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ECONOMIC ASPECTS OF AN AGRICULTURAL INNOVATION – PRECISION CROP PRODUCTION

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Abstract: Innovation in agriculture ensures the wide-spread use of the latest, up-to-date technology. Such new technology is precision farming in crop production, which serves as a validation of the criteria of environmental and economic sustainability.

The economic applicability of precision crop production depends on several factors. Among them the following aspects must be emphasized: the size of the farm, the characteristics of the production structure, the current input-output prices and their tendencies, the investment needed for transitioning to precision technology and its capital source, the level of professional knowledge and the managerial attitudes of the farm.

I have examined the economic relations between potential savings in chemicals on EU level. It has been found that after switching to precision farming, the active ingredient use for fertilizers can be reduced by 340 thousand tons at the same expected yield level in an optimistic scenario in the EU-27, while the savings in pesticide use can be 30 thousand tons (calculating with the current dose-level). If approximately 30% of the crop producing and mixed farms over 16 ESU adopt this new technology, this will diminish environmental loads by up to 10-35%.

The majority of farms characterized by greater output and size can be based on their own equipment but it might as well be presumed that smaller farms can turn to precision farming not based on their own investment. They can buy the technical service from providers, they can establish producer cooperation, for example in the frame of machinery rings.

At a certain farm size and farming intensity precision crop production is a real, environmentally friendly farming strategy, with the help of which the farm can reach earnings that cover at least the economic conditions of simple reproduction.

Keywords: farming, technology push, low speed of diffusion

1. Introduction

It was over two decades ago when the technological foundations for precision farming became available in practice. Yet, it has not become as wide-spread as it was expected. Other technological innovations, such as nozzles suitable for spraying micro-drops of pesticides etc, rapidly became widely-used, regardless of the extra costs or sometimes even the investments they required.

Precision farming is a new farming strategy in crop production which enables farmers to implement variable rate applications, primarily in using chemicals. It provides farmers with a possibility to grow crops more economically, while the environmental load is also reduced. According to *Moore et al* (1993), site-specific crop management is an information- and technology-based farming system which is aimed at identifying, analysing and handling the soil, spatial and temporal variability for the purpose of reaching optimum yield and agricultural sustainability and to protect the environment. (*Moore et al.* 1993)

Precision farming makes it possible to treat the different parts of the field separately with targeted active ingredients, which results in a more rational and reduced application of chemicals. It is based on the facts that the data of soil examination enable farmers to plan variable rate fertiliser application, while the data about pest presence, the level of infection and its estimated development dynamics enable them to make decisions regarding crop protection and the dose of the active ingredient in the different lots. The computer-operated agricultural machinery can release fertilisers or pesticides in different amounts, while it can measure the yield of each lot during harvest, which assists the following planning period. It must be added, however, that the technology can be used to its full potential only if each participant of the system can and is willing to use it in an appropriate way.

According to *Wolf* and *Buttel* (1996), in the ensuing decades, precision farming will be a reforming tool for agricultural production, the key to increasing its efficiency as well as an abiotic factor that can reduce the extent of environmental pollution. They highlight the duality of the significance of this technology. It is not only the reforming tool of people's approach to agricultural production with its chemical reducing ability, but also one of the basic factors of efficient agriculture, retaining the present industry-like farming structure, investments and certain managerial structures and operational mechanisms. Furthermore, precision farming is a real means of reducing environmental damage, and it is a means of reducing risks on the level of farmers. During crop production, yield uncertainty can be reduced and the security of farmers' incomes can be increased if the technological elements are used and combined properly, but not the incomes at every case (*Auernhammer* 2001; *Gandonou et al.* 2004; *Takács-György* 2006; *Hejmann – Lazányi,* 2007; *Chavas*, 2008).

Neményi et al (2001) emphasise that site-specific farming research goes far beyond the development of agricultural activities. They reveal the general tendency aimed at combining artificial (technological) and natural (biological, ecological, etc.) information systems.

