ŽEMĖS ŪKIO MOKSLAI. 2009. T. 16. Nr. 3–4. P. 217–223

Importance of precision farming in improving the environment

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In developed countries, it is getting more and more important to maintain the good conditions of the environment. Precision farming meets both ecological and social requirements: to keep the environment biodiversity for the future and to improve the economy. Turning to precision farming needs technical investments. The questions are on what portion of cultivated arable land can this technology be introduced and what the alternatives for decreasing the viable portion of machinery.

In this paper, the potential input and cost savings of precision weed management on the sectoral level in the EU countries are examined and forecasted.

Key words: sustainability, reduction of environmental burden, savings in chemical use

INTRODUCTION

From the middle of the 20th century, agriculture has been greatly accelerating, the natural and human (labour) resources being replaced with the industrial tools and industrial inputs. Intensive industrial assets-, and input-intensive technologies and management systems were developed (Takacs, 2008). At the same time, some trends appear to have reduced the environmental impact by reducing the amount of artificial chemicals released into the environment, so as to ensure its sustainability. The definition of sustainability of agriculture and the environment, according to Pearce and Atkinson (1995), is that natural resources and man-made capital are complementary to each other in the production process, so that natural resources create the limiting factors to the increase of production, and they should be used rationally. By the turn of the millennium, sustainability has got a broader interpretation. The new paradigm of agricultural research and development was considered as an interaction on three factors: ecological sustainability, economic efficiency combined with equal opportunities, as well as mutual help from government and non-governmental sectors to improve the enterprise system's performance and profitability. This has become the basic paradigm of the 1990s and of the following decades in sustainable agro-economics (Caffey et al., 2001; Bongiovanni et al., 2004; Lang, 2003; Csete, Lang, 2005; Várallyay, 2007).

At the different levels of economic development, different farms can employ different management approaches / strategies:

• overall reduction of pesticide use. Here, one way is to use the chemicals that are persistent, have a curative effect, and thus during the plant lifespan less treatment is needed. In this case, the technical development of agriculture is very important (Lehoczky, 2006);

• the chemical-less (prohibiting the use of any synthetic chemicals) types (a great variety of organic farming dealing with this). They are used from the environment-safety point of view. This development is a possible alternative to reduce the environmental chemical load, but at the same it time requires compensation for the loss of income. If the price premium is declining because of the market saturation with new producers, the extra incentives are not capable to compensate this; therefore, the viable level of these farms can be up to 30% higher compared to conventional farms (Takacs, 2006);

• the rationale of an integrated crop management system (the Integrated Pesticide Management);

• precision farming allows target-oriented treatments, spot treatment applications. Fertilization – depending on the target of production – generally can lead to a low level of savings. In the case when the goal of the spot treatment is to equal the nutrient imbalances and level them out in the area in order to achieve an equal yield, it can result in 10–15% of savings (Schnitkey et al., 1996; Watson et al., 2003; Pecze, 2006). If the aim is only to increase the yield potential for the different spots with the targeted fertility treatments, no cost saving is achievable. Precision plant protection treatments can result in 35–70% savings on plant protection materials with no significant change in the income-producing capacity. The material cost savings must be set against the extra cost of the precision technology (Takács-György, 2008; Takács-György et al., 2008).

Precision farming is a technology which will essentially not show up as a yield effect or unnecessary expenditure, but this targeted chemical application will reduce the environmental impact, thereby helping to promote 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 its usage will be economically viable only at a higher size of production. This, of course, does not mean that the economic viability level – providing a simple reproduction – must be achieved by individuals, but that an appropriate framework for cooperation (machinery sharing rings) or other services may be the economic conditions of employment (Takacs, 2000; Baranyai-Takács, 2007).

According to Jørgensen (2000), sustainability must include not only the sectoral but also the national level. Bongiovanni and Lowenberg-Deboer (2004) place precision farming on the level of sustainable agriculture. They point out that if they interpret the farm as an integral unit, then the goals of long-term sustainability are not only biological, technological and environmental, but they also need to act as an economic entity during the operation to ensure income for the participants.

The paper aims to examine how can conversion to precision farming can decrease the use of synthetic chemicals at the national level.

