STOWARZYSZENIE EKONOMISTÓW ROLNICTWA I AGROBIZNESU
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ROLE OF AGRICULTURAL INNOVATION IN REDUCING THE ENVIRONMENTAL BURDEN

ROLA INNOWACJI ROLNICZYCH W ZMNIEJSZANIU OBCIĄŻENIA ŚRODOWISKA

Key words: precision farming, low dispersion, cost efficiency
Słowa kluczowe: rolnictwo precyzyjne, niska dyspersja, oszczędności

Abstract. Precision farming means a new farming strategy in crop production which encourages the farmer to adapt the technology to the micro-plot, primarily in regards to chemical use. It may ensure more efficient production for the farmer with less burden on the environment. But the dispersion of this innovation is low due to the lack of information about the economic and environmental advantages of the technology. But it is proved by farm level data that precision farming can reduce the amount of artificial chemicals and at the same time the farmer can achieve surplus income.

Introduction

The large-scale crop production has required the implementation of highly-mechanized technologies, in which – as an important pillar of technical development – chemization, use of artificial fertilizers and synthetic herbicides contributed to the utilization of biological potential that was increased by crop breeding. The overuse and non-differentiated use of synthetic materials, however, resulted significant burden on the environment thus endangering the natural environment and the human health. The innovation processes in agriculture are going in different directions. The biotechnological research aims the breeding of crop varieties which have better nutrient utilization and greater resistance against pesticides. The new results, however, raise new problems (see GMO related debates). New pesticides and herbicides have been developed which can be sprayed in smaller doses and have differentiated impact spectrum. The development of machinery and equipment (that is well-adjustable, able to spray smaller quantities in differentiated way, geographically controlled, etc.) suitable for precision work is permanent, the use of GPS technology enables the locally specified, precision crop production. Precision farming enables targeted agent spraying by spot treatments and results rational chemical use and reduction of quantities of chemicals. Precision fertilizing has already proved its cost efficiency, while the cost reducing impact of precision crop protection has been less examined by the researchers. The quantity of agents sprayed, however, can be further decreased by the reduction of number and volume of treatments and by the proper selection of dose according to the soil qualities [Wolf, Buttel 1996, Tamás 2001, Tamás, Pechmann 2002, Takácsné 2006, Takács-György, Takács 2009]. It should be added that precision farming is a real instrument to cut down environmental damages, but it is also the tool of reducing the risks at the level of farming. The appropriate implementation and combination of technological elements of crop production can reduce the yield uncertainty and increase the safety of farmers' income [Auernhammer 2001, Gandonou et al. 2004, Takácsné-György 2006, Chavas 2008].

Innovation usually means increasing efficiency, exploring of new possibilities and „solution" of probably important social problems. Innovation and research-development is often considered equal. The basis of innovation chain lasts from the new idea until the introduction of the product to the wide public in the market, when farming can be performed profitably, or from other aspects, when the given product or service can be accessed by the wide range of society. Since the end of the innovation chain from the one side – company side – is profitability, from the other side is the wide accessibility, it is very important to describe the conditions and circumstances of this state. [Oslo Manual 2006] An innovation can be regarded complete if the market introduction has been made (product innovation) or it has been implemented in a production process (process innovation). The basic model of innovation process is linear, the applied sciences – applied research – produces new ideas and products („science push”) by utilizing the basic scientific achievements from basic research. Then the market forces take over the leading role („market pull”) in the introduction of innovation in the market [Arnold, Bell 2001]. Permanent innovation (in Porter’s approach [Porter 1990]) and strategic innovation exist together in the agricultural innovation processes. As regards agricultural innovation, it should be highlighted, that subsidies – either in connection with innovation, or investment – have key role in the diffusion phase [Késmárki-Gally 2008]. The importance of creating introduction-friendly environment is also stressed. Precision crop production, as agricultural innovation, can be described as a demand-creating model. The technological pressure is very strong on behalf of producing-supplying corporations. It should be noted, however, that the demand-following feature has already appeared in dissemination and this trend will probably grow by the increasing need for environmentally conscious farming. It is technical-technological innovation from the aspect of farmer, while environmental innovation from the aspect of economy. If we also list here the changes in the labour organization connected with its introduction, then the precision crop production also fits into the concept of structural innovation, because the group of tasks that should be considered during the work process will also change by the construction of maps and registers required for the technology.

