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Sustainable new agricultural technology – economic aspects of precision crop protection

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Abstract

The sustainable development can be interpreted in many aspects. The Earth's growing population, the efficient use of land, as a limit resource is both requiring the practical application of production technology, like precision farming. Innovation in agriculture ensures the wide-spread use of the latest, up-to-date technology, but it is still evolving and boarding. It is a fact that not every farm can implement precision crop production into practice, it depends on their size, production structure, technical level/equipment and finally on the labour skills. In this study we have examined why is so slow its diffusion besides the provenenvironmental benefits and real economic benefits is. Crop production has evolving role in Hungary and in Romania. With model calculation we have estimated the economic relations between potential savings in pests on EU level. It has been found that after switching to precision weed management, the savings in pesticide use can be 30 thousand tons (calculating with the current dose-level in the EU-27) in an optimistic scenario. 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%.

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1. Introduction

The term "sustainabledevelopment" includes thecurrentandlong-run sustainableproductionand the controversies of environmental protection that assurance the right quality of life, and hard-preventable, but rathertoleratedconflicts. In the realization seriousregional, national, social(and of course,political) interests, momentary, shortandlong-runvisions clash, they oftenconfront. Theinterpretation ofsustainability is extended by Chilinskyandhis colleaguesin 1998 that the production must be sustainable in an economicsense. AccordingtoJørgensen(2000)sustainabilitymust include the farming that allow for easyreproduction theassetsneeded for productionnotonlybusiness managementlevel,butalsoonanationallevelmanagement irrespectively ofthesourceof capital necessary for farming. It is also important to maintenance of rural areas.

According to the sustainability of energy-based approach, the sustainable existence is, when the energy produced are not created with an extend energy compared to the previous level. (Neményi, 2008) A system-oriented approach is needed. In this study the main focus is: can we implement such new technologies as the result(s) of new agricultural innovation that meets the dual requirements, fitting to the food production need, reducing environmental pollution and being sustainable from economic side at the same time. From this view we have to go back to economic development. . In the developed countries, the role, the economic and social judgment of agriculture has changed. The intentions are getting stronger, particularly in agriculture, to reduce the intake of artificial inputs, the chemicals within it. The basic role of sustainable agriculture, to find and apply the technologies and processes beside ecological and social conditions, by which to maintain of environment and the economical production can be realized at the same time.

The degrowth, as a new paradigm in economic science, do not look back on a long past, although the spirit within the history of humanity was a recurring thought. It should be mentioned within the antecedents the report of Club of Rome in 1971 titled "Limits to Growth" (Meadows) report, in which the environmental crisis and the need for answers has already appeared. The Earth's growing population generates increasing demand for natural and artificial resources, especially food, energy, drinking water in which resource production the agriculture and environment management have a significant role.(Mészáros, 2011; Ocampo, 2010; Ryden, 2008

Latouche (2011) summarized the conditions which must be characterize the non-growth autonomous society, what shortened have known as 8-R. ´(Latouche, 2011) From the eight “R” here we highlight first the thought to return to the local, the thought of redistribution (the aim is the re-allocation of natural resources, the widening of access possibility at a global, social, intergenerational level) and the thought of reconstruction the concept of economy, scarcity, and artificially induced property. "The economy forms the natural abundance to scarcity with the creation of artificial lack and demand, while appropriate nature and convert it into commodity." (Latouche, 2011:pp. 50-52)Before him, Konrad Lorenz has summarized the eight sins of the civilized mankind in the early 1970s, calling attention that humanity imagines itself omnipotent use up its living space. (Lorenz, 2001)

We agree that this goal is reasonable and necessary at a certain level, since the support of the Earth's and each country’s growing population and the maintenance of food security would be inconceivable without modern varieties and factors of production - including labor - efficient, productive enhancing technological solutions. Precision farming is a technology, which application contributing to the production of food and industrial raw materials are required. Over the next decade, the players who are not apply, lose their competitiveness and may be driven out of business. The documentation of precision technology creates the follow-up, food safety, which is also expected of the agricultural and food products for customers delivering.

The chemicals used in agricultural production, indispensable to the production level, that is needed for the world's population food supply, needed to produce raw material on the one hand, and mean the risk of human existence on the other hand. Appraising the crop production as a system in the curse of finding the degree of intensity and form of business that eligible for the environment, must take into account the losses of the negative environmental and human consequences that harmful, pathogenic organisms may cause.

