ECONOMIC, PRACTICAL IMPACTS OF PRECISION FARMING – WITH ESPECIAL REGARD TO HARVESTING

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Summary: Today agricultural practice is faced with a paradigm shift. In terms of natural resources, the World's growing population calls for rational management and environment-conscious behaviour. Precision farming may provide a solution for the above mentioned criteria and problems. It has an array of technological equipment, elements and complete systems which are in themselves suitable to create conditions for efficient farming, to reduce environmental load and to provide farmers with optimal return on their investment.

Agricultural production has started to focus mainly on efficient crop production and machine operation. Due to this trend, machinery exploitation emerges as a secondary priority for agricultural enterprises. The underlying reason behind this shift is primarily the rise of machinery operation costs. Efficient machinery operation can provide farmers with a solution to reduce their expenditure and through better logistical organization they can obtain extra returns.

On the leading edge of my research is to introduce, quantitatively underpin and to justify the application of precision technologies. Our fundamental research methods rely on scenarios and economic calculations.

Keywords: precision farming, logistical optimization, sustainable agriculture, efficiency, effectiveness

Introduction

Precision agriculture is the key tendency of technological development in today's agriculture. It comprises new innovation technologies such as matching farming practices to production areas, integrated plant protection, inter-field variable cultivation technologies, remote sensing, the practical application of GPS technology and geographic information software in agriculture etc. This is a complex system that allows improved adjustment to heterogeneous soil conditions, correction of logistical and organizational failures, rational use of available input materials and building up a record of farm activities. Moreover, the large scale benefit of this system is that all the above mentioned are infinitely reproducible in spatial and temporal terms. Precision farming is a tool and an opportunity for agricultural producers to optimize their farming practices, to improve organization, to foster traceability, to generate and to store information which improves their decision-making.

The system allows farmers to use more economic and environmentally sound farming practices. It is noteworthy and can be significantly detected in itself that through site-specific fertilizer application, regarding soil heterogeneity, the quantity of applied plant protection products and fertilizers can be reduced, resulting in lower environmental load (Takács-György 2012).

Moore et al. (1993) claim that precision technology is a system relying on an information and technological basis, which seeks to respect soil properties and to achieve agricultural sustainability and environmental protection.

Precision farming is a modern tool in agricultural production; in fact, this is the key to boost efficiency and to cut environmental load (Wolf and Buttel 1996). Moreover, precision farming in itself can imply the mitigation of environmental damage and farmers' risks. This means that yield insecurity can be diminished and revenue safety for farmers can be enhanced provided that these technological elements are used and applied appropriately; however, all this in itself cannot guarantee revenue growth without exception (Takács-György 2012).

Referring to Mondal-Basu (2009) the precision agriculture is a tool in farmer's hand to optimize yield with minimum input use and reduced environmental pollution. Countries have to face with the challenge of economic and social growth which causes more increasing consumption. (energy consumption, food consumption, etc.)

The technological starting point of the system is precision soil sampling, which provides real-time information of each plot through the evaluation of the related results. These data show the condition, the nutrient and the microelement content of the soil. Based on these data, various maps can be drawn up by computer software. Application maps, indicating e.g. the application of fertilizers, plant protection products or sowing maps, are developed in consideration of soil sample data.

Their most pivotal element is that the program relies on soil sampling data, taking account of soil heterogeneity and generates maps, i.e. generates optimal input use to minimize environmental load and to allow farmers to obtain optimal revenue (Bongiovanni, Lowenberg-Deboer 2004). In addition to all these, it keeps records of each plot and provides farmers with precise data on production costs regarding crops and sites. If farmers have access to information on plot-level expenditure and through technologies they can improve yield safety, prospective revenues may be calculated which is a cornerstone of present day farming. It is a matter of common knowledge that due to the seasonal nature of agricultural production, farmers' revenues and expenses are temporally very different. The other essential element of the system is GPS communication. Navigation techniques can be successfully used in the period of soil cultivation and sowing, fertilization and plant protection (Swinton 1997).

This cordless technology integrates farming methods among machines, machine owners and machine operators. Its use lends itself to blending machine optimization, logistical optimization and fostering decision-making in agriculture. Farmers can achieve various levels of navigational accuracy; however, the so-called RTK real-time kinematic systems operating with the accuracy of 2 cm and can provide the users of precision technologies with highest accuracy.

The control system of precision crop production is divided into four main sub-categories:

DATA COLLECTION→
→DATA-PROCESSING→DECISION-
MAKING→INTERVENTION

Importantly, documentation should be developed during the whole process to ensure that system data can be retrieved and measured. Besides documentation, the background support of information technology and communication among machines allows potentials for intervention.

