SOME INVESTIGATIONS IN PRECISION AGRICULTURE

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Abstract. A brief review of the current situation and activities in precision agriculture in Latvia are given. In the latest years investigations are carried out in directions: yield and weedy monitoring; monitoring of soil properties and its changes; ecological grain drying with microclimate monitoring and distance control; impact of the plough body parameters on the ploughing efficiency, criteria determination for efficiency estimation of agricultural machinery in field crop cultivation; impact of the soil humidity on the ploughing resistance. The use of computerised ventilated bins for drying and storing grain is purposeful in the organisational, as well as economical and ecological aspects. It facilitates the farmer to organise the harvesting process, to use favourable weather conditions to a full extent, to obtain a higher-quality product and sell it on more profitable terms. Minimum fuel consumption and costs can be achieved by aggregates completed with efficient up-to-date tractors and tillage machines that are suitable for local conditions and have optimal design and applications parameters, improving the tractor loading and aggregation patterns. Humidity most of all impacts the soil hardness and cutting resistance which considerably dominates in the summary resistance of the plough body. An increase in the soil humidity leads to a decrease in the ploughing resistance that is more remarkable on clay soils.

Key words: precision agriculture, yield monitoring, dynamics of soil properties, energy saving technologies.

Introduction

In Latvia, investigations in Precision Agriculture (PA) were started only some years ago by the researchers of the Research Institute of Agricultural Machinery joined by the researchers-agronomists from the Institute of Soil and Plant Sciences [1, 2]. On the basis of the Vecauce Research and Training Farm (further RTF) of the Latvia University of Agriculture (further LUA), "PA Research Centre" has been organised with an aim to expand and coordinate the research of problems related to precision agriculture, putting the new findings into production and efficiency estimation. Experimental studies have started in precision crop production. The grain combine harvester Claas Lexion 420 was equipped with a device for the determination of grain yield and moisture content by fixing in the GPS coordinates to produce digital maps of the grain yield. The yield maps showed great spatial yield level variability. Studies have been carried out to clarify its causes and work out the measures for the yield levelling upwards, as well as to improve maintenance of machines and to reduce energy consumption and costs.

Materials and methods

The objects of the research were technologies, machines and the equipment for the implementation of PA in the field crop production under Latvian conditions, as well as the quality and energy economy in soil tillage and the post-harvest (drying) process. Generally adopted methods are used in the investigations of PA. In order to perform energetic estimation of the tillage machines, their statistic and dynamic resistances were determined. The soil resistance was determined by a certified device of the company Eijkelkamp.

In the latest years investigations are carried out in such directions:

- yield monitoring depending on soil properties and its changes;
- ecological grain drying with microclimate monitoring and distance control;
- criteria determination and their evaluation for efficiency estimation of agricultural machinery in field crop cultivation;
- impact of soil humidity on the energy consumption for ploughing.

Results and discussion

Yield monitoring depending on soil properties and its changes. The experiments were arranged in the RFS Vecauce during the years 2001 - 2007. Field trials were settled in loamy sand sod-podzolic soils with equalized micro-relief. Winter wheat was grown after clover – timothy mixture.

The field was treated with glyphosate herbicide after harvesting of fore-crop. Soil tillage included soil deep loosening in the following treatments: untreated (without tillage), deep loosening at 0.25, 0.35 and 0.50 m depth. Subsequent soil treatment included soil ploughing at 0.22-0.25 m depth and direct sowing. The chosen fields had wavy meso-relief [10].

Soil deep loosening has a significant role on packing prevention technologies of the soil layer beneath topsoil, but it demands high energy consumption. This investigation was intended to clarify the effectiveness of deep loosening in various field relief conditions.