It should be highlighted that the novelty of this technology can be found not only in the above but also in the additional impacts and positive externalities related to the reduction of environmental burden. It can be realized, however, only if the users of the technology are trained and skilled according to the technological development required by precision crop production, as (also) a computer-based production technology. Wide range diffusion can be expected if the producers approve that „independent farming” is not a must that should be reached at any price. Utilizing services based on extension service, or the development of machinery sharing arrangements – cooperation – presumes that there is an appropriate level of trust among the parties. Both forms – large corporations undertaking the practical dissemination of innovation through the appropriate knowledge base and technology, as well as the virtual farms based on the voluntary cooperation of farmers – have the advantage that the production and transaction costs can be reduced, the primary basis of which is the utilization of size-efficiency advantages. It is also important to implement precision technology with appropriate skills and expertise [Takács 2008, Pecze 2009, Sinka 2009]. Precision farming is a technology, which will not essentially show up as a yield effect nor unnecessary expenditure, but this targeted chemical application will reduce the environmental impact, thereby helping to promote the environmental sustainability. It should be noted, that these trends usually appear in mixed forms in the day-to-day management. Since the technology consists of high-tech equipment – extra investments – are required, therefore usage of this will be economically viable only at a higher level of production size. This of course does not mean that the economical viability level – providing a simple reproduction – must be achieved by individuals, but that an appropriate framework for cooperation (machinery sharing rings) or others’ service may be the economic condition of employment [Takacs 2000, Baranyai, Takács 2007, Takács, Baranyai 2010].

In case of EU-25, the volume of arable land where precision crop protection can potentially be implemented is 9.905 thousand hectares, if 15% of farms shift to it; 16.508 thousand hectares if one-fourth of farms chooses this technology and in more favourable case, it consists of 26.413 thousand hectares if 40% of the farms applies precision crop protection,. At the level of EU-25, in case of precision nutrient supply altogether 32 thousand tons less effective agent should be sprayed in order to reach the former yield if the savings are at 5% and 15% of the represented area shifts to precision technology. 127 thousand tons less fertilizer should be used, if the presumed savings are 20%. Assuming the shift of 25% of farms, the quantity that can be saved is 53 thousand tons, considering a 5% saving level. The yields are expected to grow in this case, the objective of precision nutrient supply is the spraying of optimal dose to the cells within the plot. If 25% of the farms shift to precision nutrient supply and optimizes the yield level, 211 thousand tons can be saved, and if 40% shifts 85-338 thousand tons can be saved. On the one hand, the proportion of that area where crop protection treatments can be eliminated is higher – depending on the infection level and heterogeneity of pesticide organs – on the other hand, the spot treatments result real material savings in crop protection agents. The estimated degree of pesticide effective agent savings is about 5.7 thousand tons if 5% of the farms shift and the degree of savings is 25%. In case of 30% savings, it is 8.9 thousand tons. And if the level of effective agent saving is 50%, 11.4 thousand tons less pesticide effective agent should be sprayed, if 15% of the farms shift to the new technology. In case of 25% shift, presuming 25% savings, the chemicals to be sprayed are less by 8.2 thousand tons, in case of 30% savings 10.4 thousand tons less and presuming 50% savings 14.1 thousand tons less chemicals should be used. If the proportion of shifting farms is 40%, with the least (25%) savings 15.2 thousand tons, with 30% savings 21.3 thousand, while in case of the most favourable 50% savings, 30.4 thousand tons of chemicals can be spared.

