CRITERIA FOR THE SITE SPECIFIC SOIL TILLAGE

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Abstract. Investigations were carried out in 2004 – 2006 at 47 stationary observation points on the production plantations of the Kurpnieki massif, the Vecauce Research and Training Farm (Vecauce RTF) of the Latvia University of Agriculture (LUA), into the factors that affect the yields of winter wheat and winter canola. The yields in these trials were determined by means of the yield maps developed by using the Claas Lexion 420 GPS and the AGROCOM Software. As the factors affecting the yield were studied: thickness of horizon Ap of soil, the organic matter content in soil, the penetrometric resistance of soil in its deeper layers to the depth of 50 cm, the soil and the subsoil moisture. The research was carried out at stationary observation points of the local GIS of the farm. A significant impact of the observation time and soil moisture was established on the differences in soil resistance. A different penetration resistance of the subsoil layer affects the yield rather than soil resistance in its upper layer. Measures for the minimisation of soil resistance should be planned when the penetrometric resistance of soil in its deeper layers to the depth of 30 to 50 cm is within the range of 600 – 700 kPa cm^{-2}.

Key words: GPS, GIS, precision field management, soil properties, site specific soil tillage, winter wheat.

Introduction

Precision agriculture (PA), sometimes called precision farming, is a new approach to the field crop and animal production management – a modern form of farming. It is an information-driven production system that has a close link with the elaboration and introduction into agricultural production of information technologies, such as the Global Information System (GIS), the Global Positioning System (GPS), the field heterogeneity estimation (field maps), the spot fertility levelling upwards, the improvement and monitoring systems, the process management and control systems, as well as the systems for structural planning, economical and ecological estimation of farming [3].

The Latvian fields reveal great heterogeneity of spatial soil properties and yield variability. Investigations are carried out in order to clarify their causes and find the measures of their levelling.

The main factors affecting the level of yields are: soil fertility, soil density (resistance), weediness, the weather conditions [1-3].

The obtained analytical correlations allow assessment of the draft resistance of the soil tillage machines (ploughs, cultivators) depending on soil moisture and composition, as well as on their design parameters and working speed [4, 5].

In order to differentiate soil tillage on the patches of the field, all-round information is necessary about the physical and mechanical properties of soil there and their impact on the yield capacity of cereals. This research is devoted to their elucidation.

The elements of precision agriculture are appearing on the Latvian farms during the recent years, first of all, the equipment of grain harvesters for the formation of the yield maps. The next stage – the application of the yield map is connected, first of all, with the investigation into soil properties [1-3]. It means that the farms should form their own local geographic information system. The research material of the soil properties serves as a basis for the introduction of differentiated, GIS-based resources-saving soil tillage. Already in the previous years research was conducted in Latvia into the possibilities to optimise the measures of soil tillage by using the GPS [3].

The aim of the research is to systemise and analyse the obtained data material and recommend the difference criteria of soil tillage using site specific soil tillage.

Materials and Methods

Field trials were carried out at the Vecauce Research and Training Farm of the Latvia University of Agriculture during the years from 2005 to 2006. The weather conditions in both the years were different: the year 2005 was characterised by lowered mean air temperatures but the year 2006 – by a pronounced low rainfall and subsequent moisture deficit in the soil (Figures 1 and 2).

During the production trials on the Tarso winter wheat variety at 47 stationary observation points of the Kurpnieki massif the differentiation possibilities of soil tillage were clarified in relation to the characteristics of soil properties. The same wheat growing agrotechnology was used on the entire massif, the principle of the single difference being applied at the GPS points. Positioner Germin iQ 3600 was used to determine the point coordinates. The yield capacity was determined by means of the yield maps developed by using the Claas Lexion 420 GPS and the AGROCOM Software. As the factors affecting the yield were studied: the thickness of horizon Ap of soil; the organic matter content (which was determined in a certified agrochemical soil laboratory); the penetrometric resistance of soil in the layers to the depth of 50 cm being determined before the sowing of wheat, at the stage of one or two leaves in autumn, at the end of the clustering stage in spring. Soil moisture in the arable layer and under it was determined alongside with the penetrometric resistance of soil. The Eijkelkamp penetrometer with electronic data recording was used for the measurements and the Erisearch Equipment equipped with a sensor and an electronic data recorder served to measure moisture.

