Economic Indicators of Precision Guidance in Crop Production in Agricultural Corporation Belgrade (PKB)

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This paper examined the level of savings in the application of modern technical systems for satellite guidance and control over performing agricultural operations throughout the season. The exemplary property was Agricultural Corporation Belgrade (PKB), which covers about 21,000 hectares of arable land. The effects of plot shape and direction of movement of tractor-attachment units in calculating the savings from reduced overlapping of adjacent passes were studied. The analysis was carried out of savings per crop (maize, wheat, soybean, sugar beet and alfalfa) and the operations for each crop separately, based on the manufacturing technology applied to an exemplary property. Comparing the achieved level of savings, the application of guidance for the type of the most economically viable operations was found as well as the needed equipment level of guidance devices and management. In particular, the analysis involved the functional dependence of the economic savings in fuel and inputs for the operations such as mineral fertilizers distribution and chemical plant protection. The estimates for the degree of anticipated savings for operations related to the five analyzed crops are tabulated.

Keywords: *precision farming, satellite navigation, plot, fuel, inputs, savings.*

1. INTRODUCTION

The most direct result of equipping the tractors and other machinery for satellite positioning and automatic control is more precise parallel swatting. This implies more accurate guidance of machines in the direction and reduction of overlapping (consequently, reduction of the number of passes per plot) during the performance of certain operations.

A more precise machine guidance in the direction results in the following direct benefits and savings: reduction of losses and damage to plant mass and better structure. From reducing the number of passes per plot there follow the direct benefits and savings such as: reduction of agricultural inputs, reduced fuel consumption, improved environmental conditions, improved ergonomic conditions, increased labor productivity. The degree of these direct benefits and savings in a particular agricultural operation varies depending on the requirements of operations themselves.

The use of satellite navigation brings about two indirect benefits and savings that apply to all agricultural operations. The first indirect advantage is the possibility to work at night, which is especially important when the time for carrying out certain agricultural operations is limited. This limitation mainly comes from adverse weather conditions. Overlapping at undermining/harrowing and manual specifying by day is 10 – 20 cm, and at night 40 – 50 cm. When using the precise guidance with the help of satellite guidance, overlapping can be reduced to 5 – 10 cm under all conditions [1]. Another indirect benefit is related to the fact that most systems are with integrated satellite guidance and other functions, which may well be used for management, accounting, various documentation and future production planning. All these benefits and savings are rounded by financial savings.

Precision agriculture is now a term that is increasingly used in agriculture worldwide. Precision agriculture is a farming management concept based on observing and responding to intra-field variations. Precision agriculture aims to optimize field-level management with regard to: crop science by matching farming practices more closely to crop needs (e.g. fertilizer inputs); environmental protection by reducing environmental risks and footprint of farming (e.g. limiting leaching of nitrogen); economics by boosting competitiveness through more efficient practices (e.g. improved management of fertilizer usage and other inputs). It largely emerged from the scientific framework and found application in practice, bringing profit to those who dared to use it. Precision agriculture is not a name with only one technology, but it is used for a set of technologies from which farmers can choose the components themselves, form a system that meets their needs and management style. This technology has become commercially available only since the year 2000. Specific guidelines are relatively new addition to the package of precision farming technologies. Increasing the use of positioning system that uses satellite signals is constant. However, the use

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of these systems is mainly focused on the technology of precision farming. Precision farming also uses information technology [2,3]. With a system for satellite positioning and electronic communication standards, the position and time can be integrated in all procedures related to agriculture. Implementing these new technologies enables one to obtain large quantities of geographic information and helps to control the monitoring of the process which further results in better quality of final products [4,5]. When it comes to reducing errors in chemical treatment of soil, using GPS can increase profitability and reduce consumption of pesticides and nutrients in agricultural operations, and cost savings are reflected in the decrease from 15.2 to 17.5 % of the costs in the areas of each field map obtained with a map-based automatic boom section control. Savings are visible and with some degree of resolution. Savings only to the operations of dissipation of mineral fertilizers and spraying, by cultivating a crop during the season on an area of 300 ha, make this system worth less than one production year. The results of some analyses show that even when considering only the private benefits, the value obtained by an accurate system for spraying can be significant [6].

Direct and most tangible return on this investment is the reduction of pesticides so as to avoid double chemical treatment of soil in the areas that overlap. The results indicate that overlapping can be reduced with a map-based automatic boom section control. When it comes to implementing a GPS system for harvesting, the study shows that the introduction of GPS systems to combine, along with other features, the savings would be 1902 €/year. The calculation of the annual cost of software was based on four years of work and hardware investment is estimated to be paid within 5 years [7].