Material and methods

In the research we used the plot level data of a Hungarian large-scale farm in order to explore the changes of fertilizer and plant protection chemical use before and after the shift to plot-specific crop production. We made comparing analysis and model calculations for savings and yield correlations. The Agárdi Farm Ltd cultivates 5850 hectares on an area that is sensitive to nitrate pollution. Soil sampling and soil mapping are the basic conditions of introducing precision farming. The production structure of the farm is determined by the large stock of dairy cattle. The production structure is more diversified than the average (maize-silage maize, wheat, sunflower, rape, winter and spring barley, alfalfa, green peas, rye grass) as regards crop production, the primary objective of which is the supply of animal husbandry with high quality mass fodder.

The examinations were made at plot level and farm level, too, the starting presumption was that the shift to precision fertilizing can result at least 15% savings without yield reduction and the technology is implemented for all the crop cultures within the production structure of the farm. In case of precision crop protection, 30% of effective agent can be spared on average. In regards to crop protection, the precision spraying is not possible and not justified economically for all the fieldcrops (Tab. 1 and 2). These conditions were drafted on the basis of the references. On the basis of plot-level data of the farm we determined the degree of potential savings, considering the actual date of shifting to precision crop protection, too. We also modeled what savings could be reached for 10 years if the technology was introduced earlier.

Results

The results of calculations prove that the shift to precision crop protection actually results chemical savings even in the early period of changeover. The saving can be confirmed at plot level, too (Tab. 1 and 2).

As regards the savings on active ingredients of fertilizer, the saving is 20 kg per hectare and 105.6 t for the whole farm, on the basis of the total area of the farm – considering the volume. This amount should certainly be considered if we speak about the importance of innovation. The present study does not deal with the economic payback of the shift to the new technology because we have reported about this aspect in former papers. Considering the extra costs of change-over, the payback period – even with a pessimistic scenario – is two and a half, three years in case of large-scale farms, while a medium-scale agricultural plant with 250-300 hectares can calculate with an approximately 5-year payback period under Hungarian conditions [Takács-György 2008, Lencsés 2009].

Since the chemical spared with precision technology can be regarded as chemical that is not needed and not taken by the crop, the significance of the technology is outstanding in the reduction of environmental burdens, too. In the examined farm, spot treatments are not yet implemented in crop protection due to the relatively high investment costs of available automatic systems (e.g. Weed Seeker is a supplementary element which can be used on large plots and the adapter mounted on wide machines further increases the investment costs. E.g. the extra investment costs of an adapter installed on a tractor that is used in maize (sensor and jet costs 1800 EUR, that is 65000 EUR in case of a 36-line maize cultivation range. The smaller farms use cheaper spraying machines, such an investment is almost equal to the price of the spraying machine.), the extremely high book cost and the high labour time need of traditional methods based on manual weed mapping, which can hardly be introduced in the practice. The weed control with spot treatment which is outstanding in regards to cost efficiency could not be introduced in Hungarian practice yet. The examined farm has had some savings in insecticide effective agent use at farm level (Tab. 1). It was due on the one hand, to the phase-control of spraying machine in precision crop protection because there was not any unnecessary overlapping and double treatment of plot parts, and on the other hand, to the strip spraying technology applied on the farm.

The insecticide saving on the individual plots basically depends on the following: how many times and when should the different crop protection treatments be applied on the crop cultures grown on the given plot in the given year; and which pests will probably appear in such a differentiated way that spot treatments are worth implementing within the plot. As regards the crop

Table 1. Chemical use on the Plot No. 58 of Agárdi Farm Ltd., 202 ha (2000-2010)
Tabela 1. Zużycie środków chemicznych na polu nr 58 w gospodarstwie Agárdi Farm Ltd., 202 ha (2000-2010)