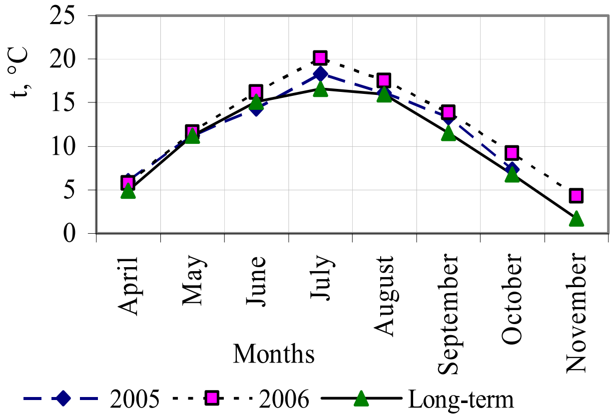

Fig. 1. **The mean day-and-night air temperature in the years 2005 and 2006, °C (acc. to Dobele HMS)**

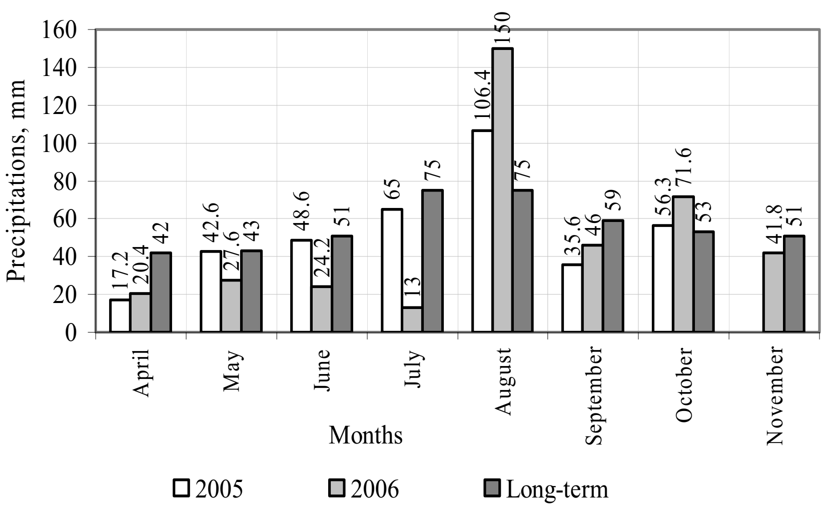

Fig. 2. **The mean amount of precipitation in the years 2005 and 2006, mm (acc. to Dobele HMS)**

Analysis of the research and discussion

Uncontrolled factors: the organic matter content in soil and the thickness of horizon Ap, which are of essential importance in the decision making system on the soil tillage differentiation in the aspect of the yields of winter wheat. No linear correlation with the yield was established for the granulometric content of soil characterised in the trials as physical clay content in soil, %. (Figures 3 and 4).

From the landowners' point of view, the most appropriate for the depth difference of the presowing soil tillage and basic tillage are cartograms (maps) of the thickness of horizon Ap. They are justified by the cost comparison for making analyses and cartograms. In order to obtain the cartograms of the organic matter and the granulometric content of soils, special analyses are necessary, but the thickness of horizon Ap can be determined by the landowner himself.

