soil properties. It suggests that farms should form their own local geographic information system. The research material of the soil properties is used as a basis for the introduction of differentiated, GIS-based resource-saving soil tillage. In the research conducted in Latvia in the previous year, possibilities to optimise the measures of soil tillage by using the GPS (Lapins et al., 2007) were considered. The effect of terrain often is not taken into account.

Topography is responsible for soil fertility and the agricultural land value. This will greatly affect the water and wind erosion as well (Shpedt & Nikitina, 2009). The risk of vulnerability of crops becomes more accentuated under climate change (drought, increased rainfall variability). A micrometeorological model for hilly areas was recently developed and calibrated. Results for wheat show that in the UK, winter wheat is mainly influenced by differences in annual rainfall distribution, but the distribution of yield in the area does not change much. In the south, yield variability is significantly related to the slope gradient height index (Ferrara et al., 2009).

To study the effects of the curvature of the soil, moisture index and winter wheat yields in varied areas, trials in sandy loam soils were conducted in Canada. Grain yield in the trial showed a significant correlation between the upslope length (R^2 = 0.60) and wetness index (R^2 = 0.46), while curvature of the soil surface explained only 15% of changes in grain yield (Si & Farrell, 2004).

Experiments reveal coherence of the grain yield and topographical parameters (the slope gradient, surface curvature). For example, in years with lack of precipitation the impact of the soil surface curvature reflects on grain yield, but abundance of water may reduce the grain yield of wet years. Moreover, the slope aspect and elevation show a significant effect on winter wheat yield and quality. However, the relationship between topography and grain yield is often poor in different fields. According to Yang, etc. (1998, cited by Si & Farrell, 2004) topographic characteristics explain only 13–35% of grain yield variability in fields, but likewise, Miller, etc. (1988, cited by Si & Farrell, 2004) found no correlation between the slope and winter wheat yield.

The aim of the analysis of the research results is to investigate coherences among the altitude of stationary observation points and development of winter wheat, wheat grain yield and soil moisture in different meteorological conditions.

MATERIALS AND METHODS

Field trials were carried out at the Research and Study farm “Vecauce” of the Latvia University of Agriculture during the years 2006–07 in field “Kurpnieki” with total acreage of 49 ha, where 47 observation points in a grid of 50x×50 m were determined. Meteorological conditions differ between trial years. The observed average air temperatures were above the long term in both trial years, especially in the second part of the year 2006 (Fig. 1).

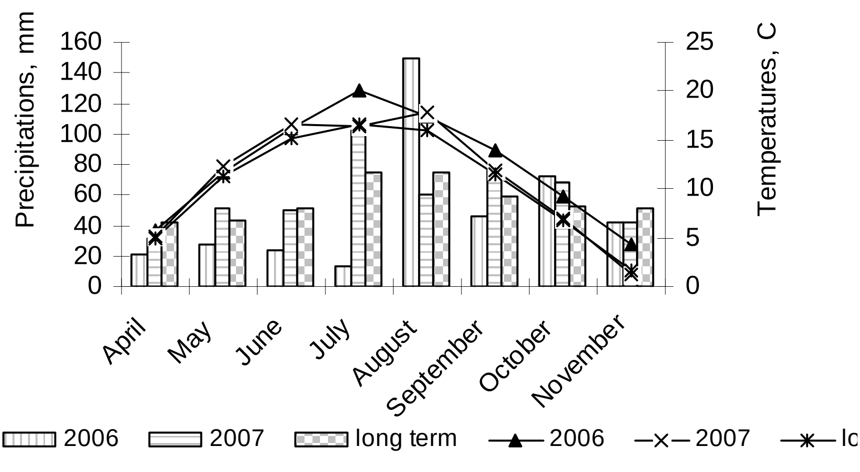

Figure 1. Average day and night air temperatures (showed as lines) and precipitation (showed in columns) in years 2006 and 2007, °C (according to Vecauce HMS).

