INVESTIGATIONS IN PRECISE AGRICULTURE: RESULTS, PROBLEMS, PERSPECTIVE DEVELOPMENT

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Abstract. A brief review is given of the current situation, activities, views and trends in precision agriculture (PA). PA is an information-driven production system having close connection with the elaboration and introduction into agricultural production of information technologies, such as the Global Information System (GIS), the Global Positioning System (GPS), estimation of the field heterogeneity, the spot fertility leveling, the improvement and monitoring systems, the processing management and control systems, as well as determination criteria for efficiency estimation of agricultural machinery in field crop cultivation; impact of the soil humidity on the tillage energy consumption, structural planning systems, economical and ecological estimation of farming. Highly developed computerized system, provided with sensors DS1923, allowed the introduction of monitoring the technological grain drying process, ensuring its operative control thus obtaining high-quality dry grain with low energy consumption and expenses. The main goals of the PA in the crop production are yield maximization, input minimization, maximizing financial advantages and minimizing the environmental impact. There are some problems for the implementation of PA: a lot of labour-consuming and expensive measurements and analyses are required; comparatively high investments for its implementation are needed; unpredictable weather conditions and variability have great influence on spatial yields. Prospectively, it is necessary to carry out a field surface levelling in order to prevent lowland cornfield area of ducking out. In Latvia PA would be efficient for increasing the production and minimizing its expenses and undesirable impact on environment. It is the farming system of the future.

Keywords: precision agriculture, yield maps, yield spatial heterogeneity, soil properties variability, energy consumption, resources saving, ecological grain drying.

Introduction

At present efficient agriculture is increasingly based on the knowledge of biological, chemical, physiological and other processes having influence on the growth of the plants or cattle breeding. Precision agriculture (PA) is a new concept in production – a new approach to crop management. It has a close link with the elaboration and introduction into agricultural production of information technologies. PA in plant growing can be defined as a comprehensive system designed to optimize agricultural production through the application of crop information, advanced technologies and management practices. A truly comprehensive approach to PA begins with crop planning, and it includes tillage, soil fertilizing, planting, application of chemicals, harvesting and post-harvest processing of crops. PA is becoming popular in the whole world, and it receives new challenges in Europe, however in Latvia, as well as in the other new developing countries, this system is new and less known [1 – 8].

Investigations in PA were started in 2003 by the researchers of the Ulbroka Research Centre, now called the Research Institute of Agricultural Machinery. In 2004 the researchers-agronomists joined from the Department of Soil Management, now called the Institute of Soil and Plant Sciences.

Purpose of the investigation: to study and estimate the PA situation and development, to obtain the necessary information and create the database for PA management, to clarify and analyse the trends, results and problems existing in the field of research and practice.

Materials and Methods

The objects of the research are technologies, machines and the equipment for the implementation of PA in the field crop production under the Latvian conditions, as well as the quality and energy economy in soil tillage and post-harvest processes. Generally adopted methods are used in the investigations of PA (Fig. 1) [4]. In order to perform the energetic estimation of the tillage machines, their statistic and dynamic resistances are determined. The tillage quality is estimated by testing. The soil resistance was determined by a certified device of the Eijkelkamp company. For computer-based weed detection detailed visible spectrum digital images and aero-photos are used.