In what follows, I intend to look at the issue from the point of view of innovation. For that reason, it is important to clarify the notion of innovation. Innovation refers to the process of applying knowledge (*Oslo Manual* 2006) The process is not for itself, it is important to use its result in practice – applied research. An innovation can be regarded implemented when it has been launched (product innovation) or when it has been applied during a production process (process innovation). The process of the innovation basis model is linear. Applied science (applied research) produces new ideas and products by using basic scientific results (basic research) called as science push line, which is followed by the launch of the innovation, when market forces take the leading role (market pull). (*Arnold – Bell* 2001) In this respect, precision crop production as an agricultural innovation belongs to the 'science push' category. Other authors call this type a demand-creating model (technology push). (*Pakucs – Papanek* 2010).

Precision farming technology became part of crop production in the United States of America in the 1990's. In 1992, 3% of American farmers used yield mapping combined with GPS (*Lowenberg-DeBoer* 1999), while in 1998, only 5% of them used some kind of a precision technology device (*McBride – Daberkow* 2003). However, precision soil sampling techniques and variable rate fertiliser applicators spread rapidly. In 1996, 29%, in 1997 33%, while in 1999 43% of American farmers used GPS-based soil sampling methods. While in 1996, only 13% of the farmers combined precision fertiliser release with variable rate applicators, this ratio was estimated to be 37% in 1999 (*Akridge – Whipker* 1997). In EU-member states, the spreading process started later and its extent also remained below the level of proliferation in the United States. Presumably, one of the reasons is the difference in farm size. According to a survey carried out in 2002, slightly more than 1% of Danish farms (400) apply this technology, on an average of 200 hectares, and only 10 farms reported to apply more than one precision element. (*Pedersen et al.* 2010)

Adaptation refers to the diffusion and proliferation of the innovation. Despite its 20 years, precision technology can still be categorised as being in the early stage of launch. Although it has already left the stage of innovations, its development is still being carried out, i.e. there are still R&D activities connected to that technology. Lack of capital as one of the main elements hindering innovation and its diffusion cannot be disregarded (*Pakucs – Papanek* 2010). Otherwise innovation is a tool for being adaptive to the new challenges. *(Marselek et al. 2008; Buday-Sántha, 2009)* Another important factor in spreading innovations is the role of mass communication channels since potential appliers can primarily be informed about the presence and details of an innovation through these channels. After the initial phase, however, the role of interpersonal communication channels increases (e.g. discussions between experts) as individuals base their decisions mainly on the information coming through these channels (*Csizmadia* 2009). We must also bear in mind the IT skills, however basic they are, required from the appliers of this technology. It must be underlined the important role of extension services and communications, the communication of economic and other usefulness of novelty in the diffusion of precision technology. (*Griffin et al.,* 2004; *Kalmár* 2010; *Kutter et al.,* 2011) The causes of the slow spreading process also include lack of education and expertise (*Attanandana et al., 2007; Pecze* 2008; *Takács* 2008; *Magda et al.* 2008; *Kalmár* 2010; *Nábrádi* 2010). Moreover, the new technology requires high-level managerial skills, accuracy as well as relatively high extra investment costs and the lack of proof for the cost-efficiency of the technology (*Lencsés – Takácsné* 2010). Accuracy is needed during proper application of precision technology, but often this becomes one obstructive factor of using it in farms. (*Arnholt et al.,* 2001; *Sinka*, 2009)

The amount of chemicals saved by precision technology can be regarded as chemicals not required and not taken by crops and also not released into the environment, thus playing an important role in reducing environmental load. The positive impacts of the technology are unarguable both on the level of farms and on the level of the national economy as several earlier studies found cost-effectiveness in farms, however, their detailed discussion cannot be included in this paper. (*Goldwin et al.* 2003; *Swinton* 2005; *Dillon – Gandonou* 2007; *Chavas* 2008; *Takács-György* 2008; *Lencsés* 2009; *Lencsés – Takács-György* 2009) The reduction of environmental burden can be considered as other positive impact. (Chilinsky et al., 1998; Pretty et al., 2000; Szűcs et al., 2004; Jongeneel et al., 2008; Takács et al., 2008; Magda et al., 2009)

The objectives of this paper are as follows:

- examination of the macroeconomic relations of precision crop production as an agricultural innovation and the modelling of active ingredient savings in case of applying this technology;
- revealing the causes of its slow proliferation.