Year/ *Rok*	Crop sown/ *Uprawa*	Average fertilizer/ *Średnie nawożenie*	Possibility of reduction/ *Możliwości ograniczenia*	Reduced fertilizer/ *Ograniczone nawożenie*	Average insecticide*/ *Średnie zużycie insektycydów*	Possibility of reduction/ *Możliwości ogranicznia*	Reduced insecticide/ *Ograniczone insektycydy*
		kg/ha		kg/ha	kg/ha		kg/ha
2010	maize/*kukurydza*	133.6	I	133.7	2.00	I	1.40
2009	wheat/*pszenica*	132.5	I	112.6	2.05	N	2.05
2008	rape/*rzepak*	203.3	I	172.8	1.93	I	1.93
2007	wheat/*pszenica*	183.5	I	183.5	3.05	N	3.05
2006	maize/*kukurydza*	417.0	I	417.1	1.00	I	1.00
2005	maize/*kukurydza*	176.6	I	176.7	4.00	I	4.00
2004	wheat/*pszenica*	273.7	I	273.7	3.00	I	3.00
2003	oil radish/*rzodkiew*	111.7	I	111.7	2.66	N	2.66
2002	maize/*kukurydza*	184.1	I	184.1	5.00	I	5.00
2001	maize/*kukurydza*	135.5	I	135.5	3.20	I	3.20
2000	maize/*kukurydza*	144.1	I	144.1	14.00	I	14.0
Average/*Średnio*		190.5		185.9	3.81		3.75

* the active ingredient quantity of insecticide contains all the herbicides, pesticides and fungicides calculated per ingredient kilogram/*ilość aktywnych składników owadobójczych zawartych we wszystkich herbicydach, pestycydach i fungicydach w przeliczeniu na kilogram składnika*
Source: own study
Źródło: opracowanie własne

Table 2. Chemical use on Plot No. 55 of Agárdi Farm Ltd, 86 ha (2000-2010)
Tabela 2. Zużycie środków chemicznych na polu nr 55 w gospodarstwie Agárdi Farm Ltd, 86 ha (2000-2010)

Year/ *Rok*	Crop sown/ *Uprawa*	Average fertilizer/ *Średnie nawożenie*	Possibility of reduction/ *Możliwości ograniczenia*	Reduced fertilizer/ *Ograniczone nawożenie*	Average insecticide*/ *Średnie zużycie insektycydów*	Possibility of reduction/ *Możliwości ogranicznia*	Reduced insecticide/ *Ograniczone insektycydy*
		kg/ha		kg/ha	kg/ha		kg/ha
2010	sunflower/*słonecznik*	313.4	I	266.4	2.40	I	1.68
2009	maize/*kukurydza*	56.6	I	48.2	3.50	I	2.45
2008	wheat/*przenica*	163.7	I	139.1	4.70	N	4.70
2007	green peas/*groszek*	158.1	I	158.1	5.00	I	5.00
2006	maize/*kukurydza*	269.6	I	269.6	1.00	I	1.00
2005	maize/*kukurydza*	282.6	I	282.6	4.00	I	4.00
2004	wheat/*pszenica*	253.5	I	253.5	3.05	N	3.05
2003	maize/*kukurydza*	112.6	I	112.6	3.76	I	3.76
2002	wheat/*pszenica*	149.7	I	149.7	6.45	N	6.45
2001	maize/*kukurydza*	213.8	I	213.8	3.18	I	3.18
2000	wheat/*pszenica*	130.9	I	130.9	2.35	N	2.35
Average/*Średnio*		190.5		185.9	3.81		3.75

Explanation: see tab. 2/*Objaśnienia: jak w tab. 2*
Source: own study
Źródło: opracowanie własne

structure of the examined farm, such cultures are the maize, rape, sunflower and green peas. Considering also the ratios within the production structure, precision crop protection – on average and on a yearly basis – can be applied on 30-35% of the area. The probable degree of savings is 0.46 kg per hectare, that means about 2.5 t insecticide on farm level.

