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EFFECTS OF PRECISION FARMING IN LARGE SCALE FARMING PRACTICE

A precíziós növénytermesztés hatásai a nagyüzemi gyakorlatban

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Abstract

The authors investigated the effects of precision farming investment was carried out in late 2008 in Agárdi Farm Ltd. situated in middle of Hungary. In the frame of the project a complete precision farming system have been established covering high precision positioning (RTK), autopilot applications, section and rate control of planters and sprayer, dose control of fertilizer spreaders. The primary goal of the study was to investigate whether the potential advantages of this technology can be realized in a large-scale farm practice. The SWOT analysis created revealed the potential of this investment with respect to the facilities of the selected farming company. Weaknesses and threats were revealed as well. Based on their experiences the authors stated that in given points the site-specific technology has an extra labour and input demand despite it promises even the contrary. It is in concordance with international experiences. According to the authors' opinion, it is partly caused by the level of mechanization which is more prepared for the traditional farming. Besides, some critical issues were discovered as well which significantly influence the return and economic efficiency of the investment. These results highlight the importance of economic analysis of precision farming applications based on databases of real practical application.

Keywords: economic affects, return period, practical experience, large scale farming practice

JEL Code: Q12; Q15

Összefoglalás

A szerzők a 2008 végén, az Agárdi Farm Kft-nél történt precíziós növénytermesztési beruházás hatásait vizsgálták. A project keretében egy komplett precíziós növénytermesztési rendszer került kiépítésre, mely nagy pontosságú helymeghatározást (RTK), robotpilótákat, vetőgépek és permetezőgép automatikus szakaszvezérlését és tő-, illetve dózisszabályzását; valamint műtrágyaszóró gépek dózisszabályozását foglalja magába. A tanulmány elsődleges célja annak vizsgálata volt, hogy e technológia potenciális előnyei menyiben realizálhatóak a nagyüzemi gyakorlatban. Az elvégzett SWOT analízis feltárta a beruházásban rejlő lehetőségeket, figyelembe véve a választott gazdaság adottságait. Gyengeségek és kockázati tényezők (veszélyek) szintén felmerültek. Tapasztalataik alapján a szerzők megállapítják, hogy bizonyos elemeiben a helyspecifikus technológia többletmunka és input ráfordítást eredményez, szemben annak alapvető ígéretével. Ez a megállapítás ugyanakkor összhangban van számos nemzetközi tapasztalattal. A szerzők véleménye szerint ennek oka részben a gépesítettség jelen állapota, mely sokkal inkább a hagyományos, homogén művelésnek felel meg. Számos kritikus tényező is feltárásra került, melyek jelentősen befolyásolják a beruházás megtérülését és hatékonyságát. Ezen eredmények rávilágítanak a precíziós növénytermesztési alkalmazások gyakorlatból származó adatokra alapozott ökonómia elemzésének fontosságára.

Kulcsszavak: ökonómiai kérdések, megtérülési idő, nagyüzemi növénytermesztési gyakorlat

Introduction

Precision or site-specific farming becomes more and more well-known not only within scientist circles but also by farmers. This process takes part in Hungary as well; nonetheless its extensive practical application is question of time, engineering and economic background as well.

According to *Blackmore* (1999) precision farming is "the management of arable variability to improve the economic benefit and reduce environmental impact." *Doluschitz* (2003) specifies these benefits as follows. Major benefits could be a more optimal production with decreased input utilization, increased product quality and yield stability which lead to cost reduction and environmental protection. *Jürschik* (1999) declares similar arguments. What is more, referring to *Győrffy* (2001) precision agriculture is the only solution for both ecological and economic problems of plant production. Beside advantages, *Doluschitz* (2003) mentions disadvantages as well such as costs of data acquisition, the over-supply of data, and the time-consuming handling of software. *Takácsné* (2010) emphasized the role precision plant protection as a key factor in potential saving in chemical use. (*Takácsné*, 2011a)

It is a question of high importance in case of any kind of investment to be aware of its direct and indirect favourable and unfavourable effects – its externalities. Emerging questions or negative externalities are to be investigated in order to eliminate or compensate them and thus be able to be able to exploit the true potential of the new investment.