According to Weiss (1996) "precision farming is the sampling, mapping analysis and management of production areas in recognition of this spatial variety."

The John Deere Company, which introduced satellite-based guidance systems approximately 15 years ago, played a key role in the development and dissemination of precision technologies. With a keynote on innovation, it offers farmers inventions such as the application of cordless technologies.

(JD Link-Logistical and remote administration optimization) Our modern world requires farmers to keep up with the latest technologies to be able to optimize their revenue. It is expedient to use high-priced input materials more rationally, as a single bad decision may lay heavy burdens on farmers, let alone the unnecessary loading of the environment.

When considering the benefits of precision systems, farmers primarily focus on cost efficiency. Typically, they are not yet aware of their responsibility to protect our natural resources. This might be due to inadequate communication and to the fact that farmers do not have access to new information. Unfortunately based on practical experience, this is highly characteristic of Hungary.

Spreading of precision crop production is firstly an economic decision from farmer's view because they have to invest their capital. Because of it is not enough to examine the changes of the crop yield we have to examine the product price too so that the farmers can make a responsible and sustainable decision (Swinton, Lowenberg-DeBoer 1998).

The application of precision technologies in Hungary shows a very slow progress. The reason for this lies in the fact that the application of the system requires farmers to possess some kind of calling, managerial skills, system-based approach, background knowledge of information science and last but not least, a considerable amount of capital to invest.

Studies also shown that the application of precision crop production is hardly to implement. One reason is that the production is limited by the need for additional investment and the other is the availability of labour. We can establish that the adoption of precision farming technology is in early stage in Hungary (Takácsné, Lencsés, Takács 2013.).

Further obstacles to hinder the widespread use of this system are the lack of farmers' necessary knowledge, practice and experience to use these technologies (Nábrádi 2010).

Our research attempts to investigate a farm that switches from traditional farming practice to precision technology gradually.

This present study is based on an innovative technology exhibition in Hungary, focus on the significance of logistic optimalization in agriculture. The exhibition was held on 5 july 2012 in Zichyújfalu by KITE Zrt.

Our hypotheses are the fallowing:

H1. are farmers tend to concentrate mostly on efficient machine operation?

H2. the cost-efficiency achievable by the application of precision technologies?

Material and methods

The underlying condition in our research was identified as follows: the application of precision technologies is traceable and quantifiable by the optimization of logistical systems and operations during the harvesting. This scenario has been verified, as it was confirmed by an innovative field-level exhibition.

According to the previous practice (personal experience as well) stated that during the harvest, harvesting equipment and transport operators (harvesters, tractors, trucks, etc.) synchronization of significant losses in time and sometimes yield loss has occurred. For example when the harvester is full with crop, but the transport vehicles not arrived there or not ready yet for unloading. In this case, the harvester is forced to stop, it may also can happens, that should have to left c the current swath to empty the tank, and then have to go back to continue the harvest task. This is a significant loss of time and results in unnecessary fuel consumption and greatly reduces the daily performance. In the followings I will show that the precision farming tools (GPS antenna, on-board computer, automatic steering, RTK radio, onboard softwares) can be used to provide solutions for these problems.

On 5 July 2012 a firstly applied field experiment was performed in Zichyújfalu (Hungary) with a completely new approach. The organizer of the venue was KITE Zrt. and technological control was provided by an official of John Deere. The exhibition saw twelve GPS-controlled combines which showcased the JD harvesting equipment of various sizes. The latest „S series“ combines were paraded with the seed tank capacity of 10.600 litres. Twelve harvesting equipment with GPS navigation, RTK real-time kinematic system, AutoTrack steering (a navigation solution reproducible on the same track with the highest accuracy) and a summarized cutterbar width of 90 m opened the exhibition. The machines of W, T and S series were launched on the plot by satellite navigation. Harvesting equipment is required to feature complexity, which partly includes the performance of the machine's main task (harvest); on the other hand, it has to operate efficiently, in all circumstances. The total mechanical power of harvesting machines was 4800 horse power, their total seed tank capacity was 134.000 l and the hourly capacity of grain harvest was 360–400 t. It is to be noted that if anyone operated a machine stock of this volume, all kinds of losses, such as deficiencies in the logistical system would result in tremendous financial losses.

We should bear in mind that the application of the satellite system is not merely accurate, precise, ready for easy documentation and infinite reproduction, but its application mitigates trampling damages, improves or positively influences yield quality.

Besides the joint mechanical power of harvesting machines all the three series of combines received due attention. The greatest breakthrough can be achieved by the machines of "S series".