It was established that deep loosening of soil should be carried out when the penetrometric resistance of soil exceeded 600 $kPa \cdot cm^{-2}$ in the depth of 40-50 cm. Soil deep loosening at the depth of 0.50 m gave winter wheat yield increase by 7.3 % or 0.4 $t \cdot ha^{-1}$ on average of three year field trials. However, there is a possibility of decrease in winter wheat yield because of uneven mezzo-relief with not enough precipitation. The cause of decrease in winter wheat yield after deep soil tillage in the depth of 50 cm was the decrease in the soil humidity in the higher areas of mezzo-relief [10, 11]

Ecological grain drying with microclimate monitoring and distance control. In the Baltic States with their humid and unstable weather conditions, the production of high-quality food and forage grain harvested by means of combine harvesters and suitable for continual storage requires its careful treatment after harvest: removing admixtures, drying, sorting, i.e., conditioning and proper storage. On small and medium-size farms ventilated bins that combine the grain drying and storage functions are most appropriate. They are of more universal character and do not need high investments for their erection. Solar heat, accumulated by means of a film collector, is used to warm up the air but a generator of heat (a firewood burning furnace) is provided as a reserve source of heat [3]. The weak point of these drying systems is that they do not have a control implement of the drying process, which causes insufficient or too great desiccation, lowering of the quality of grain, uneconomical utilisation of the days suitable for dr~~a~~ying, and over consumption of energy. Therefore, the investigation was carried out to ensure uninterrupted control (monitoring) of the grain drying and storage process.

A self-made ecological barn, which has a grain storage–drying facility, was equipped with computerized monitoring of moisture, temperature and the air flow intensity. Five sensor arrays were located in three different places of the storage-drying facility to control the flow of air over the grain, one of them to control the inflow of air, and another one to control the condition of air outside the barn. Special equipment was made for preheating air by means of the sun and/or by firewood burned in the furnace to ensure the desirable temperature and moisture.

The results obtained showed that fast and direct information about the temperature and humidity in the grain storage facility and outside is very useful to the farmer. “Soft” drying of grain in a small facility of the peasant farm can be achieved using only natural resources – the heat from the sun and firewood. Active ventilation is preferred to ensure the necessary air flow through the grain. Online monitoring of moisture and temperature in the grain storage facility prolongs the time of drying by means of active ventilation. The drying period was extended by 15-25 % every day owing to the information obtained from the digital temperature and humidity sensors.

The use of computerised ventilated bins for drying and storing grain is purposeful in the organisational, as well as economical and ecological aspects. It facilitates the farmer to organise the harvesting process, to use favourable weather conditions to a full extent, to obtain a higher-quality product and sell it on more profitable terms. This increases the manoeuvrability of production, makes it less dependent on the weather conditions and the grain reception centres and raises the profitability of grain production by 12-15 %. For example, on the farm “Mazkalnini” the income from selling conditioned wheat in the years 2007 and 2008 was twice higher than that from the sales of grain directly from the harvester. Owing to this solution the farm managed also to harvest grain in due time with minimum losses under the unfavourable weather conditions.

Criteria determination for efficiency estimation of agricultural machinery. In the Latvian agriculture the transition process from the old tractors and machines made in the former Soviet Union (now – the Commonwealth of Independent States, CIS) to new ones coming from the West European countries is going on. The new machinery is more progressive but more complicate and expensive, too. This may raise the costs of agricultural production. Therefore, measures should be taken for efficient maintenance of the new machine fleet. The data of the previous investigations [4, 5] are now obsolete and useless for purchasing of the new machinery.

To carry out comparative energetic estimation of soil tillage machines, the values of their static and dynamic resistance coefficients are compared, as well as the character of their variations. From the energetic point of view, the machines are better for which the values of the resistance indices are lower. For the machines with active working parts in addition to these draft resistance must determine the resistance moment (torque moment), too. As a result of the studies, a series of criteria were found out how to estimate the efficiency of agricultural tractors and machines used in the field crop cultivation [4-9].