Yu et al. (2003) investigated the economic aspects of applying precision farming with respect to nitrogen fertilizing in irrigated cotton production in the USA. The authors developed a dynamic optimization model to evaluate the optimal decision rules taking into account both cotton and nitrogen fertilizer prices, nitrogen residual or rather soil and location characteristics. The authors concluded that precision spatial application of nitrogen fertilizer resulted in an increase of crop yield, net revenue and productivity on a per area basis. It was also found that nitrogen has a significant effect on yield and acts more effectively utilized in site specific way than in case of whole-field farming practice. Partly conflicting results are presented by *Heijman and Lazányi* (2007) according to which variable rate nitrogen fertilizer replenishment is not profitable under the investigated circumstances. The authors point out the importance of field size and fertilizer price. *Kalmár* (2010) found farm size to be a limiting factor as well. It can be stated that not the property size is a limiting factor of economic viability, applying, the technology can be used in other machinery sharing forms like machinery rings, cooperation, paid machinery services, etc. (*Baranyai és Takács* 2008, *Takács* 2008, *Takács és Baranyai* 2010). *Nagy et al*. (2014) focused on the need of investigation as a key factor at farm level as well, and highlighted its importance in the practice. Regarding to such investigations there are critical issues should be mentioned. Regarding to field size, our experiences show that the entry level field size in Hungary concerning to precision farming decreased from 300 to 100 ha during the last 2-3 years. In this level however only single GPS light bars are applied without any VRA (Variable Rate

Application) functions. Thus results introduced by *Heijman and Lazányi* (2007) are not surprising as 400 ha was studied. Besides, the device system and rather its capabilities fundamentally influence the results of such economic studies. Precision farming systems are available in the market are capable of several functions at the same time. The simplest units for VRA fertilizing provides at list GPS guidance as well. High-end devices perform independent rate control of 4 input materials, autopilot control, section control of spray boom and planter machines or may even be used for yield monitoring. In this case the cost of investment splits among the applications mentioned above and all these functions provide additional potential savings. Of course, the more elements of the system applied the more advantages can be achieved. Thus, in case of any economic analysis the first and most important step should be to define exactly the cost of investment concerning to the investigated application.

Batte (2000) stated as well that site-specific management does have the potential to both improve the profitability of the farm and to lessen environmental damages of agriculture. According to the investigation carried out by the author farm total fixed costs are predicted to rise with site specific management due to durable investments in machinery, mapping and resource inventories, and human capital.

It is an interesting question which cost types are considered to have influence on site-specific farming economy. *Lambert and Lowenberg-DeBoer* (2000) published a comprehensive study in the frame of which this question – among others – was investigated by reviewing the concerning literature. According to the results, labour and information costs are mentioned in the most cases. Regarding to the benefits of given site-specific applications the authors publish a summary as bellow (Table 1.).

Table 1. Summary of reported benefits for PA technology combinations in the literature reviewed by *Lambert and Lowenberg-DeBoer* (2000).

Technology	Reported Benefit (%)			
	Yes	No	Mixed	Base
VRT-N	63	15	22	27
VRT-P, K	71	29	0	7
VRT-Weeds, Pests	86	14	0	7
VRT-pH	75	0	25	4
VRT-GPS Systems	100	0	0	3
VRT-Irrigation	50	0	50	2
VRT-Seeding	83	17	0	6
VRT-Yield Monitor Systems*	43	14	43	7
VRT-NPK, General	75	8	16	24
Soil Sensing	20	40	40	5
PA Technology Summary	77	0	23	14
PA/VRT Technologies combined	63	11	27	108

*These figures considered reports estimating the benefits of yield monitors in conjunction with VRT (variable rate technology), not yield monitors alone. Lambert and Lowenberg-DeBoer (2000).

Dobermann et al. (2004) summarise *Lambert and Lowenberg-DeBoer's* (2000) results as follows. The authors "reviewed 108 articles published in the scientific and popular literature reporting economic results of PF based on either simulated responses or actual field studies.

Most reports (73%) focused on VRT and 63% claimed higher profits. However, many studies omitted important costs such as soil testing, data analysis, or training."

It should be noted however that this structure may vary by time and location in accordance with the geographic and economic differences. In this concern, the level of technical background or in other words, the quality and modernity of agricultural machinery available should be mentioned as it defines the possibility of such investments fundamentally. The authors share this opinion and summarize their experiences very well reporting varied benefits of precision farming as follows. "Findings might be confused by crop type, application techniques, applied elements (N, P, and/or K), the quality of field reconnaissance maps and concomitant fertilizer recommendations, management strategies and field history, or uncontrollable variables such as weather or other climactic factors." *Lambert and DeBoer* (2000).

It can be stated that the potential advantages of precision farming are well known. *Dobermann et al.* (2004) warn however that despite examples of success have been reported in many studies, well-documented improvements in yields, profitability or environmental quality remain rare in the scientific literature.