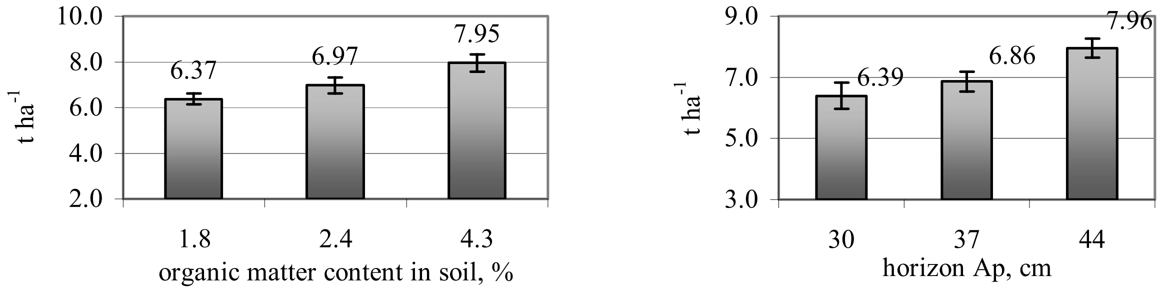

Fig. 3. **Organic matter content in soil, thickness of horizon Ap, and the yield of winter wheat in the year 2006**

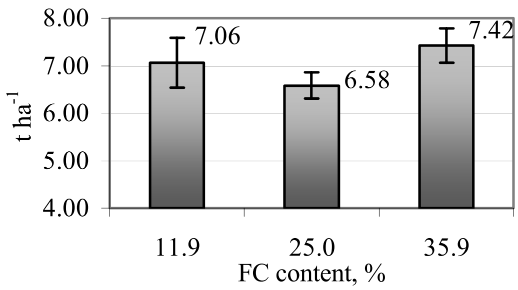

Fig. 4. **Influence of physical clay (FC), %, on the yield capacity of winter wheat**