METHODS AND CONDITIONS

During the research, it will be defined, with different scenarios drawn up, which proportion of the EU Member States' plant producers and joint management profile farms can take up the task of the technological transition, and how big a reduction of fertilizer and pesticide use can be achieved. The statistical data regarding the ownership structure were from the Eurostat, and the Central Statistical Office database data regarding the chemical from the OECD database were used (Table 1).

In Hungary, the use of fertilizers per hectare in the 1980s was 220–260 kg of active substance. It has been significantly reduced (to 30–40 kg/ha) by changing the socio-economic

Table 1. **The use of fertilizers and pesticides in an international comparison (2007)**

	Total area thousand sq. km	Major protected areas[2] % of total area	Nitrogenous fertilizers tons per sq. km of agricultural land	Pesticides tons per sq. km of agricultural land
Australia	7 741	13.0b	0.2	0.01
Austria	84	28.0	3.2	0.10
Belgium	31	3.3	10.6d	0.69
Canada	9 985	6.7	2.5	0.06
Czech Republic	79	15.8	6.8	0.10
Denmark	43a	2.0a	7.4	0.11
Finland	338	8.2	7.0	0.07
France	552	11.8	7.5	0.28
Germany	357	55.7	10.5	0.17
Greece	132	2.8	2.7	0.12
Hungary	93	8.9	5.8	0.17
Iceland	103	5.6	0.6	0.00
Ireland	70	0.5	8.1	0.05
Italy	301	12.5	4.2	0.52
Japan	378	8.0	9.2	1.28
Korea	99	3.8	18.8	1.23
Luxembourg	3	17.0	..d	0.33
Mexico	1 964	8.6	1.1	0.04
the Netherlands	42	15.6	13.4	0.41
New Zealand	268	19.5	1.8	0.02
Norway	324	4.6c	10.0	0.08
Poland	313	28.1	6.3	0.07
Portugal	92	4.9	2.3	0.42
Slovak Republic	49	25.2	4.6	0.21
Spain	505	7.7	3.3	0.14

Table 1 (continued)

	Total area thousand sq. km	Major protected areas[2] % of total area	Nitrogenous fertilizers tons per sq. km of agricultural land	Pesticides tons per sq. km of agricultural land
Sweden	450	9.2	5.1	0.05
Switzerland	41	28.7	3.6	0.10
Turkey	784	3.9	3.3	0.06
United Kingdom	244	18.3	5.9	0.19e
United States	9 632	19.5	2.6	0.08
G7	21 448	13.1	3.3	0.12
OECD Europe	3 243	14.3	6.0	0.23
EU–15	35 096	12.4	2.2	0.07
OECD Total	7 741	13.0	0.2	0.01

.. – not available;
1 – figures for the latest available year; they include provisional figures and the Secretariat estimates; varying definitions can limit the comparability across countries;
2 – IUCN management categories I–VI and protected areas without IUCN category assignment;
a – greenland excluded;
b – Great Barrier Reef Marine Park included;
c – Svalbard, Jan Mayen and Bouvet islands excluded;
d – Belgium and Luxembourg;
e – Great Britain;
f – England and Wales;
g – partial totals.
Source: OECD in Figures 2008 – OECD © 2008 – ISBN 9789264055636.

system in 1990–1995. In 2002 this value was 62 kg/ha and in 2007 81 kg/ha. The international outlook compiled for 2007 enabled to make the model counts for this year (Table 2). In Hungary the use of plant protection products per hectare / arable land (based on the available 2002 data) was 1.4 kg/ha; of them, 44% were herbicides, 28% fungicides, 16% insecticides, and 12% other substances (Environmental Statistical Yearbook, 2003).

I used the following assumptions during my modeling:

• for the examination of necessary additional investments into precision farming and its return, I used a farm category system based on the European size unit (ESU) income earning capability of the farm, listed as SHF output, and distinguished six different categories. I assumed, in case of over 100 ESU farm size, that they are plant crop farms (cereals, other crops and animal feed crops), and based on their size and quality they are able to switch to precision farming, based on their investments. In case of farm size of 16–40 and 40–100 ESU, I presumed that a common form of cooperation is required amongst the farms to be able to transfer to precision crop management. I also examined this issue for the Hungarian conditions by taking into account that the areas larger than 300 hectares (plant producers and mixed enterprise farms) could count on their own financing for their transition. The size selection is based on previous calculations; in Hungary, the additional investment return coverage is at the size 250 ha (Takácsné, 2004; Takács-György, 2007).