It has to be mentioned as well that the most of the concerning papers are based on modelling and excluding field evaluation tests. Returning to the study carried out by *Lambert and Lowenberg-DeBoer* (2000) this ratio reaches the 60% of the total 108 articles were studied and only 3 of them were such field studies which were published in peer-reviewed scientific journals and deal with site-specific treatments over several years.

These facts are undoubtedly tough-provoking. Even despite the mentioned article is published in 2000. Based on the review of the Hungarian literature it can be stated that the situation is very similar: there is probable not any economic research based on real and complex farm data. (*Pecze* 2008, *Sinka* 2009, *Kalmár* 2010, *Pecze et al.* 2010, *Takácsné* 2011b; *Smuk – Milics,* 2012) It is however far not the researcher to be blamed. Also very rarely it is examined the farmers knowledge on the technology and the process of the diffusion. It was carried out in a Hungarian survey that one reason of the slow diffusion is the relatively low economic advantage in small and medium sized farms and also the negative attitude to new solution and the lack of management skills. (*Lencsés*, 2013; *Takács et al*., 2013). There is simply very few data available mainly because precision farming technology appeared in Hungary significantly later comparing to its formation in the USA, only some years ago. Besides, taking into consideration its spreading nature, single GPS light bars were mainly sold in the first years. First complete systems covering more functions (autopilot, variable rate control systems, etc.) have been established in late 2008. Consequently, first databases appropriate for economy studies are just being collected.

Beside direct economic benefits, technological advantages (improved work quality, decreased load on the driver, etc.) may also be achieved using precision farming.

Because of the above mentioned facts and the importance of these studies we strongly believe that analysis of the first real field data and review of the experiences already available is essential in order to react to the unfavourable tendencies if any in time.

Materials and methods

It was examined the effects of a precision farming investment. The company studied is the Agárdi Farm Ltd. running 5850 ha situated in Fejér County, approximately 15 km far from Székesfehérvár. Wheat (1400 ha) and maize (1500 ha) are produced in the largest area, sunflower and canola are the next ones in the queue (600-600 ha).Only those plant are produced which are supported by EU and national subsidy programmes. The predecessor of the company was involved in the agricultural environment management programme since 2004 covering the 78% of the total area. Field are rented from the government and the quality is 26 – 34 AK. As Lake Velencei is 10-20 km-far this area is sensitive concerning to nitrate pollution.

The precision farming investment has been realised in August 2008 in harmony with the demand of environment protection and environment friendly and efficient plant production. The precision farming and GIS system has been established is probable the most complex and largest scale one in Hungary which involves the most elements of available site-specific applications. Soil analysis and fertilizer advisory services are taken into resort. The 56 million HUF (approximately 200 000 EUR) investment was carried out in the frame of a programme for horticulture machinery and technological equipment investments ensuring 35% non-refundable subsidy. The system involves the followings:

- Trimble RTK base stations (for 2 cm positioning accuracy) – 2 pieces
- AgLeader Insight board computers – 9 pieces
- Trimble Ag GPS 252 RTK GPS receiver – 9 pieces
- Trimble Autopilot systems – 11 pieces
- Automatic section control and seed rate control for planters and seed control for seed drills – 2 pieces
- Automatic section and dose control for self-propelled sprayer – 1 piece
- Yield mapping systems – 6 pieces
- Variable rate fertilizer spreader control systems (disc-and pneumatic types) – 4 pieces

(2 pieces of Accord pneumatic spreader was purchased as well in a value of 13 200 000 HUF (appr. 4 900 EUR) with 25 % state subsidy.)

The authors have been monitoring the initiation of the new technology from the first installations. Analysis of the data collected – yield, as applied fertilizer and herbicide maps, and running costs of the company – since than were done. The positive and negative effects were revealed based on deep interview with the company leaders and own experiences.

Results

The SWOT analysis was carried out confirmed that the introduction of precision farming technology in the Agárdi Farm Ltd. has significant potential from both practical and economic sides. The firm facilities – favourable climatic circumstances, large and fertile fields, high level of mechanization - ensure the fundament for an investment aiming the improvement of efficiency.

According to the analysis it can be achieved by decreased input utilization; automatic data collection and effective data processing proved to be significant as well. The weaknesses of the company such as significant within field heterogeneity and the continuous increase of applied inputs were clear calling voices for introducing precision farming as a solution to avoid the potential treats. The most momentous ones are to be able to fulfil for the more and more strict environmental regulations while continuing intensive agriculture production or rather the frequent weather extremities especially drought. Results of SWOT analysis are summarised in Table 2.