As mentioned above, complexity is a fundamental characteristic of the system. JD offers a full software base to foster work for farmers. Such technology is JD Farm Sight, which combines machine and logistical optimization and improves decision-making (JD Link). The JD Link unit of remote administration and logistical optimization absolutely offers practical benefits.

The exhibition highlighted the usefulness of the system in the logistical organization of harvest by a control combine with RTK real-time kinematic and satellite navigation. As mentioned above, the innovative nature of the exhibition was demonstrated by the debut of the so-called John Deere MachineSync system for the first time in Europe. By using the system, the combine driver can take over control from the power machine pulling up to the trailer on-the-go, so the seed tank of the combine can be unloaded with due safety on-the-go. The application of unloading and harvesting in one go proves to be very efficient to eliminate logistical losses both loss in crop and loss in time..

The machines of "S series" are capable to harvest an hourly volume of 30–35 t crops (wheat). Harvest by a control combine equipped with the required satellite navigation can save up 30t crop in one shift, i.e. this is the amount of loss if the harvester and the transporting trailer are not synchronized.

During the calculations we used the currency rates valid on 15 July 2012, which was 1 EUR = 290 HUF.

The values what are used in the calculations are from the author's own data fetching and practical measures from yield mapping system of test fieldplots in Zichyújfalu.

Results

As for wheat:

Harvest loss during one shift (10 hours) is 30t due to the deficiencies of logistical optimization. By the required satellite-based communication system and software the amount of excess crop is 3 t/ hour, which might mean that more efficient machine operation can approximately result in surplus harvest of one hour per day or a quantity of two days in a season.

The harvest season of wheat is about 20 days. By the satellite communication system the season is two days shorter, or if harvest is done in a lease arrangement, a surplus output of two days can be gained.

Calculations have been carried out for maize by using the same harvesting machine and communication system. My hypothesis, claiming that a well-organized system can increase the number of working days by 3 days per season, was justified as long as lease harvesting was the farmer's primary profile. However, if positive effects are considered from another viewpoint, the season is cut by three days, which means cost-efficiency for those who harvest on their own lands.

To further explore how cost efficiency or revenue growth due to the application of the precision system in the harvest season can be expressed quantitatively, calculations were divided into two parts: for maize and wheat crop cultures. The present study focuses on these two crops, as they are the most significant ones in Hungary.

Table 2. presents the two cases, when harvest time can be reduced or lengthened by an equal amount of time.

A shorter harvest season can be especially crucial if farmers harvest on their own plots with their own machines. In this case it is crucially important to use a lower amount of fuel,

Table 1. Quantified impacts of logistical optimization during wheat and maize harvest

Name	Wheat	Maize
Harvest capacity	30–35 ton/hour	60 ton/ hour
Daily capacity	350–400 ton	600 ton
Seed tank intake capacity 7.5 ton		
Hourly unloading	4	8
Average unloading	3 minute	3 minute
Number of daily cases of unloading	40 pc	80 pc
Time spent on unloading during one shift	120 minute (cc. 2 hour)	240 minute (cc. 4 hour)
If during 50% of unloading the combine keeps on harvesting		
daily saving	1 hour or 30 ton	1 hour or120 ton
Results:		
Number of days in an average season	20 days	16 days
Positive effects of unloading on-the-go:	season is 2 days shorter or the same machine can work two days longer	season is three days shorter or the same machine can work three days longer

Source: Author's calculations

Table 2. Quantification of benefits due to logistical optimization in wheat and maize cultures

		Wheat	Maize
Benefits:	A) In case of a shorter season	Saving a fuel amount of 2 days 2.000 litre of diesel Price of 1 litre = 1.45 EUR therefore: 2000 litre × 1.45 EUR = 2.900 EUR fuel cost	Saving a fuel amount of 3 days 3000 litre of diesel Price of 1 litre = 1.45 EUR therefore: 3.000 litre × 1.45 EUR = 4.350 EUR fuel cost
		the hourly wage of combine and transporter operators can be saved 4 persons about. 20 hour/person, which results in the saving of 80 working hours' wages Wage per 1 working hour is 5.2 EUR therefore: 80 hour × 5.2 EUR = 416 EUR wage cost	the hourly wage of combine and transporter operators can be saved 5 persons about. 30 hour/person, which results in the saving of 150 working hours' wages Wage per 1 working hour is 5.2 EUR therefore: 80 hour x 5.2 EUR = 780 EUR wage cost
		More favourable content values, which are not quantifiable	
	B) In case of a longer season	Period of lease harvest is 2 days longer	Period of lease harvest is 3 days longer
		If daily 50 hectares are harvested, it means the harvest of 100 hectare surplus area	If daily 60 hectares are harvested, it means the harvest of 180 hectare surplus area
		Lease harvest rate: 69 EUR/hectare, which means a surplus revenue of 6.900 EUR for the farmer (service provider)	Lease harvest rate: 83 EUR/hectare, which means a surplus revenue of 14.940 EUR for the farmer (service provider)