• The ratio amongst the farms that have chosen transition is 15–25–40% at the pessimistic, ignorant and optimistic scenarios of the event.

• The savings in case of fertilizers are 5–10–20% and in case of plant protection materials 25–35–50%. In order to calculate the applied quantity of fertilizers and pesticides,

Table 2. **The use fertilizers and pesticides in 2007**

Country	Total area	Amount of protected area from the total area	Fertility	Pesticide
	ezer ha	%	Arable land kg/ha	
OECD	35 0960	18.3	22	0.7
EU–15	32 4300	15.1	60	2.3
Hungary	9 300	18.9	58	1.7
the Netherlands	4 200	18.9	134	4.1
Germany	35 700	31.5	105	1.7

Source: OECD Figures – 2008.

I used the data for 2007 of OECD foundation, and presumed that the EU-15 value is the base; in case of Hungary, I used the 2006 actual data.

• In relation to Hungary, I determined (based on the arable land use) the amount of field coverage by the companies that are capable to finance and switch to precision plant technologies from their own investments. Based on previous calculations, this circle includes farms that are farming on at least 300 hectares. Thus, 2030 thousands of hectares, i. e. 45.1% of the arable land, belong to the potentially changed area. I also accomplished three scenario calculations for these data.

RESULTS AND DISCUSSION

The test farm database of the European Union (FADN) in 2006 represented 1897900 farms, and these used up to 82787 thousand ha of agricultural land. From this area, 51.4% was used for cereals, 16.7% were occupied with other crops, and on 20.5% fodder plants were grown. After examining the economic size categories, the observation was that the share of cereals did not change significantly, – they remained within 48–53%, although along with the increasing growth rate of the economy, the size of the farms and the ratio of filed crops increased at the expense of fodder crops. This suggests that in case of larger farms a proportionally larger area can be used for high-precision plant growing due to changes in the production structure (Table 3).

Savings on fertilizer use

According to the initial assumptions, I determined the potential savings on fertilizer use for the area represented by the EU-25 where the high-precision technology had been established. Although 5–10–20% of savings on fertilizers counted in the models should be conditionally used, if the purpose of the precision fertilization implementation is to compensate the yield in case of heterogenic nutrient levels, in this case the 20% saving per unit is not achievable. In this case, if we waive this fact and if 15% of the farms will switch to precision farming, we can expect savings between 32 and 127 thousand tons of active fertilizers with the help of precision fertilization treatment, keeping the yield at the previous level. If we assume a 25% switch to precision farming, the volume of savings can vary between 53 and 211 thousand tons; in case of a 40% switch, savings can vary between 85 and 338 thousand ton of active fertilizers per year (Table 4). From the economic point of view, such kind of decline in the use of fertilizers at the unchanged yield level can result in significant cost savings. At the production level, amongst the costs, the cost of nutrient materials is 8 to 15% in

Table 3. **The number of farms and the distribution of arable land use in the European Union, 2006**

	Number of represented farms	Total utilized arable area	Cereals		Other field crops		Fodder crops	
Unit of measurement	pieces	ha	ha	%	ha	%	ha	%
0 < 4 ESU	292 430	2 675 558	1 292 069	48.3	210 070.7	7.9	808 644.6	30.2
4 < 8 ESU	569 770	6 528 542	3 463 584	53.1	564 111.5	8.6	1 436 500	22.0
8 < 16 ESU	361 330	7 550 018	4 136 706	54.8	836 458.4	11.1	1 638 650	21.7
16 < 40 ESU	339 540	14 642 742	7 692 267	52.5	1 913 621	13.1	3 058 418	20.9
40 < 100 SU	211 970	19 266 127	9 911 176	51.4	3 167 148	16.4	3 882 972	20.2
>= 100 ESU	122 860	32 123 988	16 024 500	49.9	7 136 114	22.2	6 157 000	19.2
Total	1 897 900	82 786 975	42 520 301	51.4	13 827 523	16.7	16 982 184	20.5

Source: our own editing based on FADN database.