The average temperature of July 2006 was by 3.5 ºC higher than the long-term observed. Combined with an insufficient amount of precipitation it caused rapid ripening and early harvesting of winter wheat compared with the long-time observed harvesting time. The sum of precipitations was low in both trial years, but during the period of April–August it was lower in 2006 than in 2007 despite the high amount of precipitation in August 2006 (Fig. 1).

Soil characteristics in “Kurpnieki” field: predominant soil type sod podzolic loam soil, humus content 14−91 g kg^{-1} (by Tjurin's method), soil reaction pH_{KCL} 6.0−7.4, phosphorus content 102−394 mg kg^{-1} and potassium content 102−333 mg kg^{-1} (by Egner-Riehm method). Relief – wavy terrain, area with explicit macro-relief. The field has a drainage system.

The same agrotechnology for growing winter wheat cv. ‘Tarso’ was used on the entire field: forecrop – winter oil seed rape, soil tillage before drilling – soil deep loosening at depth of 0.35–0.50 m and following soil ploughing at depth of 0.18 m. Drilling of winter wheat was done with combined drilling-soil tillage equipment with a vertical power harrow, sowing rate – 270 kg ha^{-1}. Fertilizers: in autumn $N_6P_{26}K_{30}$ with dose rate 300 kg ha^{-1}, in spring ammonium nitrate (N_{34}) two times per 200 kg ha^{-1}. Weed control and fungicide applications were done as needed.

GPS receiver Germin iQ 3600 was used to determine the point coordinates with accuracy at field condition ± 3 m. The yield was determined by means of the yield maps developed by using the Claas Lexion 420 GPS and the AGROCOM software. The altitude of the stationary observation points was determined by using Magelan eXplorist 600 with accuracy ± 3 m. Soil moisture in the soil layer of 0.00 – 0.45 m was determined by means of Eijkelkamp Agrisearch equipment in autumn after the drilling of winter wheat and in spring after the renewing of vegetation. The data was analysed using descriptive statistics and correlation analysis. The average differences are used for relevance assessment for experimental results from the heterogeneous groups with a different number of observations and it is displayed as the error interval using the y-bar method.

RESULTS AND DISCUSSION

Analysis of results shows linear negative correlation between the altitude of the stationary observation points and soil moisture – upper parts of the trial field were characterised by lower soil moisture in the sub-soil layer (Fig. 2). Correlation is significant $P < 0.05$ in both trial years but coherence is tighter in the year with a reduced amount of precipitation, as observed in April–July 2006.

Significant linear negative correlation was also observed between the altitude of the observation points and winter wheat grain yield in both trial years. A heightened level of probability $P < 0.01$ of relationship was determined in year 2006 because of lack of moisture during the spring–summer growing period. This coincides with conclusions drawn by Ferrara et al. (2009) that in semi-arid regions yield variability is significantly related to slope x elevation index that increases crop failure in drier elevated spots. Although the trial site was not located in a semi-arid region, weather conditions in 2006 with high temperatures and a low amount of precipitation were not typical for the temperate climate zone.