The savings that can be confirmed in chemical use mean real savings in production costs. On the opposite there are those – often not directly observable – surpluses that are connected with the introduction of precision crop production as a new technology. In order to implement all the elements of the technology properly, not only the technical-technological conditions should be developed in terms of farm economy. Up-to-date information about the earlier developed soil sampling system, the plant health conditions, water balance and other parameters of the soil is a precondition of introducing the technology. The machine operators should have appropriate computer skills and should be able and willing to perform work with centimeter precision. The commitment of both the employers and the employees is necessary for the proper implementation. The actors should cooperate in all the fields of agronomy in order to avoid mistakes.

The example of Agárdi Farm Ltd proves that the introduction of the new technology was carried out – quite a few years later than the potential availability – when the management became convinced that this technology would result higher income than the traditional one. It should be noted that the farm – due to the land qualities and location – has limited possibilities in fertilizer spraying because it is obliged to participate in the Agricultural Environmental Management Program. The efficiency of the farm could not be increased by increasing the nutrient supply and thus the yield.

Precision crop production has proved its cost-efficiency in the examined farm, and has had further additional impacts and positive externalities in the reduction of environmental burdens. The qualification level of the technology users should follow the technology development that is projected by precision crop production, as a production technology based (also) on computer. The practical training of the technology should be introduced at all levels of education. The appropriate management skills are very important to adapt the farms to the changing conditions. The most important task is to convince the farmers about the advantages of the technology. Only those farmers can be convinced, however, who know their jobs and are not afraid of the "technique". It draws the attention again to the importance of knowledge and expertise, as well as to the importance of management skills. It is absolutely necessary that the distributors and extension agents give good and customized advice in cooperation with the farmer. Since the actors of Hungarian agriculture are very polarized in regards to size, age, and qualification, the dissemination of information about precision farming means a long-term task. The practical experiences confirm that many of the farmers use fertilizers without any soil sample analysis and do not give a thought to the possible cost advantages of a differentiated nutrient supply, implemented according to the soil qualities. It is the responsibility of the service providers to give expertise to their services, to offer "joint thinking", not only to inform but also to convince the farmer about the economic and environmental advantages, thus helping the practical dissemination of the innovation.

Discussion

The primary reason for the slow expansion of precision farming is the lack of information about the technology on behalf of the farmers, as well as the high investment costs and extra precision needs which cannot be or would not be undertaken by all the farmers. In spite of this, in our opinion, the implementation of the technology is reasonable on the basis of farm-level experiences. Fertilizer use is a technological element which can be applied in all the cultures and its introduction is suggested especially in those areas where the farms participate in the Agro-Environmental Management Program, while precision crop protection means a higher level implementation. The wide range expansion of the technology can be assisted by appropriate training and information services, setting up of the infrastructural background – services, machinery sharing arrangements, etc. – as well as the compulsory prescription of the technology. In regards to Hungary, the change-over to precision farming at sector level – presuming permanent output – would result 964-3780 to savings in fertilizer use if 15% of farms shifts to the technology. 2025-8110 tons can be spared if 25% of them changes and 2520-10090 tons if 40% changes the technology. In Hungary the farm sizing on the basis of the area enables the change-over to precision technology on 45,1% of arable land in terms of farm economy. In case of farms with more than 300 hectares, the estimations concerning pesticide savings prove that 35-69 tons can be spared if 15% of farms changes (137,960 ha), 80-160 tons if 25 changes and 128-256 tons of pesticide can be spared at national economy level if 40% changes [Takács-György 2009].

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Streszczenie

Rolnictwo precyzyjne wyznacza nową strategię w produkcji roślinnej, która zachęca rolników do dostosowania technologii do małych pól, przede wszystkim w odniesieniu do środków chemicznych. Może to skutkować większą efektywnością produkcji, a jednocześnie mniejszą uciążliwością dla środowiska. Jednak dyfuzja innowacji jaką jest rolnictwo precyzyjne do rolnictwa jest niewielka, głównie ze względu na brak informacji o jego korzyściach ekonomicznych i środowiskowych. Artykuł ma na celu ocenę innowacji jaką jest rolnictwo precyzyjne ze środowiskowego i ekonomicznego punktu widzenia.

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