Table 4. **Expected savings on fertilizers by the farms that switched to precision farming**

			Farms in conversion		
			15%	25%	40%
16–100 ESU	Conversion area (ha)		5 086 330	8 477 217	13 563 547
	Savings on fertilizers (t)	5%	16 276	27 127	43 403
		10%	32 553	54 254	86 807
		20%	65 105	108 508	173 613
>= 100	Conversion area (ha)		4 818 598	8 030 997	12 849 595
	Savings on fertilizers (t)	5%	15 420	25 699	41 119
		10%	30 839	51 398	82 237
		20%	61 678	102 797	164 475
Total	Conversion area (ha)		9 904 928	16 508 214	26 413 142

Source: our own calculations.

cereal production. Within the cost of materials, this saving can be 0.6–6.2%; this can improve the income of the cereal production. Another considerable benefit is the reduction of the environmental impact thanks to the unused artificial chemicals.

In case of Hungary, at the sectoral level, the transition to precision farming (assuming the same output) can result in 964–3 780 tons of nutrient savings in case of 15% of the farm conversion; if the conversion is 25%, the savings can reach 2 025–8 110 tons, and in case of 40% conversion 2 520–10 090 tons (Table 5).

Save on pesticide use

In my view, converting to precision farming is more important for the reduction of pesticide use. On the one hand, the areas that can be left without pesticide application can be increased depending on the area's pest infestation and on the uniformity of this infection; on the other hand, the spot treatments will result in actual material savings. The estimated savings on pesticide materials are 5.7–11.4 thousand tons in case of 15% of the farms converted to precision farming, in case of 25% conversion the savings can be 9.5–13.1 thousand tons, while in the best case a 40% conversion – savings can reach 15.2–30.4 thousand tons (Table 6). When we take into account the role of agricultural production as part of food security, this saving creates a considerable quantity when we evaluate the complex impact of the precision technology.

In case of Hungary, at the sectoral level, the transition to precision farming can result in 140–275 tons of pesticide savings in case of 15% of farm conversion; if the conversion is 25%, the savings can reach 230–585 tons and in case of a 40% conversion 470–940 tons (Table 7). This is significant because, with the same pesticide application efficiency, a smaller environmental impact will rival with the precise plant protection treatment.

From the farm economy point of view, in Hungary, the farm plant design based on the size of the level of worked area can allow to convert 45.1% of the farms to precision technology. After the calculated pesticide savings, we can conclude that, if 15% of the farms that is working over 300 hectares (137 960 hectare) would convert to precision technology, the material savings will be 35–69 tons, the 25% of conversion level will result in 80–160 tons of savings, and at 40% of conversion the savings will be 128–256 tons of pesticide savings at the national level.

Table 5. **Expectable savings on fertilizers at the farms that converted to precision framing in Hungary**

			Farms that changed to conversion		
			15%	25%	40%
16–100 ESU	Conversion area (ha)		10 3 559	172 598	276 157
	Savings on fertilizers (t)	5%	535	892	1 426
		10%	1 070	1 783	2 853
		20%	2 140	3 566	5 706
>= 100	Conversion area (ha)		132 353	220 588	352 941
	Savings on fertilizers (t)	5%	424	1 136	1 094
		10%	821	2 272	2 188
		20%	1 641	4 543	4 376
Total	Total area of conversion (ha)		235 912	393 186	629 098

Source: our own calculations.

Table 6. **Expected savings on pesticide amounts amongst conversion farms**

			Farms that changed to conversion		
			15%	25%	40%
16–100 ESU	Conversion area (ha)		5 086 330	8 477 217	13 563 547
	Savings on pesticides (t)	5%	2 925	4 874	7 799
		10%	4 095	1 950	10 919
		20%	5 849	3 900	15 598
>= 100	Conversion area (ha)		4 818 598	8 030 997	12 849 595
	Savings on pesticides (t)	25%	2 771	4 618	7 389
		35%	4 095	6 465	10 344
		50%	8 190	9 235	14 777
Total	Total conversion area (ha)		9 904 928	16 508 214	26 413 142

Source: our own calculations.

Table 7. **Expectable savings in pesticide usage on the farms that converted to precision farming in Hungary**

			Farms in conversion		
			15%	25%	40%
16–100 ESU	Conversion area (ha)		103 559	172 598	276 157
	Savings on pesticides (t)	5%	60	101	265
		10%	85	232	370
		20%	121	331	529
>= 100	Conversion area (ha)		132 353	220 588	352 941
	Savings on pesticides (t)	5%	77	128	205
		10%	108	180	287
		20%	154	257	410
Total	Conversion area (ha)		235 912	393 186	629 098
	Total savings on pesticides (t)	25%	137	229	470
		35%	192	411	658
		50%	275	587	940

Source: our own calculations.