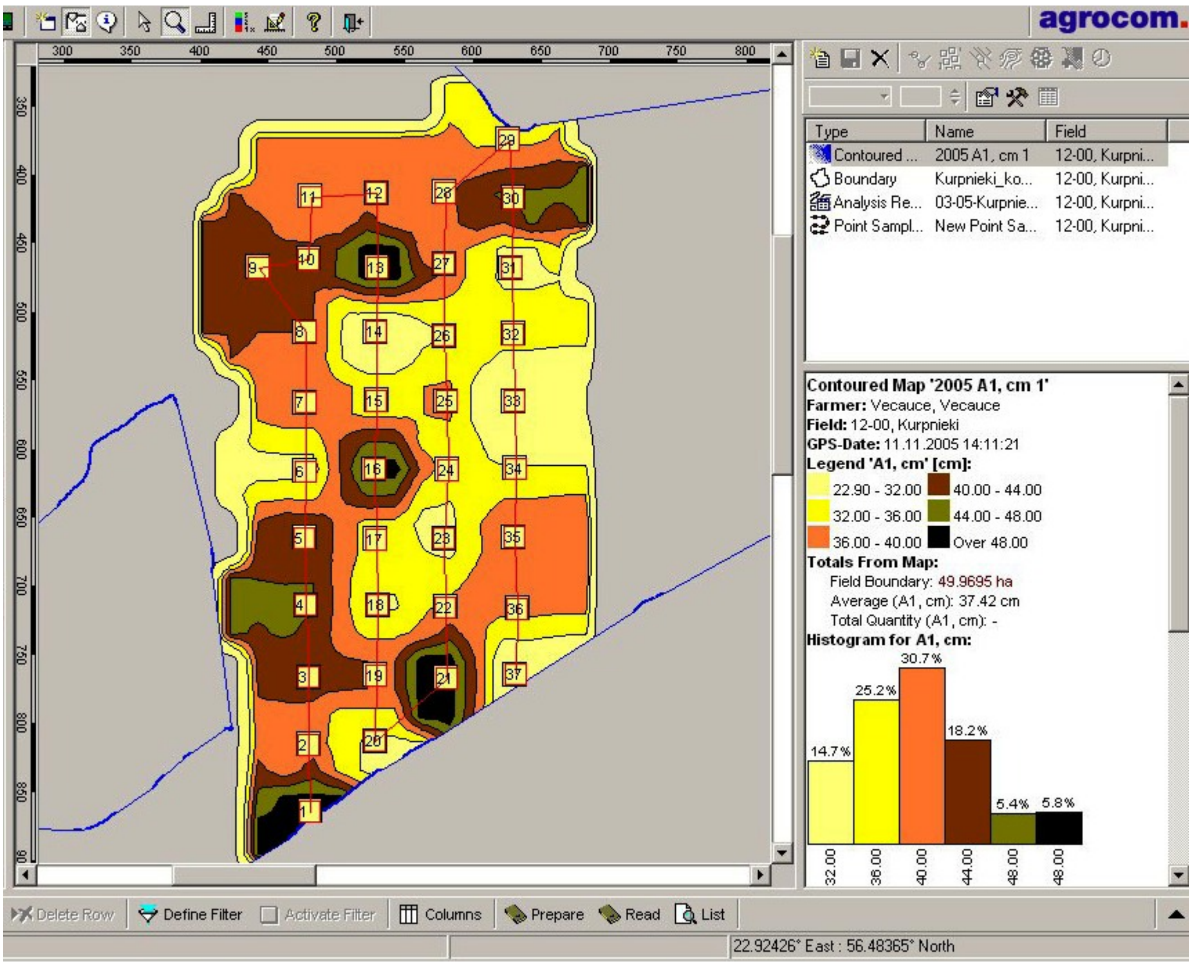

Fig. 5. **The GIS cartogram of the thickness of horizon Ap in the Kurpnieki massif**

The obtained cartograms allow site specific reduction of the depth of basic tillage when the thickness of horizon Ap is greater than 36 cm. On the experimental field it constituted 60.1% of the entire area (Figure 5).

It was established in the trials that at the GPS points with increased thickness of horizon Ap there is also increased organic matter content, which generally reduces also the risk of minimised basic soil tillage and presowing tillage in relation to the yield capacity of winter wheat. On the experimental areas with an increased organic matter content over 2% and the average thickness of horizon Ap 33.4 cm, it was significantly less ($P<0.05$) than at the organic matter content in soil over 2% (38.8 cm). Correspondingly, at the same GPS points with the average organic matter content 1.8 and 3.1% the introduction depths of the seeds of winter wheat were 3.2 and 3.7 cm respectively ($P<0.05$), and the values of the variations coefficient S % of the sowing depth were 9.2 and 16.9%. This testifies that on the parts of the area with an increased organic matter content over 2%, and the depth of horizon Ap over 40 cm rolling down should be applied during the presowing tillage or alongside with sowing (Figure 5).

The cartograms of the organic matter or Ap may be applied for the optimisation of the primary soil tillage or sowing (see Figure 5) with which the source material used for the formation of the local GIS closely correlates.

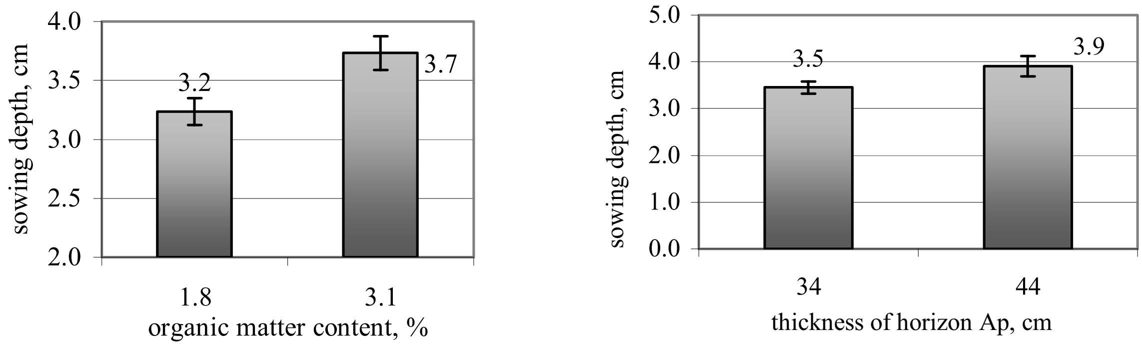

Fig. 6. **Dependence of the sowing depth of winter wheat on the organic matter content and the thickness of horizon Ap**

The cartograms of the organic matter or Ap may be applied for the optimisation of the primary soil tillage or sowing (see Figure 5) with which the source material used for the formation of the local GIS closely correlates.