The positive (favourable) and negative (unfavourable) externalities of the introduction of the precision farming technology in Agárdi Farm Ltd. are summarised in Table 3.

Table 2. Results of SWOT analysis

Strengths	Weakness
• Favourable climatic conditions • Fertile soils (24-36 AK) • Long-term land lease contracts • Large field size (200-600ha fields, may be cultivated effectively) • Available integrated plant production system • Modern machinery • High yields	• Significant within field heterogeneity • High production costs • Increasing input prices • Selling price is determined by market conditions (limited ability to influence) • High transport costs (road based public transport) • Companies providing inputs are not prepared to variable rate technology • Large company – time is a significant limiting factor
Opportunities	**Threats**
• Modern information system and efficient data • automatic data collection • well trained employees • possible demo farm status • increased market share based on controlled quality production (e.g. barley – Glencore – Korea) • better market position	• To fulfil for Agri-environmental program (it may means additional costs) • The sector is characterized by increasing price competition (export markets) • Increasing production costs • increase of land lease cost • Frequent droughts

The payback of precision farming investment is expected within an optimal period of time. In our former researches connected with return calculation we stated that the paying back period of a necessary precision farming investment is 3-4 years at a farm size of 300 ha at average production structure (*Takácsné* 2006, *Lencsés* 2009, *Sinka* 2009, *Lencsés és Béres* 2010). The investment profitability studies were carried out yet based on the Agárdi Farm Ltd. data showed that payback time may be shorter than 2,5 years which is acceptable.

Table 3. Positive and negative externalities

Positive	Negative
• decrease of overlapping, increase of area coverage • decrease of chemical load of agro-ecological environment and the threat of natural wildlife • 4% seed saving • the plant population density can be may be adapted to within-field conditions • 15% fertiliser saving • nitrate load of underground water may be decreased	• reservations from employees' side • education needed • fertilisers can be applied only in form of mono agents => this means separate rounds in case of each agent => increase of fuel consumption => more working time => multiple soil compaction

The practical experiences revealed some important issues which have significant effect on the production and thus on the efficiency and return of the studied investment. The effect of decreasing the load of the environment by introducing the technology is undoubted. Its application requires however significant efforts from each concerned ones. Increased adaptability and intellectual performance is expected from the employees. They had reservations in this concern as they had to learn the necessary computing knowledge. Therefore leaders should pay attention to make the employees see the point of the technology and its usability. Despite the time demand of planning the work processes increases (e.g. preparing prescription maps, machine adjustments) the more accurate and up-to-date administration (traffic log books, daily performance, already harvested area, etc.) makes the management diary keeping easier and helps data management on the other side. Furthermore, one of the most effective costs saving application is the automatic section control of planters and spreaders which eliminates causeless overlapping. It is based on the logging of areas where seeding or fertilizing has already done (coverage logging). However, at the present state the system capable of automatic section control on the own coverage of any implement, thus utilizing e.g. two spreaders together one spreader will overlap the area already covered by the other. There are potential solutions to avoid this phenomenon (e.g. new farming practice) but under practical circumstances, in case of large farms where application of several machines at the same field at the same time occurs it means that the advantages of automatic section control can be taken only partly. Furthermore, as ratio of the nutrient agents should be controlled independently (NPK ratio changes within the field) the given agents should be applied in mono fertilizer forms in separate runs. Thus it means additional time and fuel consumption and extra soil compaction as well. It should be mentioned that the established precision farming system is capable of simultaneous control of several agents but the disc spreaders available are not. This is however not a unique case, such spreaders are capable of multiple agent control are almost not present in the Hungarian practice. There is another issue with the seed rate control. Distributors of seed-corns are unable to provide useful information about the allowable rate changes. Its control system is one of the most expensive ones and capable of changing seed rate within a wide range but the suggested rate change was far less than ±5% in case of maize which may not have real effect on production as the plant itself can compensate a significantly wider range of population change in yield.

Consequently, there is a complicated and expensive application but because of the lack of agronomic information it cannot be effectively applied. Besides, the additional labour demand of data collecting, processing and application (e.g. fertilizing) planning were found to be momentous.

Discussion

It can be stated that this initiative analysis of the data collected in Agárdi Farm Ltd yet provided already important experiences. The precision farming system established in the Agárdi Farm Ltd. proved that most of its potential can be realized in practice. Well known advantages such as input savings and increased environment protection were observed. The research drew our attention to some practical experiences which should be taken into account during the further analysis. The issues of overlapping, seed rate and mono fertilizers are factors which cannot be taken into account in case of model-based examinations. They can be understood and their effects can be calculated only studying practical applications.

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