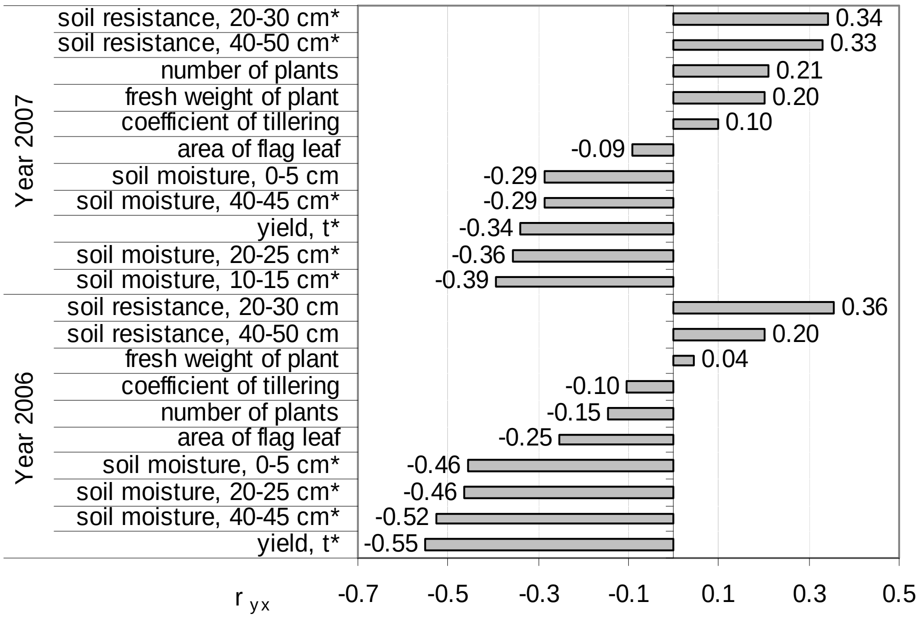

Figure 2. Coefficients of linear correlation, r_{yx}, among altitude of stationary observation points and factorial indices; * $P < 0.05$.

Analysis of correlation shows significant coherence between the altitude of the observation points and soil penetrometric resistance at the depth of 20−30 cm that was verified by a decrease of soil moisture in places with increased altitude. Analysis of correlation does not show significant coherence among altitude of observation points and number of plants per m^2 before wintering, fresh weight of wheat plants in spring at BBCH 29, the coefficient of correlation and area of flag leaf at BBCH 71 (Fig. 2).

Soil moisture at the depth of 40−45 cm was below optimum – 25% – in both trial years and also in both stationary observation levels with average altitude 95 m and 102 m above sea level. Soil moisture was significantly lower in the highest points of the terrain (Fig. 3).

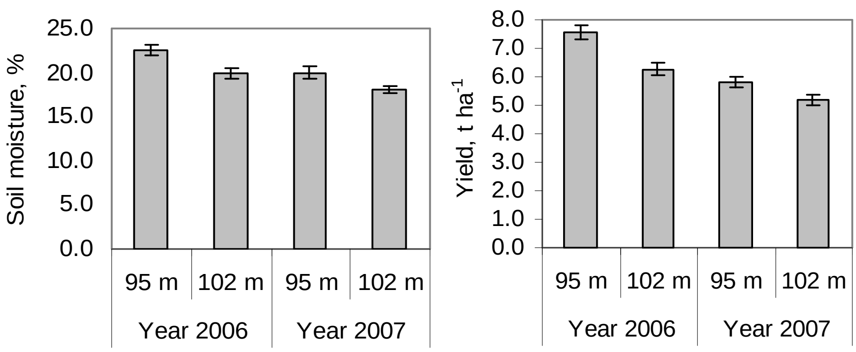

Figure 3. Dependence of altitude on soil moisture (%) at the depth of 40−45 cm and on winter wheat grain yield (t ha^{-1}) with standard errors at 95% confidence level.

Significantly higher winter wheat grain yield was obtained in field points with an average altitude 95 m above sea level. This coherence is more explicit in a year with lower precipitation, as in 2006 (Fig. 3). Results obtained in year 2006 showed that an increase of soil moisture above 25% also significantly increased grain yield compared to points where soil moisture was below 20% (Fig. 4). Referring to trials conducted in Lithuania (Kadžiene, 2009), where it was established that direct drilling could provide a solution for saving moisture in subsoil layers in dry weather conditions, we can presume that deceasing the depth of soil tillage has to be applied at the highest points on the elevated parts of fields.

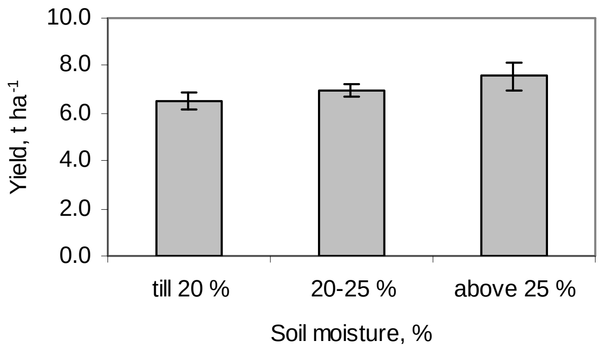

Figure 4. Dependence of winter wheat grain yield (t ha^{-1}) on soil moisture (%) at the depth of 40–45 cm in year 2006 with standard errors at 95% confidence level.