Source: Author's own calculations

Table 3. Actually realizable cost-efficiency indicators through logistical optimization in wheat and maize cultures

		In 1 year	In 5 years
Wheat	In case of a shorter season	3.316 EUR	16.580 EUR
	In case of a longer season	6.900 EUR	14.940 EUR
Maize	In case of a shorter season	5.130 EUR	25.650 EUR
	In case of a longer season	14.940 EUR	74.700 EUR
Total	In case of a shorter season	8.446 EUR	42.230 EUR
	In case of a longer season	21.840 EUR	89.640 EUR

Source: Author's own calculations

and to save labour costs. Conversely, if combines are leased, the number of hours per season should be increased, as it results in surplus revenue.

Costs were calculated by using the currency rates valid on 15 July 2012, which was 1 EUR = 290 HUF.

As for wheat and maize, actually realizable surplus revenues are presented in Table 3.

Tables 2. and 3. summarize costs to be achieved and saved through the harvest of wheat and maize by representing real numbers

As for wheat harvest, if farmers harvest their own plots by the assistance of RTK real-time kinematic system, the harvest season is reduced by two days which results in considerable cost efficiencies. The farmer can save the cost of approximately 2000 litres of diesel for two days, which means a cost of 29.000 EUR in the present circumstances. As workers have to work two days less, their wages will reduce harvest costs. In general, 4 workers make up a harvest crew, one combine operator and 3 who help with the harvesting equipment. Their wages amount to 416 EUR, which can also appear as saving for farmers. It is seen above that the total saving is 3.316 EUR in one year in case of shorter season.

As for maize, the harvest period can be reduced by 3 days, resulting in saving the amount of 4.350 EUR, the cost of 3000 litres of gasoline. Wages here will be lower by the amount of three working days, but we should not forget that the harvest crew consists of 5 employees. Their wages are 780 EUR, which may also appear as saving. So the total saving is 5.130 EUR in one year in case of shorter season.

In one year, a farmer working on his own field, harvesting wheat and maize cultures can cut harvest costs by 8.446 EUR. This amount may yield him a cost reduction of 42.230 EUR by the 5. year of machine operation.

In another case, a contractor who performs lease harvest uses precision farming technologies with satellite communication system.

In reflection of the data in the above tables we can draw the conclusion that in this case, the operation and the efficiency of the system are highly spectacular. We assume that no lease harvesters can afford to pay surplus costs due to the inaccuracies of logistical organization and the deficiencies of using capacities if such machines are available.

As long as farmers and contractors apply logistical optimization, they can obtain a considerable amount of surplus revenue. Through capacity growth, they can use their machines two days longer in the harvest season of wheat. This may mean surplus revenue of 6.900 EUR in 1 year. As for wheat, this amount is 14.940 EUR.

Overall, as pertains to wheat and maize harvest seasons, yearly revenues can be increased by 21.840 EUR. In the 5. year of the operation period, my calculations forecast surplus revenue of 89.640 EUR.

Importantly, our calculations used actual present-day prices to ensure transparency and to prevent false speculations. We use 5 year for long-time calculation because in most cases these equipments are replaced or sold after 5 years in service.

The advantage of JD link is that the on-board computers of combines can communicate with the system of tractors and trailers controlling them through the GPS machine guidance system, and in this way, harvest potential can be maximized. There is no unnecessary downtime during the time when the trailer arrives at the combine. Logistical optimization fosters communication among machines and they are on the field in the right place and in the right time. We assume this is compelling evidence to prove that through less downtime and by precise servicing performance can be boosted, which affects farmers' profit as well.

Machines and transporters in the system monitor the level of seed tanks in combines, and they keep track of which machine will unload soon. The driver of the transporter pulls up next to the combine and takes control over it. In this way, the seed tank is unloaded in one go and the harvesting equipment is not forced to take downtime (instead of harvesting).

Our next investigation seeks to identify calculated revenues if a farmer invests in one of the harvesting equipment of the previously mentioned „S series" combines.

We start with the hypothesis that the farmer wants to invest money in a harvesting machine. It is up to his decision, whether he purchases a machine suitable for the application of precision technologies or another one, which is not. Premised on this, the actual value of investment is going to be the difference between the purchase price of the machine equipped with precision technologies and the price of the other one. This difference reveals the actual price of the technology.