Controlled factors. The controlled factor, used to form the local GIS, was soil density characterised indirectly through the penetrometric resistance (hardness) of soil at the GPS points selected for the experiment.

Soil hardness characterises the resistance to the penetration of the steel tip having a cross-section area of 1 cm^2 [4, 5]:

$$\rho_0 = \delta_0 \left(b'' + d''m\right) e^{-l''W^n} , \qquad (1)$$

where ρ_0 – soil hardness, H m^{-2};
δ_0 – soil (dried) density, kg m^{-3};
m – the contents of physical clay (particles of the size <0.01 mm, %);
W – absolute soil moisture, %;
b'', d'' and l'' – coefficients;
n – exponent; e = 2.718…

For the investigation of soil the coefficients and the exponent entered into formula (1) have the following values: b'' = 1100; d'' = 200; $l'' = 4\cdot10^{-3}$ and n = 2.

The hardness variations of soils with different mechanical composition depending on their moisture are graphically presented in Figure 7.

It is evident from the diagram that the same soil has different hardness depending on its moisture.

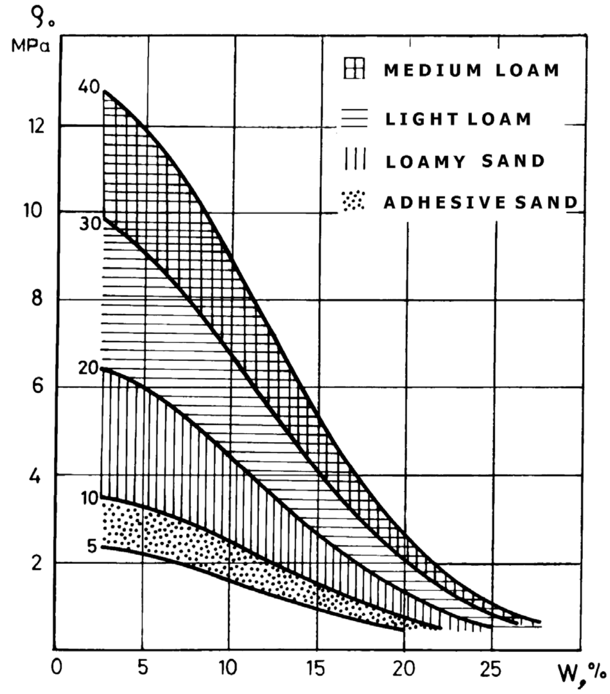

Fig. 7. **Dependence of the hardness of soils with different mechanical composition on their moisture**. *The numbers at the soil hardness curves stand for the percentage of the physical clay in soil. Soil hardness is determined by Yu.Yu.Revyakin's hardness gage having a flat tip with a cross-section area 1 cm^2*

The research results into the variations of the penetrometric resistance of soil bore evidence of their great and essential seasonality characterised by two results of resistances determined in autumn and spring (Figure 8). It was established that the main factor of seasonality in the variations of the penetrometric resistances of soil is the moisture of soil. In order to make choice between the two possible times when soil resistance is determined – autumn and spring, the correlations and the impact on the yield of winter wheat were used as the main criterion (Figure 8).

The penetrometric resistance of soil was determined at the GPS points to form the local GIS in order to differentiate sol tillage for the formation of the loose layer of soil and, first of all, the subsoil layer. A purposeful soil tillage differentiation, related to yield capacity and the consumption of resources, is ensured by the GIS of the organic matter and thickness of horizon Ap.