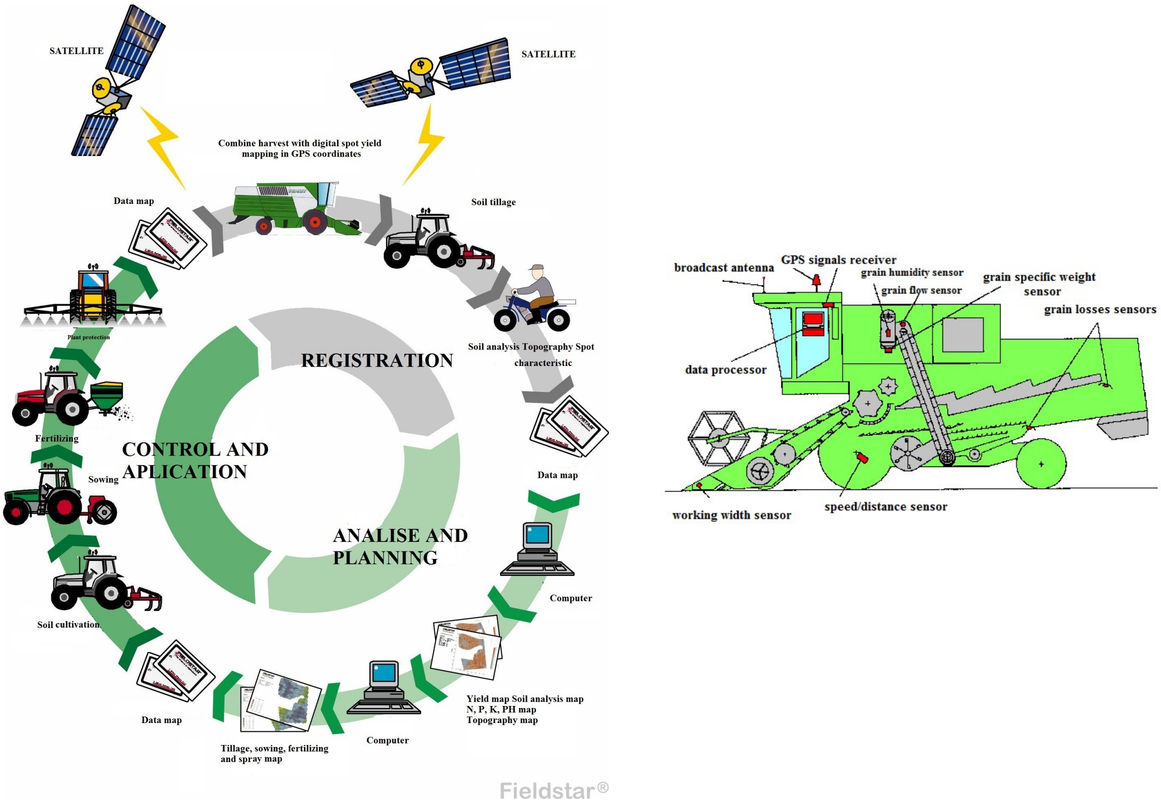

Fig. 1. **Cycle of information and measures to application GPS technologies in the Precision Agriculture. Equipment of the combine grain harvester for the determination and mapping spot yields in GPS coordinates**

Results and Discussion

On the basis of the Vecauce Research and Study Farm (RSF) of the Latvia University of Agriculture (LUA), a “PA Research Centre” has been organized with an aim to expand and coordinate research in the problems related to precision agriculture, putting the new findings into production and efficiency estimation [1-8]. Experimental studies have started in precision crop production. The grain combine harvester *Claas Lexion 420* was equipped with a device for the determination of the grain yield and the moisture content by fixing the GPS coordinates to produce digital maps of the grain yield (Fig. 1).

The yields of wheat and rape were determined in several fields. The yield maps show great spatial yield level variability. For example, a more detailed analysis of yield levels is presented for two fields: the Kaulatinas field with the area of 8.86 ha and the Gludaini field with the total area of 86.60 ha (Fig. 2). It was established that the yield levels on different spots vary in a great range. Thus, at an average yield, the respective 4.67 and 4.59 $t \cdot ha^{-1}$ patches with the yield under 2.5 $t \cdot ha^{-1}$ covered 8.0 and 0.8 %, but with the yield over 7 $t \cdot ha^{-1}$ – 8.0 and 6.2 % of the total area of the fields (Fig. 2) [1; 2].

Studies have been started to clarify its causes and work out the measures for the yield leveling upwards. The objects of the research are technologies, machines and the equipment for the implementation of PA in the field crop production under the Latvian conditions, as well as the quality and energy economy in soil tillage and grain drying processes.

The investigations are carried out in such directions:

- yield and weedy monitoring;
- monitoring of soil properties and their changes;
- criteria determination for efficiency estimation of agricultural machinery;
- detection of the intermediate regularities on the energetic parameters of tractor engines;
- ecological grain drying with microclimate monitoring and distance control.