It should be noted that the basis of various calculations the yield loss ascribed to the plant pest organisms (biotic stress) can be the 40% of the potential yield. The yield loss is 10-12% brought about by the weeds, 18-20% by pathogenic organisms, while the pests are responsible for 8-10%. This can also comprehensible that producing the yield required, 1.67 times higher area should grow crops, which is not possible due to land limitation. The ecosystem and economic growth, the sustainability and consumption, the antagonistic contradictions between the developed and developing economies(social) require the development of agriculture and strategic management issues. The legitimacy of criticism is indisputable by the advocates of the organic revolution for today's global economy(Korten, 2002), however, by their estimation, the size of sustainable global system in the current system, about a third of the population could exist. A rational response cannot be given to this antagonism. To the expectations the world's food production are facing a new boom. Satisfying the dual requirement(the pursuit of ecosystem sustainability and the social demand), at the same time, through the technological development, the agro producers have to strive after. The common element of possible responses is the reduction of negative externalities, while focusing the well-groomed, preservative of natura lresource productivity, through on remedial solutions the aim is the preservation and value increase of public goods.

Here is the point where the connection between sustainability and agricultural innovation meets. According to the complex meaning of agriculture's technical development, the technical development of agriculture is based on four main pillars: the biological, chemical, technical and human factors. Technical factors include the mechanization and architecture. This definition based on the European agricultural economists' wording drafted in Helsinki in 1995. The technical-technological development cannot be an end in itself; it must meet the criteria of economy as well. In this sense, the analysis of precision farming's context is a basis of an examination to the role and possibilities of a new technology within sustainable agriculture (Weiss, 1996; Lambert - Löwenberg-DeBoer, 2002; Godwin et al., 2003; Takács-György, 2008; RădulescuZoie et al., 2009; Rădulescu M. et al. 2011, Jensen et al., 2012; Lencsés, 2012; Takács-György et al., 2013, TurekRahoveanu A., 2013).

The results of agricultural technological development, mechanization, pesticide production, variety breeding,etc. meet the society's claim to reduce pesticide use (both in terms of applied quantity and frequency). The use of weed, disease and insect-resistance varieties, as one of the indirect tools is applied in practice, the right combination of additional agro-technical tools may be a basis for resolving the contradiction mentioned above. The potential development directions of crop production include those forms of farming which separately developed in time and space that is jointly referred as organic - ecological - farming. (Padel, 2001,Schou et al., 2002; Maciejczak – Zakharov, 2011) These directions assume that the sale of products that were produced in this way is sold in the market at a price that will cover the higher costs of the different technology (Takács, 2006). Applying the technologies that based on the reduced chemical use it can be summarized the main economical features and every alternative has its role in the diversified agriculture (Table 1.)

All these alternatives have got role in meeting the requirements of the green component of direct subsidy system of the Common Agricultural Policy for the period of 2014-2020. According to the proposals, the farmers carrying out ecological production will automatically be entitled to complementary subsidies. (Chambon – Fernandes, 2010; EC, 2011) Precision crop production is one of the outputs of agricultural innovation and can be introduced into the developing new CAP system. (Groupe de Bruges, 2012)

Table 1. Economical comparison of alternative strategies of chemical reduction

Nomination	Reduced crop protection chemical use	Chemical-free production	Precision farming
Obtainable yield	almost same as conventional	-15-35%	almost same as conventional
Production costs	almost same as conventional	80-110% of conventional	higher due to extra investment
(Extra) Investment Need	none	none	significant
Sales price	same as conventional	possible to realize premium (0-30%)	same as conventional
Subsidy	same as conventional	special target support in addition to conventional	special target support in addition to conventional
Profitability	almost same as conventional	higher than conventional in case of premium price and subsidies	depending on the size; <u>in smaller farms</u> it is less than conventional due to the big investment need; <u>in middle-size farms</u> it is the same as conventional; <u>in bigger farms</u> it is higher than in case of conventional farming
Weed control	Based on herbicides	Physical, biological and agrotechnical means	Based on herbicides according to local/area (plot) features
Crop protection	Based on pesticides	Physical, biological and agrotechnical means	Based on pesticides according to local/area (plot) features
Nutrient supply	Based on fertilizers	Use of manure and organic materials	Based on fertilizers according to local/are (plot) features
Soil cultivation	Based on rotation and ploughing	Minimum soil cultivation	Based on rotation and ploughing

Source: Takács-György – Kis, 2007.

The first aim of this paper is to summarize and define the characteristics of precision farming as an agricultural innovation, to find those factors that make influences on its low expansion among farming communities. The second objective of the researches the economic evaluation of impact of plant protection on the reduction of environmental load in a wider interpretation of sustainability in order to highlight its role in reducing the environmental burden

2. Material and methods

The economic characteristics of precision farming were summarized and based on Roger's innovation diffusion model it was described.

