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Changes in costs of precision nutrition depending on crop rotation

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Abstract: By applying precision nutrition the yield heterogeneity owing to the different features of soil spots can be taken into consideration. The planned and sprayed fertilizer adjusted to the expected yield rendered to soil spots can reduce the negative effects of artificial chemicals on soil and environment.

The aim of this paper is to examine how the quantity and the cost of fertilizer (material and operational) will change on spot level on a certain plot during a five-year period, considering crop rotation, too. The following crops are in the rotation: winter wheat, corn and sunflower. Precision nutrition can be used in all the cultures mentioned above.

Our earlier (static) model calculations have revealed that the threshold price of precision production was lower by 31% than in conventional technology. So it is necessary to explore for a longer period how the profitability of precision nutrition reacts to the changes in input and yield prices in different crops. The risk receptivity of precision nutrition can be characterized with the help of price sensitive analyses. Effects on profitability of other technological elements are not analysed in this paper.

Key words: cost of fertilizer, long-term model calculation, price-sensitivity

1. Introduction

Numerous definitions of precision farming technology are known. The common element of these definitions is that they target the locally specified treatment of factors that are different in space, heterogeneous in distribution and influence production (soil, weeds, pathogens and pests). [*Batte,* 1999; *Pecze,* 2004; *Swinton,* 2005] *Jolánkai and Németh* (2007) supplement this definition with the essential element of the precision farming technology that is to adapt the plant production technology to the conditions of the arable land as much as possible. As applying machinery in precision farming, it must be taken into consideration the capital effectiveness of technical aspects surplus. This depends on farm size as well. In Hungary the farm structure is very polarized from this aspect. [*Takács,* 2003; *Takács-György,* 2008] Above this it is very important to examine the efficiency of input and output, with regard to the nutrient supply (the optimal level of fertilizer) which take the biggest part of the cost of plant production. The methods of this examination is the price-sensitivity of the income. [*Nábrádi* et al., 2009] Some authors examine the effects of precision plant production on the quality of the products. *Neményi and Milics* (2007) defined under Hungarian conditions that nutrient supply can be optimized during the practical implementation of precision crop production, thus improving the nutrient content parameters of winter wheat. There is a positive correlation with the gluten and the protein contents, which enables to realize higher yield-price. In our opinion, precision farming technology which makes precise spreading of agent possible by plot-treatment, results rational chemical using with or instead of chemical reduction.

Wolf and Buttel (1996) states that the importance of precision farming technology is twofold: in the one hand it is a tool to change the attitude of agricultural production, might reduce the quantity of chemicals in the environment, and on the other hand the basis of efficient agriculture is to keep the industrial production structure, investments and some organization structure and operational mechanism. It should be added that precision farming technology is a real implement to reduce environmental damage, but on farm level it is a tool to reduce risks. In plant production it is possible to reduce the yield-risk and increase the stabilized income of farmers by appropriate application and combination of technology elements required by environmental conditions. [*Weiss,* 1996; *Auernhammer,* 2001; *Gandonou* et al., 2004; *Takácsné György,* 2006; *Heijman – Lazányi,* 2007; *Csiba* et al., 2009]

Precision technology in itself does not result unanimous reduction in fertilizer using. If the aim on the plot is not the heterogenic yield but the harnessing of the potential productivity of each parcel, the doze of fertilization may be higher on the total plot. The competitiveness is in the higher yield per field and in the improvement of specific income with rational fertilization (not spreading surplus nutrient). When the income of precision plant production is estimated the elements affecting the income should be determined according to the principle of (marginal) economics and the rules of detailed budget. Some researchers have revealed that there is a relation between locally specified target yield and the cost-rate income of the fertilizer spread on the basis of nutrient content of the soil. It is necessary, however, that the cost of sampling is not listed among the variable costs per year, but divided equally in, for example, five years (like amortization). Positive extra income can be expected if the yield-increase is more than 10%, due to the planning based on yield-mapping. [*Swinton – Lowenberg-DeBoer,* 1998]

There are only some references which deal with the effects of the sowing-structure on the income of precision plant production. We examined the applicability of precision weed management in maize, based on data from 2007. We stated that higher income can be achieved with whole surface precision weed control than with precision in-row spraying in maize. In the latter case the herbicide savings are between 30–50%, but compare to this there is the cost of row-cultivation which is necessary for in-row spraying. [*Takácsné,* et al., 2008]

2. Material and Methods

We made model calculations in order to examine production value with effects of costs of precision fertilization on different price-levels. The research dealt with winter wheat, maize and sunflower.

The basic data came from the soil samples and examination of Józsefmajor Experimental and Study Farm of Szent István University. On the basis of soil analysis the plots of the study farm are well supplied with nutrients. Grounds of results of soil examination tables are good provided with nutrients. Phosphorus and potassium should not be spread, therefore we calculated only with the nitrogen-agent. The soil sampling unit was 5 hectares, so yields and amounts of supply were defined also in 5-hectare units. Model calculations were made for a 30-hectare, 6-parcel plot.

In the winter wheat production one ton of principal product needs 25 kg nitrogen-agent, in the maize production it is 22 kg, and in the sunflower production it is 50 kg. [*Debreczeni,* 1979] If we know the nutrient need of plant and the nutrient content of the soil we can determine the useable amount of nitrogen-agent or fertilizer required per parcel. The agent content in the fertilizer is 34%, the price per ton is 143 EUR.

The aim of this study is to define that use of traditional (based on averaged value) or precision (based on parcel or micro-plot need) fertilization is justified from economic aspects in case of different plants (winter wheat, maize and sunflower).

Three different cases were used to determine the amount of supply to be spread.