2. MATERIAL AND METHOD

Savings (economic benefit), which are achieved using satellite positioning and automatic control, are not the same for all plant species and applied cultural practices and production technologies. When calculating the potential savings in production on the experiment fields of PKB, the data taken from the records for the previous season, i.e. 2010, the budget has been selected for five most abundant plant species, as follows:

- mercantile corn or corn silage (total 6573 ha);
- mercantile wheat or barley (total 6049 ha);
- soy flour (total 2384 ha);
- sugar beet (total 1247 ha);
- alfalfa (total 2705 ha).

In addition to the list of plant species, data are presented for the planted areas, according to the plan of sowing the crops for the period 2009/10. The mentioned crops occupy a total of 18,959 hectares or 88 % of the total of 21,491 hectares planted in the regular and the second sowing on the PKB commercial farm.

To calculate the savings in the application of technology in the domain of satellite positioning and automatic control of tractors and other machinery on the PKB commercial farms, we used a spreadsheet program *AgroKalkulator v.1 GPS* developed in the study *Profitability of GPS tracking devices and parallel swatting in the agriculture of Vojvodina* available at The Provincial Department of Agriculture, Forestry and Water Management.

In some agricultural operations (such as fertilizing and plant protection) a number of resources are used, i.e. inputs (i_1, i_2, ... i_n) at the same time, which is the amount per hectare of k_1, k_2, ... k_n, and the purchase price per unit of c_1, c_2, ... c_n.

The budget should include the total amount per hectare (if necessary divided by the number of procedures) with an average price of proportional amounts of appropriate inputs. On this occasion, we used the following relation for calculating the price of the mixture:

$$c_s = \frac{k_1 \cdot c_1 + k_2 \cdot c_2 + ... + k_n \cdot c_n}{\sum_{j=1}^{n} k_j} . \qquad (1)$$

Working widths of tractor attachments used in the calculation correspond to the actual width of machines commonly used on the PKB commercial farms. The coefficient of utilization of machines is high, 85 %, because it is considered that less than 15 % of time is spent in transit and on untilled end part of a furrow. The cost of tractor fuel is 1 €/l, fuel cost for planes is 1.6 €/l. Table 1 shows the working widths of tractor attachments on the PKB experiment fields, overlappings with and without guidance, and operating speeds with and without guidance.

Table 1. Properties of some of the machines used

Machine	Working width [m]	Overlap [m]		Speed [km/h]	
		without guidance	GPS guidance	without guidance	GPS guidance
Sub soiler	6	0.5	0.3	7	7.5
Disc harrow	6	0.5	0.3	9	9.5
Harrowing	6	0.5	0.3	10	10.5
Seedbed cultivator	6	0.5	0.3	10	10.5
Rollers Cambridge	6	0.5	0.3	8	8.5
Seeding machine	6	0.2	0.02	8	8.5
Sprayer	18	1.5	0.5	9	9.5
Fertilizer spreader	24	2	0.5	10	10.5
Agriculture plane	30	4	2	150	155
Combine harvester	9	0.9	0.5	6	6.5

3. RESULTS AND DISCUSSION

3.1 Effects of plot shape

First, studies involved the dependence of savings on the shape of the plot. Each plot is approximated by a rectangular plot of equal surface and the most similar shape. It is necessary to examine how the shape of the same land area, manifested through the length and breadth of the plot, affects the level of savings, as well as the direction of the tractor during the operation. The shape is manifested by the plot ratio r which is presented as a ratio of length a to width b of the plot: $r = a/b$. If the tractor attachment working width is d, then the number of passes lengthwise the plot is $n_a = b/d$, and the number of passes widthwise the plot is $n_b = a/d$. If p designates the reduction of overlapping during satellite-guided operation, then the total area that has not been treated twice with adjacent passes is: $P_a = bpa/d$ and $P_b = apb/d$. This implies that the savings from reduced double treatment of parts of the plots are independent of the direction of movement of tractor-attachment unit and that the tractor should take a longer route because this reduces the number of untilled end parts of a furrow, where maneuvering of the unit is performed.

Untreated zones emergence, caused by lower accuracy guidance, also has an effect on economic performance of tractor systems for soil tillage, because in these places soil is not tilled during tractor passes, or the next operations are performed on the untilled soil area, which then causes, for example, lower yield. As it is difficult to measure the surface of untreated zones, it is always assumed that overlapping is applied, which safely eliminates the formation of untreated zones.

3.2 Comparative analysis of results and cost effectiveness

Real savings for the five most abundant crops on the PKB farms vary slightly around those calculated, as a result of different plot shapes, however, the apparent tendency is to increase savings while increasing the width of the plot relative to the surface. Knowledge about the structure of sowing and the estimated savings per hectare (the diagram, Fig. 1) help in calculating the savings per crop and overall savings for the five crops (Table 2).