After it he starting point of the primary research was that conversion to precision crop production in a specified area of the farm results in considerable savings at EU-25 level. These savings can be related primarily to crop protection, which also means a reduction in the environmental load. The calculations are based on Farm Structural Survey (FSS) data provided by Eurostat (2009).

The assumption was that arable farms and mixed farms would switch to precision farming only if they were above a certain size, because of the additional equipment required for the technology adaptation. On the basis of the economic size of farms, farms above100 ESU are able to switch by making their own investments based on their farm size and production level, while farms within the 16-40and40-100ESUsize classes can convert to precision crop protection using shared machinery. In the EU,240,000 farms belong to the 16-40ESU class,covering4.2million hectares,139,000 farms belong to the 40-100ESU class,cultivating5.9 million hectares, and the number of farms over 100ESU is 77,000, which together cover11.3 million hectares. (Takácsné, 2011; Takács-György, 2012)

The degree of savings in relation to the number of converted farms and the intensity of production (chemical use) was examined by scenario analysis.

3. Results

3.1. Precision farming – as agricultural innovation. What are the economic characteristics?

Based on Rogers' (1960), precision crop production as an agricultural innovation can be described as follows, including some of the reasons for its slow diffusion in practice. In the launch phase, it had an advantage over the technological elements widely used in farming, which could have made rapid diffusion possible.

- Precision technology is less compatible, as farmers greatly vary in knowledge, skills and attitude to innovations, as well as in farm size and financial funds. Due to lack of counseling support, the process of proliferation of the new technology is slower.
- 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.
- There are several specialists, scientific conferences and presentations organized annually in order to achieve wider diffusion.
- Some of the benefits of precision technology can be observed directly (material saving, improved cost-effectiveness, yield growth). However, its indirect impacts, (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, the technology will diffuse slowly, even when the financial founds are 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, 1985). Others emphasize the effects of demand (van Rosenberg, 1976), the significant role of R&D (Freeman, 1972; Mohamed et al., 2010), or the role of the state. (Késmárky-Gally, 2008;Nelson, 1982; Pearce – Atkinson, 1995).

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, 1998).

Precision farming technology became part of crop production in the United States of America in the 1990's. While in 1996, only 13% of the farmers combined precision fertilizer release with variable rate applicators (Akridge–Whipker, 1998), this ratio was estimated to be 37% in 1999. 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 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).

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; Marin E. et al., 2009; Marin E. et al., 2010)

It is of great importance, in our opinion, to provide information for farmers on the economic benefits of the technology.

3.2. Precision farming – as agricultural innovation. What are the economic characteristics?

Implementing precision technology into practice means economic decision from the farmers. Here we are focusing on the potential chemical savings which cause cost reduction in material costs, but from other hand there can be mentioned other elements of technology where can be mentioned costs increases.

Other economic consequence of precision farming is the technical development and its diffusion into practice.

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 favorable case it is 15.2-30.4 thousand tons (Table 2).

The fertilizer savings were estimated by 5-10-20 %, because the main aim of site-specific fertilizer use is to optimize the yield depending on the soil parameters by treatment units. This savings must be considered as provisory savings. If the aim of site-specific nutrition is the optimization at heterogeneous yield, real fertilizer savings cannot be achieved. The estimated amount of pesticides saved in this way on the level of EU-25 countries is 31.7-84.5 thousand tons in case 15% of farms apply precision farming, 63.4-169.1 thousand tons in case 25% of them introduce it, while in the most favorable case it is 126.8-338.1 thousand tons (Table 3).

Considering the role of agricultural production in ensuring food safety, this 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 3).

Table 2. 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, based on Takács-György, 2012

Table3. Estimated savings in fertilizer 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 fertilizer (t)	5%	16,276	27,127	43,403
		10%	32,553	54,254	86,807
		20%	65,105	108,508	173,613
>= 100	Land using precision technology (ha)		4,818,598	8,030,997	12,849,595
	Savings in fertilizer (t)	5%	15,420	25,699	41,119
		10%	30,839	51,398	82,237
		20%	61,678	102,797	164,475
Total	Total land using precision technology (ha)		9,904,928	16,508,214	26,413,142
	Total savings in pesticide (t)	5%	31,696	52,826	84,522
		10%	63,392	105,653	169,044
		20%	126,783	211,305	338,088

Source: Author's calculations, based on Takács-György, 2012)

As macro-level modeling calculations support, precision crop production plays 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.

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