CONCLUSIONS

The basic principle of sustainable agriculture is to continue farming in the natural environment in such a way that with the applied farming methods we could reduce the emission of unnecessary and harmful chemicals, in the same time ensuring the farms' long-term viability and income; besides, the environment should be kept and maintained as part of the social function of living.

Precision farming is a technology that allows the soil–ecosystem–plant–engineering combination to apply chemicals at the parcel level and to optimize these at a known level of production cost, yield and price. The agricultural technical improvement allows the use of the newest technologies to a wide range. From the farm economy point of view, the viability means that along with the adaptation of the process, the invested cost will return as part of the income revenue, so there will be such amount of income for the farm that will assure the return of the invested capital, i. e., it will ensure a simple economic reproduction. However, conversion to the new technology will cost extra investment which not every farm can provide because of economic or other considerations. Precision agriculture can ensure a more rational use of fertilizers and also reduce the use of pesticides; realistically, we can not expect that this will be used on the total arable area in a foreseeable future. Under the requirements of this technology, both for the number of farms and in the size of the cultivated area, only a few farms can meet the expectations. The farms over 100 ESU based on their own technology, the 16–100 ESU sized farms based on common forms of machinery share rings, or with the help of other services can apply precision crop growing technologies. If we assume an optimistic scenario in the European Union (EU–25) and 40% of the above farms will convert, at the same yield level the savings of fertilizers will be 338 thousand tons, and at the same time, at the farm level, operating cost savings can be achieved that will result in an increase of the total. The saving of materials is 0.6–6.2%. Another, also rather important result is the declining use of artificial unused chemical emissions into the environment.

The conversion to precision farming plays more important role in pesticide application reduction. In this case, the spot treatments will result in actual material saving, as the experience shows that the portion of the areas that can be omitted from pesticide treatment can reach 30–70%. Also, savings can be achieved in the doses of herbicides, if they are applied with regard to soil qualities. In case of an optimistic scenario, the pesticide savings can reach 30 thousand tons. Considering the role of agricultural production as part of food security, this creates an important quantity when we evaluate the complex results of precision technology.

The projected model for the European Union base shows that on the annual basis a significant reduction can (could) be achieved in the use of chemicals with a wide spread of precision plant growing technologies. Often, no expertise is available for a sufficient adoption of the technology. In the latter case, any initiative which may be organized on the level of production (machine rings) or by the service providers (like IKR Production Development and Commercial Corporation in Hungary) can help to promote a wide-scale use of precision plant production. In Hungary, with the IKR instruments and experts, over 10,000 hectares are using precision fertility treatment, and for the precise pesticide application steps have already been initiated. If one takes into account the possible future role of this technology in reducing the environmental pollution, support of the development of this design should be considered to achieve the compliance with the requirements of agricultural pesticide reduction; also, the loss of income because of extra expenses would be compensated by the achieved income on the production level.

Received 27 May 2009
Accepted 8 October 2009

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AUGALŲ AUGINIMO TECHNOLOGIJŲ LAIKYMOSI SVARBA APLINKOSAUGOS POŽIŪRIU

S a n t r a u k a

Išsivysčiusiose šalyse gera aplinkosauga tampa vis svarbesnė. Tikslus ūkininkavimas atitinka ekologinius ir socialinius reikalavimus: saugoti aplinką ir bioįvairovę ateičiai derinant su ekonominiais reikalavimais. Tokiam ūkininkavimui reikalingos techninės investicijos. Investicijų kapitalo grąža yra lūkesčiai. Šis klausimas yra susijęs su dirbamos žemės plotų, kuriuose galima diegti naujas technologijas, dydžiu ir su galimomis alternatyvomis dėl, pvz., naudojamos technikos ratų dydžio.

Straipsnyje nagrinėjamas numatomas potencialus indėlis ir sąnaudų taupymas tiksliai tvarkant piktžoles sektoriniame ES šalių lygyje.

Raktažodžiai: nuoseklumas, aplinkosaugos naštos mažinimas