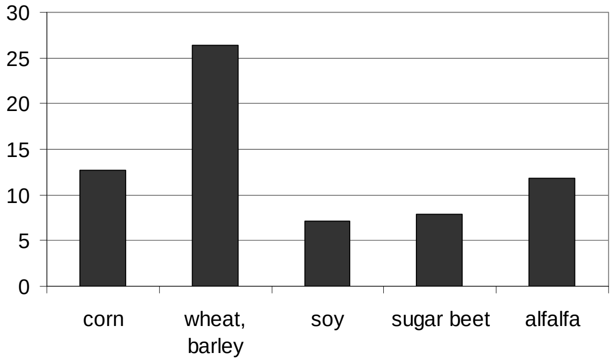

Figure 1. Comparative potential savings per hectare for the five cultures examined

As a final result of the analysis of potential savings in using satellite positioning on the PKB farms, and the automatic control of tractors and other machines, we obtain the sum of 301,980 Euros per season. The average savings per hectare in the structure of sowing in the season 2009/10 was 15.92 €/ha. These are direct savings in fuel and inputs. Be sure to keep in mind the increase in productivity, the possibility of saving from likely night work by using satellite positioning, the possibility of realizing the concept of precision agriculture through management, accounting, various documentation and future production planning, improving working conditions for machine operators and, finally, the possibility of contribution to environmental protection within the city "green ring" (Table 2).

Table 2. Survey of savings per hectare, total savings per crop and total savings for all crops in the 2009/10 season

Crop	Area under crop [ha]	Savings per crop/hectar [€]	Total savings per crop [€]
Corn	6,573	12.72	82,097
Wheat, barley	6,049	26.37	159,512
Soy	2,384	7.13	16,450
Sugar beet	1,247	7.93	9,639
Alfalfa	2,705	11.82	31,973
Total savings for all crops			301,980

Costs of the device are fixed in character. Regardless of the performance of indicators of the actual machinery, equipment costs on an annual basis remain the same. On the other hand, unit costs, expressed per unit area, decrease with increasing the area where applicable. Figure 2 shows the formation of costs per unit area (1 ha), depending on the size of the area where navigators are applied. Navigation device, or a complete system used for navigation and management of the tractor is cost effective when applied to the surface on which the expenses are less than the projected potential savings. Unit costs drop with the growth of surface cultivated using satellite guidance devices. We should bear in mind the fact of how many hectares a tractor can handle during the year. Different types of tractors are used for different operations. Mounting and removable devices can be moved from one tractor to another, but if some operations take place simultaneously, this requires purchase of two or more devices, which affects the economic indicators. Based on research results, Table 3 shows the estimates of possibility to practically realize seven advantages of precise navigation within the twenty-four most common agricultural operations in arable farming. Also, the question has been pointed out as to whether automatic control is necessary in a certain operation in order to improve it by precision guidance application.

4. CONCLUSION

Modern agriculture in developed countries faces the requirements to achieve the highest possible quality of crops, to produce them at as low prices as possible and to affect the environment in the least possible way. The application of satellite guidance of agricultural machines allows for meeting all mentioned requirements.

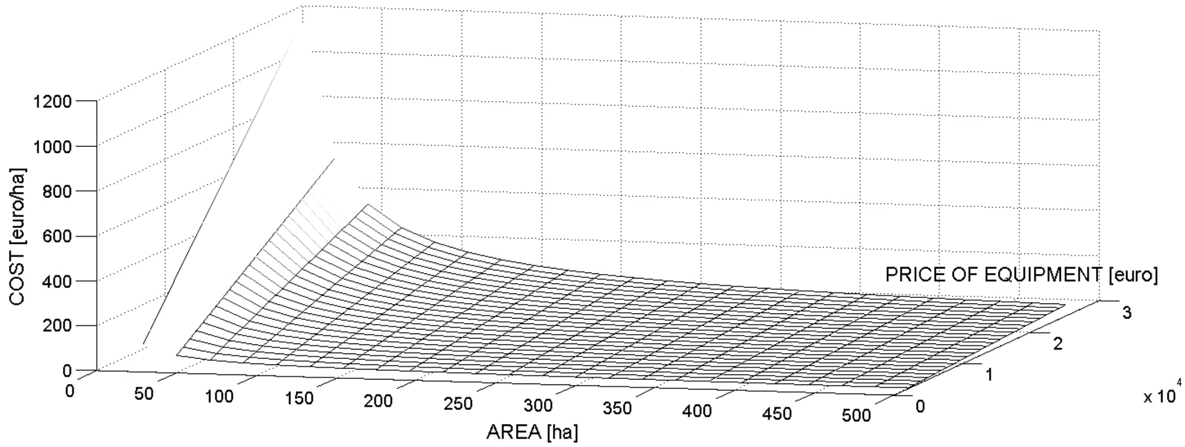

Figure 2. Cost of unit price per unit area, depending on the size of surface on which the satellite guidance system is used