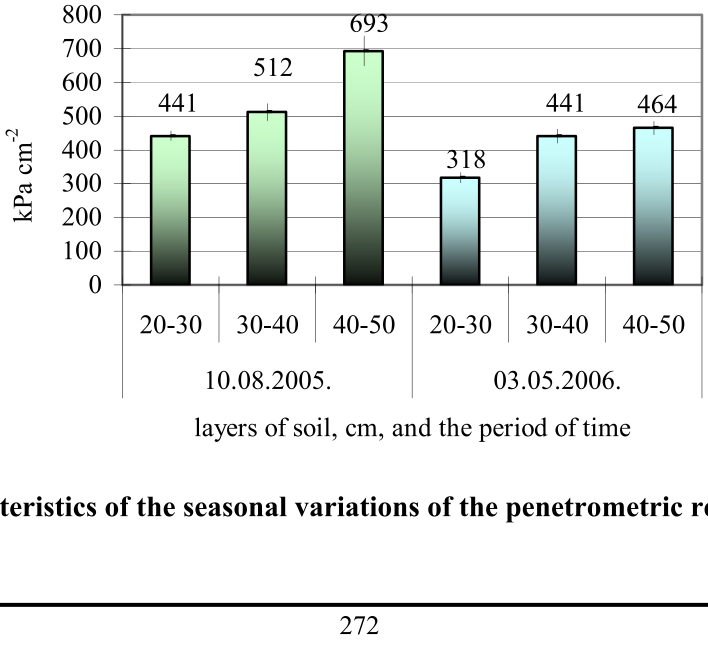

Fig. 8. **Characteristics of the seasonal variations of the penetrometric resistance of soil**

It was established that increased resistance of the subsoil layer over 600 kPa cm^{-2} (resistance being determined in spring) has a negative impact on the on the yield of winter wheat (Figure 9). However, in autumn the soil resistance, which is determined before sowing, and the GIS have faster application. The research results of the years 2005 and 2006 in the Kurpnieki massif confirmed the previous conclusions that deep loosening of soil should be carried out when the penetrometric resistance of soil exceeds 600 kPa cm^{-2}.

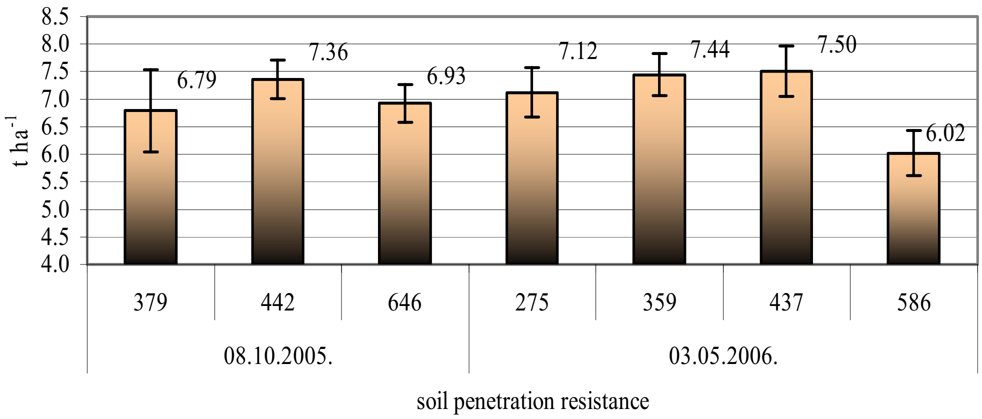

Fig. 9. **The yields of winter wheat in various soil resistance intervals in the subsoil layer of the arable land from 20 to 50 cm**