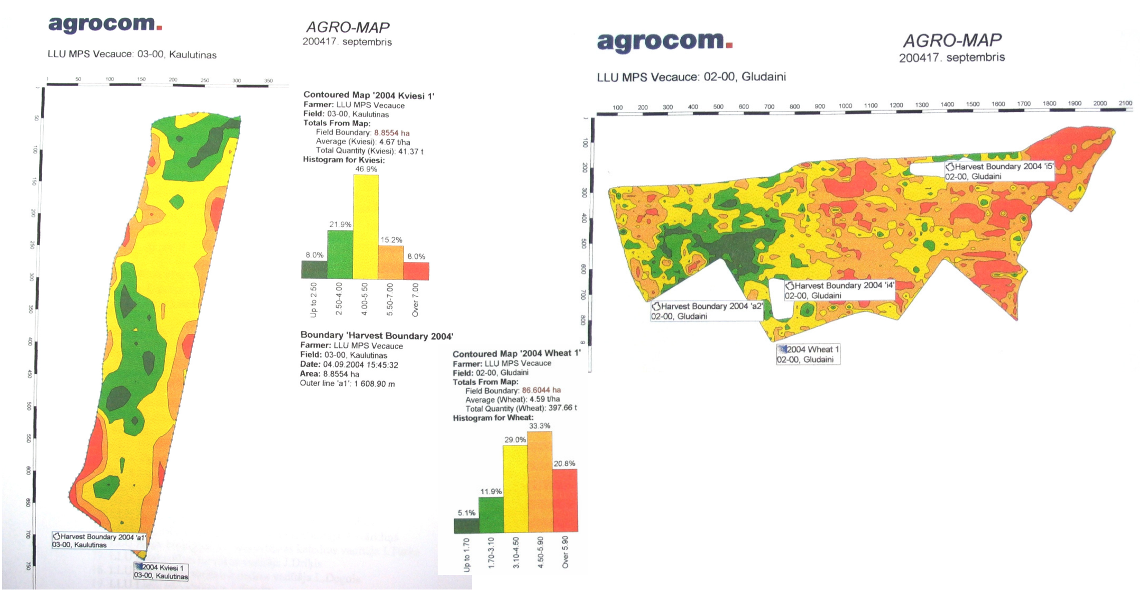

Fig. 2. **Winter wheat field yield heterogeneity in 2004 in RTF Vecauce:**
on the Kaulutinas and on the Gludaini field

Yield Monitoring Depending on Soil Properties and their Changes. The experiments were arranged in RFS Vecauce during the years 2003 – 2011. The field trials were settled in loamy sand sod-podzolic soils with equalized micro-relief. Winter wheat was grown after clover – timothy mixture. The field were treated with glyphosate herbicide after harvesting of the 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 [9].

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 $N \cdot cm^{-2}$ in the depth of 40 – 50 cm. Soil deep loosening at the depth of 0.50 m gave the winter wheat yield increase by 7.3 % or 0.4 $t \cdot ha^{-1}$ on average of three year field trials [9]. However, there is a possibility of decrease in the winter wheat yield because of uneven mezzo-relief with not enough precipitation. The cause of decrease in the 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 [9]. For example, Figure 3 shows the herbage characteristics on the Kurpnieki field depending on the soil tillage quality, soil density (penetration resistance) and yield heterogeneity of winter wheat [2 – 4].

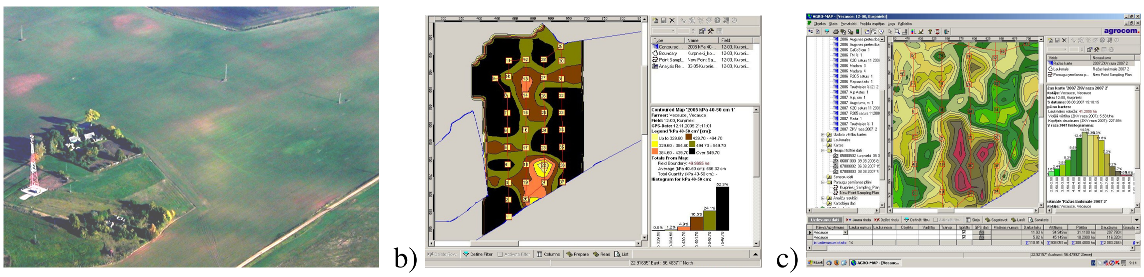

Fig. 3. **Soil and herbage characteristics on the Kurpnieki winter wheat field of *RTF Vecauce:***
a – the aero-photo of the Kurpnieki field of winter wheat in October 2005; b – the soil density (penetration resistance) at the depth of 40 – 50 cm; c – yield heterogeneity of winter wheat

The heterogeneity of the winter wheat herbage is depending on the soil properties on different field spots. The herbage is more powerful on the spots that have a deeper A_1 horizon and lesser soil density.

The soil density map allows applying a specific way of soil tillage using deep loosening only on the spots having increased density, for example, on the Kurpnieki field where it is 60 %.

Criteria Determination for Efficiency Estimation of Agricultural Machinery. In the Latvian agriculture the transition process is still going on 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. The new machinery is more progressive but more complicated 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 are now obsolete and useless for the purchase of the new machinery [10; 11].

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, those machines are better with the values of the resistance indices lower. For the machines with active working parts in addition to this draft resistance one must determine the resistance moment (torque moment), too. As a result of the studies, a series of criteria were found on how to estimate the efficiency of agricultural tractors and machines used in the field crop cultivation [10 – 12].