Table 3. Estimated profit and savings per agricultural operation by the application of satellite guidance and automated steering of tractors and other machines (0 – no impact, 1 – not at all, 2 – slight, 3 – occasionally or under certain conditions, 4 – much)

	Satellite navigation and automatic control						
	Paralel swatting (precision equidistant directions) ↑						
	precision direction ↑		overlapping ↓ (number of walks ↓)				
	losses and damage to the plant mass ↓	quality of structures ↑	agricultural inputs ↓	fuel consumption ↓	environmental conditions ↑	ergonomic conditions ↑	productivity ↑
Plowing	0	4[1]	0	1	1	4[1]	1
Scarifying	0	4	0	4	2	4	4
Disc harrowing	0	4	0	4	2	4	4
Harrowing	0	4	0	4	2	4	4
Rolling	0	4	0	4	2	4	4
Daming	0	4	0	4	2	4	4
Preseeding preparation	0	4	0	4	2	4	4
Spread by tractor	0	2	4	4	4	4	4
Spread by plane	0	2	4	4	4	4	4
Seeding at narrow-row spacing	0	4*	4	4	2	4	4
Seeding at wide-row spacing	0	4*	2	2	2	4	2
Narrow-row spacing fertilization	2	3	4	4	4	4	4
Wide-row spacing fertilization	4**	3	2	2	2	4**	2
Plant protection by sprayer, narrow-row spacing	2	3	4	4	4	4	4
Plant protection by sprayer, wide-row spacing	4**	3	3	2	3	4**	2
Plant protection by plane	0	3	4	4	4	4	4
Interrow cultivation	4**	2	0	2	2	4**	2
Small grains harvest	3	0	0	4	4	4	4
Maize harvest, sunflower harvest	1	0	0	1	1	3	1
Cutting corn for silage	1	0	0	1	1	3	1
Sugar beet harvest	4**	0	0	1	1	4	1
Mowing	3	3	0	4	4	4	4
Raking, rolling	1	1	0	1	1	1	1
Pressing, baling	1	1	0	1	1	1	1

* The application of automatic control is required; ** The application of automatic control and following the sowing traces is required; 1 – only for the first pass, and possible correction.

The analysis of potential savings showed that for production technologies used in PKB the greater savings can be achieved for crops cultivated at narrow-row spacing compared to those grown at wide-row spacing. Also, the analysis answered the question on what type of operations the use of satellite positioning and automatic control is rational and cost-effective. The greatest savings are realized in the production of crops that occupy the largest area in the PKB Corporation (small grains and corn), and by applying production technologies that require more operations. The most significant savings are realized in fertilizing and protection of plants and they are around 1 – 6 €/ha depending on the norms, the type of fertilizer and plant protection and application of spreader or sprayers or aircraft, while the savings in tillage operations are, on average, about 1 €/ha and in planting about 4 €/ha. The level of savings depends on the applied technology of production and the number of operations and their requirements, respectively. Increase of the working width increases the inaccuracy of machine and overlapping, therefore the use of satellite guidance is more cost effective in those cases.

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ЕКОНОМСКИ ПОКАЗАТЕЉИ УКЛАПАЊА ПРОХОДА У РАТАРСКОЈ ПРОИЗВОДЊИ У ПОЉОПРИВРЕДНОМ КОМБИНАТУ БЕОГРАД

Драган Марковић, Милан Вељић, Војислав Симоновић, Ивана Марковић

У овом раду испитан је степен уштеда при примени најсавременијих техничких система за сателитско навођење и аутоматско управљање при обављању пољопривредних операција током целе сезоне. Огледно имање била је Пољопривредна корпорација Београд која се простире на око 21000 хектара обрадиве површине. Анализиран је утицај облика парцеле и правца кретања агрегата при калкулисању уштеда услед смањења преклопа суседних прохода. Извршена је анализа уштеда по културама (кукуруз, пшеница, соја, шећерна репа и детелина) и по операцијама за сваку културу појединачно, према технологији производње примењеној на огледном имању. Поређењем остварених степена уштеде закључено је при којим операцијама је примена навођења економски најоправданија и колики ниво опремљености уређајима за навођење и управљање је потребан. Посебно је анализирана функционална зависност економских уштеда у гориву и инпутима за операције дистрибуције хранива и заштите биљака. Табеларно је дата процена степена свих очекиваних уштеда за операције које се односе на пет анализираних култура.