Farmers' requirements for harvesting machines:
– engine with a cylinder capacity of 430 hp, 9 litre
– a seed tank of 10.600 litre
– a thresher with a longitudinal drum and a seed separator
– cutting width of 7.5 m in crop
– 12 row Maize adapter

The purchase price of this machine is 234.600 EUR and it is to be supplemented with a crop cutting table of 28.700 EUR and a Maize adapter of 85.000 EUR. The sum total of investment is **348.300 EUR.**

As long as farmers would like to buy a machine equipped with precision technology, they will choose the JD S670i type. The technical parameters of this harvesting machine are equal with those of the previous machine, but contain the following optional items which are the indispensable elements of precision technologies:
– GreenStar 3 2630 display
– AutoTrack Complett + Harvest Monitor (SF3000 antenna)
– SF2 activation+RTK, humidity and yield detection
– GD Link Ultimate

The purchase price of this equipment is 253.600 EUR+ 28.700 EUR the price of crop cutting table 85.000 EUR is the price of the Maize adapter. The sum total of purchase prices is 367.300 **EUR.**

The difference between the purchase prices of the two harvesting machines is **19.000 EUR**, which is the actual cost of precision technologies. Therefore, precision technologies increase combine costs by merely 5.4%.

If a farm is exclusively focusing for production, where time saving is essential and the main benefit of precision technologies, Table 3. shows that yearly saving is 8.446 EUR. The prospective service life of the machine saves 42.330 EUR in nominal value. This means that the investment will pay off in the 3. year, resulting in net savings of 23.330 EUR. If we convert it to net present value, assuming an alternative interest rate of 10%, the net present value of the investment and annual savings is 13.016 EUR.

If the enterprise engages in lease services or offers its free capacities, and it is assumed that the enterprise works during the whole harvest period, then after harvesting on its own plots and executing its permanent lease activities, it can dedicate two surplus days to lease harvesting in the summer season and three ones in the autumn one. Based on our calculations (Table 3.) a farm may obtain a surplus revenue of 21.840 EUR (no surplus costs emerge, because if it failed to use GPS and unload the seed tank automatically on-the-go, time wise it would harvest equal quantity, using an equal amount of working hours and fuels) revenue of about 89.640 EUR. Clearly these revenues will pay off surplus investments already in the first year and commencing from this first year they will make positive profit. At nominal value, its sum total is 70.640 EUR; whereas at 10% alternative interest rate it is 63.790 EUR, bringing a profit of 335% in return to the invested capital.

Discussion

Our present study does not discuss the rate of reduction for harvesting activities, therefore the production cost of the whole process. Similarly, this paper does not include the calculation of what effects the other benefits of precision farming and GPS based vehicle navigation exert on costs, revenues or efficiency (several research activities have studied the impacts of steering automations and they have found them cost-effective in all cases).

This study is based on a farm-level exhibition what was held in Zichyújfalu on the 5 July 2012. The values are from the author's own data fetching and practical measures from yield mapping system of the examined exhibition. It is shown that by using the assistance of RTK real-time kinematic system, the harvest season is reduced by two days which results in considerable cost efficiencies. The farmer can save 3.316 EUR in one year in case of harvesting wheat. In case of corn the savings can be 5.130 EUR in one year with shorter season. Savings mean cost efficiency in fuel and labour hours too. In our study we used 5 year for long-time calculation because in most cases these equipments are replaced or sold after 5 years in service

The above presented and quantified data lend themselves for practical use. Our theories that satellite navigation provides significant assistance in harvesting have been verified by compelling evidence in terms of figures and values, also resulting in large-scale cost effectiveness or time saving.

Although the purchase of the technological background required for the application of technologies needs extra expenditure, the value of surplus investment is insignificant (5-10%) as compared to the already high price of agricultural machines. Our findings reveal that the investment value of precision technologies pays off in a very short time.

Our first hypothesis is proved by Table 2. and Table 3., because the savings be efficient -cost and time- machine synchroning can quantify. The second hypothesis is about the cost-efficiency by the application of technologies also can be truth, it is true that the technology is a significant cost for the farmers but in exchange for he can total (wheat and corn) save 8.446 EUR in shorter season or can save 21.840 EUR in longer harvest season

In closing, we would like to highlight that farmers today need to keep up with technological development. A great achievement in our days is the system of precision technologies. More accurate and precise technologies are greatly needed and wanted by farmers to operate their machines more efficiently and to exploit natural resources only to the required extent.

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