2. Material and methods

During my research, I had the following presumption: in EU-25 countries, the transition of a certain number of farms to precision crop production would result in saving a significant amount of active ingredients, particularly in the field of crop protection, which would reduce the environmental load as well. Using scenarios, I modelled the changes in the amount of the fertiliser and pesticide applied presuming crop producing and mixed farms adopt the new technology to different extents. The statistical data concerning farm structure were collected by EUROSTAT and the Central Statistical Office of Hungary, while those concerning chemical use were collected by the OECD (Table 1).

Table 1. Fertiliser and Pesticide-Herbicide Application, 2007

Country	Total arable land	Fertiliser	Pesticides
	thousand ha	kg/ha arable land	
OECD	350,960	22	0.70
EU-15	324,300	60	2.3
Hungary	9,300	58	1.7
Netherlands	4,200	134	4.1
Germany	35,700	105	1.7

Source: OECD in Figures 2008

The European Size Unit, which categorises farms according to their profitability (SGM output) and distinguishes 6 categories, served as a basis for identifying the farm size where the extra investment of adopting precision farming technologies pays off. Based on their size and farming standards, crop producing farms (cereals and other field crops, as well as fodder production) over 100 ESU were presumed to be able to adopt precision farming with the help of their own financial resources. I also presumed that farms of 16-40 and 40-100 ESU would be able to adopt precision crop production with the help of machinery rings (*Takács* 2000). In the EU, there are 240 thousand farms of 16-40 ESU, accounting for 4.2 million hectares of land. The number of farms of 40-100 ESU is 139 thousand, accounting for 5.9 million hectares, whereas the number of farms over 100 ESU is 77 thousand, and they account for 11.3 million hectares of land. The basis of the calculations at national level was also the above categorisation.

The ratio of farms deciding on adopting the new technology is 15, 25 and 40%, in case of pessimistic, indifferent and optimistic scenarios, respectively.

Savings for fertilisers are 5, 10 and 20%, while for pesticides they are 25, 35 and 50%.

3. Results and discussion

3.1. The diffusion of precision crop production – how it looks like and the reasons for its slow speed

Based on Rogers' (1960) typology of the diffusion of innovations, precision crop production as an agricultural innovation can be described as follows, including some of the reasons for its slow diffusion in practice:

1. In the launch phase, it had an advantage over the technological elements widely used in farming, which could have made rapid diffusion possible.
2. Precision technology is less compatible, as farmers greatly vary in knowledge, skills and attitude to innovations, as well as in farm size and financial background. Due to lack of counselling support, the process of proliferation of the new technology is slower. In this respect, the Hungarian practice has several positive features, such as the successors of the production systems set up several decades ago, and the counselling networks.
3. The application of precision crop production must be considered from two points of view. Although the adoption of the element of the technology is not complex, it requires far more attention, a wider information base and also more accurate work.
4. The key figures of letting farmers learn more and test the new technology are the participants of agriculture and providers. (There are several specialist, scientific shows and presentations organised annually in order to achieve wider diffusion.)
5. Some of the benefits of precision technology can be observed directly (material saving, improved cost-effectiveness, yield growth), similarly to extra costs and investments. However, its indirect impacts, such as the reduction of the environmental load and increased food safety, are less obvious. As long as the positive impacts of the new technology are not obvious and measurable for farmers, and the perceived risk of its introduction is high, the technology will diffuse slowly, even when the financial background is sufficient. (This phenomenon can be observed both in the United States of America and in Europe.)