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 the 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 efficiency, 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 those aggregates should be used for soil tillage and other work 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 the time consumed for its application should be determined [10].

The obtained intermediate regularities of the main parameters of the tractor diesel engines allow calculate for a known value of one parameter the values of other parameters. They may be used to create a computer program and an algorithm for the calculation of the values of the engine working parameters and assessment of efficient use of a tractor [11].

Impact of Soil Humidity on Energy Consumption for Soil Tillage. The deduced analytical correlations and the developed computer algorithm allow assessment of the forces acting upon the operating surfaces of the soil tillage machine working parts 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 [12]. 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 corresponds to the values of the specific force of its adhesion to the working share-mouldboard surfaces. The correlations obtained allow assessment of the working resistance depending on the soil humidity, mechanical composition and the working speed, 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 %.

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 careful treatment after harvest: removing admixtures, drying, sorting, i.e., conditioning and proper storage. On small and medium-size farms the most appropriate are ventilated bins that combine the grain drying and storage functions. 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 [13]. 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 drying, and overconsumption 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 the 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 (Fig. 4).

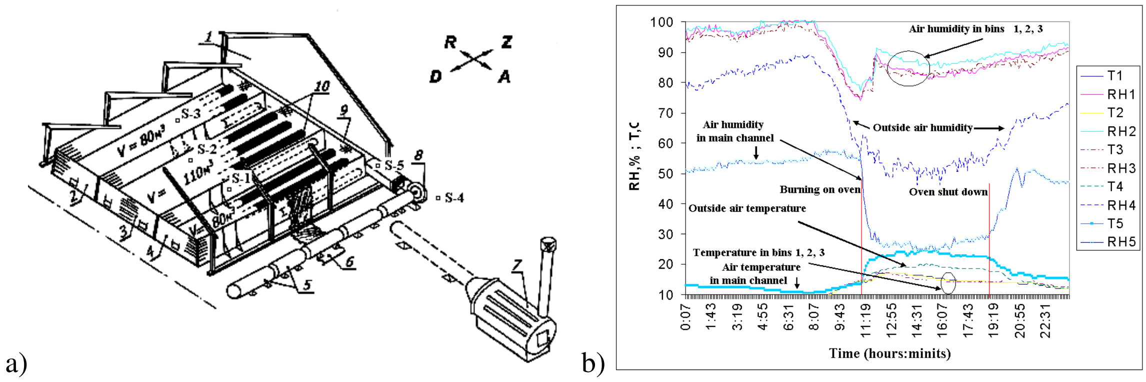

Fig. 4. **Scheme of ecological grain drier-storage plant having ventilated bins provided with sensors (a) and single-day monitoring results of the grain drying process as an example (b):** 1 – barn; 2, 3, 4 – ventilated grain drying-storage bins; 5 – air collectors; 6 – solar energy absorption film; 7 – heat generator (furnace) 40 kW; 8 – radial fan HL 15; 9 – main air channel; 10 – operating channels; S-1, S-2, S-3, S-4, S-5, S-6 – sensors DS1923

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 farm can be achieved using only natural resources – the heat from the sun and the 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 allows farmers 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 as much as 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.

There are some problems for the implementation of PA:

- a lot of labour-consuming and expensive measurements and analyses are necessary;

- comparatively high investments for its implementation are needed;
- unpredictable weather conditions and variability have great influence on spatial yields.

In the perspective it is necessary to carry out field surface leveling in order to prevent lowland cornfield area of ducking out.

In Latvia precision agriculture would be efficient for increasing production, minimizing expenditures and saving the environment. It is the farming system of the future.

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 leveling.
2. The main factors affecting the level of yields are: soil fertility, soil density (penetration resistance), weedy and weather conditions. Unpredictable weather conditions and variability have great influence on spatial yields.
3. Deep soil tillage is necessary if the soil penetration resistance in the depth of 40 – 50 cm exceeds 600 $N \cdot cm^{-2}$. 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 working speed. In order to perform unbiased energetic estimation of the soil tillage machines and optimize the 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 $m \cdot s^{-1}$ is 18…22 %.
6. By means of appropriate technologies and machines it is possible to attain satisfactory soil preparation and seed placement under normal, as well as under extreme weather conditions.
7. The use of computerised ventilated bins for drying and storing grain is purposeful for the organisational, as well as economical and ecological aspects.
8. The problems for the PA implementation are the comparatively high investments that can pay back only in long-term on larger areas, as well as insufficient data bases.
9. In Latvia precision agriculture would be efficient to increase production, minimise expenditure and save the environment. It is the farming system of the future.

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