Evaluations of factorial indices show that soil moisture at the depth of 40–45 cm has significant positive impact on the winter wheat grain yield (Table 1). The increased altitude of the field had significant negative effect on winter wheat grain yield in both years, but a negative effect on soil moisture was statistically significant only in year 2006 which can be explained by lack of precipitation in the winter wheat growing period that year.

Table 1. Correlations among factorial indices.

Year	x	Y	r_{yx}	r^2_{yx}, %
2006	altitude, m	yield, t ha^{-1}	-0.55*	30.48
	soil moisture at the depth of 40-45 cm	yield, t ha^{-1}	0.47*	21.97
	altitude, m	soil moisture at the depth of 40-45 cm	-0.52*	27.51
2007	altitude, m	yield, t ha^{-1}	-0.34*	11.44
	soil moisture at the depth of 40–45 cm	yield, t ha^{-1}	0.34*	11.57
	altitude, m	soil moisture at the depth of 40-45 cm	-0.29	8.25

* *P < 0.05*

Soil moisture at the depth of 40−45 cm in the cereal tillering stage showed significant positive impact on the area of winter wheat flag leaf (Table 2). The impact of soil moisture on other studied winter wheat grain yield formatting indices was not statistically significant.

Table 2. Impact of soil moisture at the depth of 40−45 cm on formation of winter wheat grain yield.

Year	x	r_{yx}	r^2_{yx}, %
2006	fresh weight of plant	0.04	0.13
	coefficient of tillering	0.26	6.95
	area of flag leaf	0.49*	24.49
2007	fresh weight of plant	0.18	3.20
	coefficient of tillering	0.24	5.96
	area of flag leaf	0.53*	27.96

* $P < 0.05$

CONCLUSIONS

Analysis of the results shows significant linear negative correlation between the altitude of the stationary observation points and soil moisture, and also winter wheat grain yield. Coherence shows a tendency to be tighter in years with a reduced amount of precipitation during the growing period.

Analysis of correlations does not show significant coherence among the altitude of observation points and the number of plants per m^2 before wintering, fresh weight of wheat plants in spring at BBCH 29, coefficient of correlation and area of flag leaf at BBCH 71.

Soil moisture at the depth of 40−45 cm was significantly lower in the highest points of the terrain and was below optimum level, 25%, in both trial years. An increase of soil moisture to above 25% significantly increased grain yield if compared to points where the soil moisture was below 20%. Accordingly, soil moisture content has to be considered as an important yield limiting factor and is linked with differentiation of soil tillage.

REFERENCES

Ferrara, R.M., Trevisiol, P., Rana, G., Richter, G.M. & Baggaley, N. 2009. Topographic impacts on wheat yields under climate change: two contrasted case studies in Europe. Springer –Verlag. Published online.

Kadžiene, G. 2009. *Integrated assessment of the variation of soil properties in different soil tillage – fertilization systems.* Summary of doctoral dissertation, Akademija, Lithuanian university of Agriculture. 18 pp.

Lapins, D., Vilde, A., Berzins, A., Plume, A. & Dinaburga, G. 2007. Criteria for the Site Specific Soil Tillage. In *Proceedings of the 6th International Scientific Conference Engineering for Rural Development* (Jelgava, Latvia University of Agriculture, 24–25 May). LLU, Jelgava, pp. 268–275.

Si, B.C. & Farrell, R.E. 2004. Scale-dependent relationship between wheat yield and topographic indices: A wavelet approach. *Soil Science Society America Journal* **68** (2), 577–587.

Shpedt, A.A. & Nikitina, V.I. 2009. The Influence of Microrelief on the Agrochemical Properties of Chernozems and the Yield of Spring Wheat and Barley. *Eurasian Soil Science*. **42**. 8, 909–915.