The most important factor that can speed up the diffusion and wider application of the innovation is its profitability (*Samuelson – Nordhaus* 1985). Others emphasise the effects of demand (*van Rosenberg* 1976), the significant role of R&D (Freeman, 1974; Szűcs et al., 2010), or the role of the state (*Nelson* 1982; *Késmárky-Gally* 2008; *Pakucs – Papanek* 2010). According to some economic theories, demand-creating innovations can be expected to diffuse if using the limited resources with the new technology results in economic efficiency. The diffusion of precision crop production and its wide-spread application in practice is an economic decision from farmers side when they have to invest their capital. Thus, it is not sufficient to examine the changes in the variable costs incurred by production but it is also important to consider the changes in product prices as well as the rate of interest of credits so that farmers can make a reasonable decision (*Swinton – Lowenberg-deBoer* 2001). The dynamic spreading of the technology can be expected in countries where there is a scarcity of human labour, the amount of arable land is not limited, the selling prices are high, while the rate of credit interest is low.

Husti (2008) states that innovation is not generated by farmers in Hungarian agriculture, which results from the polarised and highly fragmented farm structure, the shortage of capital and the lack of entrepreneurial affinity. The majority of agricultural businesses are characterised by a survival or sometimes consolidation strategy, which does not contribute to investment in the future of production. From technical size to implement all the necessary machines and other facilities the farmers can buy the technical service from providers, they can establish producer cooperation, for example in the frame of machinery rings. *(Takács 2000; Baranyai – Takács 2007; Baranyai – Takács 2008)*

In my opinion, it is of great importance to provide information for farmers, particularly information on the economic benefits of the technology.

3.2 The environmental and economic benefits of precision crop production

Modelling the savings of active ingredients of fertilisers and those of costs in case of switching to precision technology showed the following results: on the level of EU-25 states, the widespread application of precision farming in crop production may save 959-10082 t of fertiliser active ingredient, amounting to €327.1-1308.3m, while the costs of pesticides saved may range between €1674.1-3348.1m (using 2006 price levels) (Tables 2 and 3).

Primarily, precision nutrient supply may be the method of using the yield potential of the field, thus it is not a constant amount, and can even mean higher fertiliser application in certain cases. Naturally, there is considerable fertiliser saving when planning the consolidated field-level yield. Precision farming has an even greater significance in reducing the amount of pesticide used.

One of the main advantages of precision crop production is that site-specific treatment of lands with pesticides or herbicides may save a considerable amount of chemicals when only a small proportion of the land is infected. The estimated amount of pesticides saved in this way on the level of EU-25 countries is 5.7-11.4 thousand tons in case 15% of farms apply precision farming, 9.5-13.1 thousand tons in case 25% of them introduce it, while in the most favourable case it is 15.2-30.4 thousand tons (Table 4).

Considering the role of agricultural production in ensuring food safety, this

Table 2. Estimated savings in fertiliser application of farms introducing precision farming (EU-25)

Category			Farms applying precision technology		
			15%	**25%**	**40%**
16-100 ESU	Land using precision technology (ha)		103,559	172,598	276,157
	Savings in fertiliser active ingredient (t)	5%	535	892	1,426
		10%	1,070	1,783	2,853
		20%	2,140	3,566	5,706
>= 100	Land using precision technology (ha)		132,353	220,588	352,941
	Savings in fertiliser active ingredient (t)	5%	424	1,136	1,094
		10%	821	2,272	2,188
		20%	1,641	4,543	4,376
Total	Total size of land using precision technology (ha)		235,912	393,186	629,098
	Total savings in fertiliser active ingredient (t)	5%	959	2,027	2,521
		10%	1,890	4,055	5,041
		20%	3,781	8,109	10,082

Source: Author's calculations

Table 3. Savings in fertiliser costs

(million euros)