The efficiency of tractors and machines applied in agriculture is usually estimated as an integrated value including the indices of their intensive and extensive use. The application intensity of tractors and machines is characterized by their working capacity per unit of time but its extensity - by the length of the consumed time in a season (year). However, in order to obtain more objective estimation data for the used tractor aggregates, their performance should be evaluated by optimal parameters: their working width and their speed. One of the ways how to raise the labour efficiently, to cut the fuel consumption and the production costs, as well as to improve the ecological situation is to improve the tractor loading and aggregation patterns. Only the aggregates should be used for soil tillage and other works which ensure their performance with minimum fuel consumption and costs. This can be achieved by aggregates completed with efficient up-to-date tractors and tillage machines that are suitable for local conditions and have optimal parameters. In order to estimate the application intensity of the tractor, its engine loading (fuel consumption per unit of time) should be measured and fixed in the data logger; to estimate its extensity - the length of time consumed for its application should be determined [4-9].

The obtained intermediate regularities of the main parameters of the tractor diesel engines allow to calculate for a known value of one parameter the values of other parameters. They may be used to create a computer programme and an algorithm for the calculation of the values of the engine working parameters and assessment of efficient use of the tractor (see in these Proceedings the article: Arvids Vilde, Edmunds Pirs: Intermediate regularities on the energetical parameters of the tractor engines).

Based on the results of this theoretical investigation the tractor Mc CORMIC is equipped with a computerised device for carrying out experimental trials in order to fix its energetic indices and assess the efficiency of the tractor usage.

Impact of soil humidity on energy consumption for ploughing. The deduced analytical correlations and the developed computer algorithm allow assessment of the forces acting upon the operating surfaces of the plough body and determination of its draft resistance depending on the value of the soil humidity and composition, as well as its design parameters and working speed [6-9]. The value of the cutting resistance of the soil slice is dependent on the thickness of the share edge and has changes in accordance with the variations of the soil hardness. Variations in the draft resistance caused by the weight and inertia forces of soil correspond to the values of the friction resistance, but the resistance caused by the soil adhesion correspond to the values of the specific force of its adhesion to the working share-mouldboard surfaces. The correlations obtained allow assessment of the ploughing resistance depending on the soil humidity, mechanical composition and the working speed of the plough, determination of the optimal soil humidity range when the tillage capacity is the lowest. Humidity most of all impacts the soil hardness and cutting resistance which considerably dominates in the summary resistance of the plough body. An increase in the soil humidity leads to a decrease in the ploughing resistance that is more remarkable on clay soils. The optimum humidity of sticky clay soils when ploughing at a speed 2-2.5 $m \cdot s^{-1}$ is 18-22 %. [6].

Conclusions

1. Latvian fields reveal great heterogeneity of spatial soil properties and yield variability. Investigations were carried out to clarify its causes and find the measures for its levelling.
2. The main factors affecting the level of yields were: soil fertility, soil density (penetration resistance), weediness, weather conditions. Unpredictable weather conditions and variability have great influence on spatial yields.

3. The deep soil tillage is necessary if the soil penetration resistance in the depth of 40-50 cm exceeds 600 kPa·cm^{-2}. However, there is a possibility of decrease in winter wheat yield because of uneven mezzo-relief with not enough precipitation.
4. The obtained correlations allow assessment of the draft resistance of the soil tillage machines (ploughs, cultivators) depending on the soil humidity and composition, as well as on their design parameters and the working speed. In order to perform unbiased energetic estimation of the soil tillage machines and optimisation parameters (working speed and width) of the tillage aggregates one should find out the static resistance and the coefficient of the dynamic resistance.
5. Humidity most of all impacts the soil hardness and cutting resistance which considerably dominates in the summary resistance of the plough body. An increase in the soil humidity leads to a decrease in the ploughing resistance that is more remarkable on clay soils. The optimum humidity of sticky clay soils when ploughing at a speed 2-2.5 m·s^{-1} is 18-22 %.
6. Precision agriculture, based on wide and versatile information, is a resource-saving farming system that allows obtaining maximal yields by minimal consumption of fuel, chemicals and other expenses. The problems for the PA implementation are the comparatively high investments that can pay back only in a longer period on larger areas, as well as insufficient databases.

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