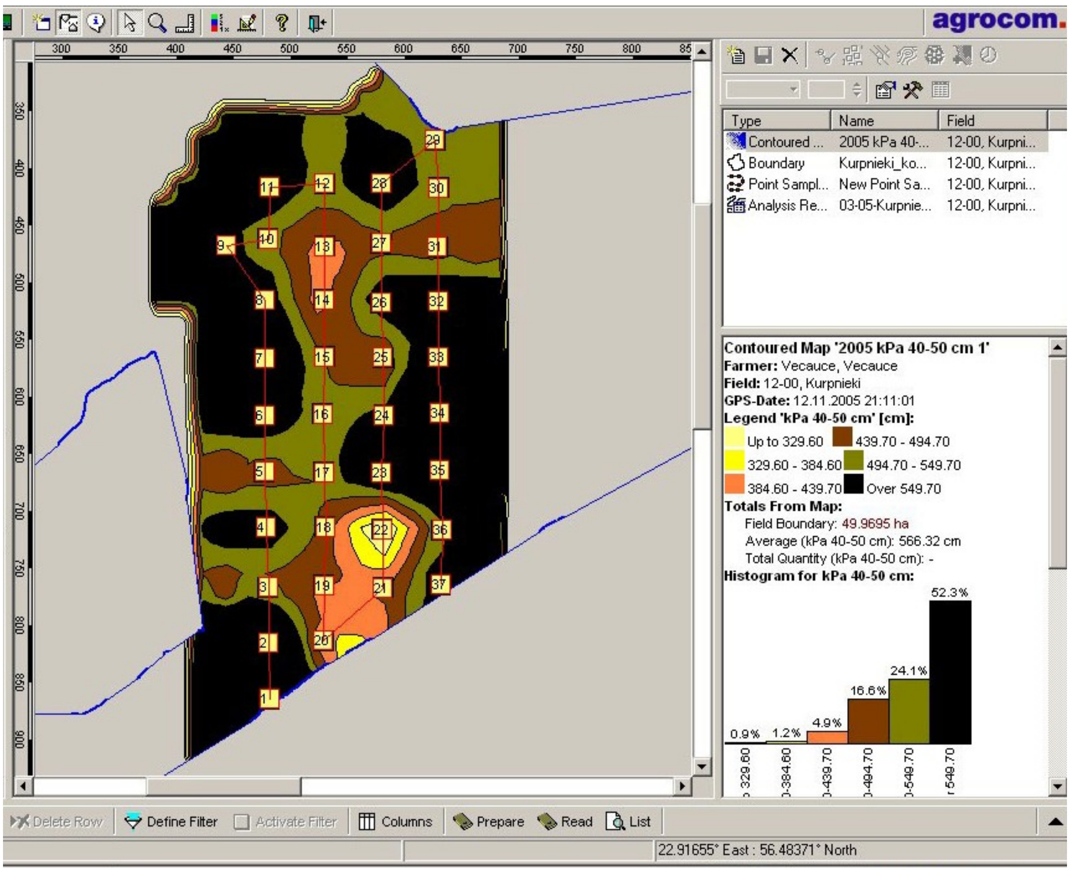

Fig. 10. **The penetrometric resistances of soil at the depth from 40 to 50 cm, kPa cm^{-2} (a cartogram)**

The local GIS map (Figure 10) formed on the basis of the data of the penetrometric resistance measurements of soil allowed drawing a conclusion that the total amount of deep loosening of soil in the Kurpnieki massif can be reduced by 48% of the entire area.

Conclusions

1. In the aspect of yield capacity of winter wheat the organic matter content in soil and the thickness of horizon Ap are of essential importance in the decision making system about the soil tillage differentiation on individual patches of the field.
2. The GIS cartograms allow site specific reduction of the basic tillage depth when the thickness of horizon Ap is greater than 36 cm, which constituted 60.1% of the total area of the experimental field.
3. At the GPS points with the average organic matter content 1.8 and 3.1% the introduction depths of the seeds of winter wheat were respectively 3.2 and 3.7 cm ($P<0.05$), and the variation coefficient of the sowing depth S % was respectively 9.2 and 16.9%. It testifies that on the parts of the area with the organic matter content over 2% and also the thickness of horizon Ap over 40 cm rolling down should be applied during the presowing soil tillage alongside with sowing.
4. The results of the variations of the penetrometric resistances of soil bore a witness of their essential seasonality. The main factor of seasonality is the moisture of soil.
5. Significant negative influence of increased resistance over 600 kPa cm^{-2} (if there is such a resistance in spring) of soil under the arable layer was established on the yield of winter wheat.
6. It was established that deep loosening of soil should be carried out when the penetrometric resistance of soil exceeds 600 kPa cm^{-2} The local GIS map allows reduction of the total amount of deep loosening of soil by 48% of the entire area.

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