Country	16-100 ESU farm group			>100 ESU farm group		
	5%	**10%**	**20%**	**5%**	**10%**	**20%**
Denmark	2.398	4.796	9.592	3.654	7.309	14.617
United Kingdom	9.982	19.964	39.928	25.585	51.169	102.338
France	48.870	97.739	195.478	50.547	101.094	202.189
Netherlands	1.349	2.698	5.397	2.052	4.105	8.210
Poland	12.927	25.855	51.709	9.185	18.369	36.738
Hungary	3.641	7.282	14.563	4.913	9.826	19.652
Germany	19.362	38.724	77.448	40.025	80.049	160.099
EU-25	156.259	312.519	625.037	170.815	341.629	683.258

Source: FADN data base, edited by author

Table 4. Estimated savings in pesticide application of farms introducing precision farming (EU-25)

Category			Farms applying precision technology		
			15%	**25%**	**40%**
16-100 ESU	Land using precision technology (ha)		5,086,330	8,477,217	13,563,547
	Savings in pesticide (t)	25%	2,925	3,574	7,799
		30%	4,095	3,950	10,919
		50%	5,849	4,900	15,598
>= 100	Land using precision technology (ha)		4,818,598	8,030,997	12,849,595
	Savings in pesticide (t)	25%	2,771	4,618	7,389
		30%	4,095	6,465	10,344
		50%	8,190	9,235	14,777
Total	Total land using precision technology (ha)		9,904,928	16,508,214	26,413,142
	Total savings in pesticide (t)	25%	5,695	8,192	15,188
		30%	8,190	10,415	21,263
		50%	11,391	14,135	30,375

Source: Author's calculations

Table 5. Savings in pesticide costs

(million euros)

Country	16-100 ESU farm group			>100 ESU farm group		
	25%	**35%**	**50%**	**25%**	**35%**	**50%**
Denmark	18.272	25.580	36.543	19.127	26.778	38.254
United Kingdom	127.923	179.092	255.845	139.921	195.889	279.841
France	252.736	353.830	505.471	239.276	334.987	478.552
Netherlands	10.262	14.367	20.524	26.884	37.637	53.767
Poland	45.923	64.292	91.846	31.010	43.414	62.020
Hungary	24.565	34.392	49.131	22.043	30.860	44.085
Germany	200.123	280.173	400.247	191.189	267.665	382.379
EU-25	854.073	1 195.702	1 708.146	820.023	1 148.032	1 640.046

Source: FADN data base, edited by author

amount cannot be ignored. It has great importance since the same effects of crop protection can be achieved with a significantly lower level of environmental load if precision crop production is applied (Table 5).

As macro-level modelling calculations support, precision crop production plays an determining role in reducing the environmental load, along with the other agricultural technological innovations. However, precision farming has a greater importance in the reduction of the amount of pesticides used. On the level of farms, site-specific crop production leads to the reduction of material costs, as the necessary pesticide amount is 8-10% lower (calculated in active ingredient) than in case of traditional treatment Savings in pesticide use affect not only costs but also competitiveness, and have great importance in environmental protection as well.

In the above situation, individual and societal benefits coincide, thus serving sustainability. In agriculture, the diffusion of every technological procedure that has a positive impact on conserving or re-producing natural resources and can be implemented in a profitable way on the level of farms (economic efficiency) supports sustainability. Furthermore, the proliferation of precision crop production promotes societal sustainability, together with the reduction of environmental pollution and the production of foods, industrial raw materials and energy plantations.

Apart from economic arguments, precision technology can be supported by other factors as well. First and foremost, we must refer to its role in the reduction of the environmental load. However, it is not an important motivating factor for farmers, unlike for those who consider the transition to organic farming. Nevertheless, precision farming must be given outstanding attention in sustainable agriculture in developed countries. It must, however, be examined how it can be a real alternative in an economic respect. As it requires extra investment, expertise and accuracy, and its risks depend on a lot of unknown factors, farmers will not apply precision farming exclusively for ’philosophical’ reasons.

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