Case 1: No fertilizer use, because the soil is well provided with nutrients.

Case 2: The quantity of required agent or fertilizer is determined not on the basis of plot-level soil analysis, but on the basis of average nitrogen content. Amount of the yield means plot-level average value.

Case 3: Different yields were planned on different parcels (the average yield of the field is the same like in case 2)

We examined savings of nitrogen-agent (kg/parcel) and differences in incomes per parcel with the precision fertilization (Case 3) compared to the traditional technology (Case 2).

With the help of model calculation the variations in incomes were examined in case of different prices, the step of the price change was 18 EUR. Variable costs of production without costs of fertilization were based on the test farm data of Agricultural Economics Research Institute (AERI) *(Table 1.)*

Table 1. Material and operational costs of traditional plant production technology without nutrient supply *

	Material cost (EUR)	Operational cost (EUR)	Total variable cost (EUR)
Winter wheat	2 357	1 964	6 058
Maize	5 893	3 054	11 048
Sunflower	4 071	3 036	8 528

Source: AERI, 2007 * on 30 hectares

On the basis of our former research with model calculations, the operational cost of precision farming technology was higher by 20% than the cost of traditional technology, therefore in the material cost we can calculate with 40% reduction. [*Takácsné György – Lencsés,* 2008]

The total variable cost of plant production was calculated in the model, so the conclusions concern not only the fertilization but the complex traditional and precision farming technology.

3. Results

By evaluating our results it cannot be forgotten that these results are valid only under the given condition system.

3.1. Results of no fertilizer use (case 1)

In case of no use of nutrient supply on the examined 30-hectare plot, the total planned yield in winter wheat is 90 tons, in maize production it is 120 tons, and in the sunflower it is 45 tons. If the yield price increases by 18 EUR the

Table 2. Incomes of plant production technology without nutrient supply at different price-levels*

		Winter wheat	Maize	Sunflower
Planned yield (tons)		**90**	**120**	**45**
Yield price (EUR/ton)	**71**	-404	-3 416	
	89	1 203	-1 273	
	107	2 810	870	
	125	4 417	3 013	
	143	6 025	5 156	
	161			-2 071
	179			8 036
	196			8 839
	214			9 643
	232			10 446

Source: own calculation * on 30 hectares income per hectare increases by 54 EUR in the winter wheat production, 71 EUR in maize production and 27 EUR if the cost of production does not change. *(Table 2.)*

3.2. Results of applying traditional fertilization like average need (case 2)

When traditional fertilization technology is applied, the yield of winter wheat is 166 tons, which needs 3 750 kg nitrogen-agent supply, the yield of maize is 288 tons, which needs 4 620 kg nitrogen-agent supply and the yield of sunflower is 68 tons, which needs 3 000 kg nitrogen agent on 30 hectares. *(Table 3.)*

Table 3. Material and operational costs of traditional plant production technology *

	Material cost (EUR)	Operational cost (EUR)	Total variable cost (EUR)
Winter wheat	1 576		1 736
Maize	1 941	161	2 102
Sunflower	1 261		1 421

Source: AERI 2007, own calculation * on 30 hectares

If fertilizer doze per hectare is the same on the whole plot, the income is positive even on the smallest examined yield price. If the yield price increases by 18 EUR the income per hectare increases by 99 EUR in winter wheat production, 138 EUR in maize production and 41 EUR if the cost of production does not change. *(Table 4.)* The incomes increase by 59% if the yield-price grows by 25% in winter wheat production, the income increase is 94% in maize production. In case of sunflower the income change is more than 74% with the same yield-price change.

3.3. Results of applying precision fertilization on parcel level (case 3)

In case of precision fertilization on the 30-hectare model plot (30 hectares) the total amount of the yield is the same like in Case 2, differences are only on parcel level. *(Table 5.)*

Table 4: Incomes of the traditional plant production technology at different price-level*

		Winter wheat	Maize	Sunflower
Planned yield (tons)		**166**	**228**	**68**
Yield price (EUR/ton)	**71**	5 042	4 331	0
	89	8 010	8 411	0
	107	10 979	12 490	0
	125	13 947	16 570	0
	143	16 916	20 649	0
	161	0	0	1 645
	179	0	0	2 861
	196	0	0	4 078
	214	0	0	5 294
	232	0	0	6 510

Source: own calculation * on 30 hectares

Table 5. Quantity of planned yield and necessary nitrogen-agent per parcel in case of precision nutrient supply

Number of parcel*	Winter wheat		Maize		Sunflower	
	Planned yield (tons/ parcel)	Nitrogen-agent (kg/ parcel)	Planned yield (tons/ parcel)	Nitrogen-agent (kg/ parcel)	Planned yield (tons/ parcel)	Nitrogen-agent (kg/ parcel)
1/1	28,19	637,08	38,63	782,08	11,60	512,08
1/2	27,32	615,33	37,64	760,33	11,16	490,33
1/3	27,15	610,98	37,44	755,98	11,07	485,98
1/4	27,49	619,68	37,83	764,68	11,25	494,68
1/5	27,84	628,38	38,23	773,38	11,42	503,38
1/6	28,25	638,53	38,69	783,53	11,62	513,53
Total**	**166,24**	**3750,00**	**228,45**	**4620,00**	**68,12**	**3000,00**

Source: own calculation * 1 parcel = 5 hectares,
** at total field (30 hectares)

The material and the operational cost of complex precision farming technology is 3418 EUR in the winter wheat production (more than half of it is the cost of fertilization). The total variable costs in maize production amount to 6036 EUR, in which the fertilization cost is 35%. On 30 hectares the total variable cost of sunflower production is 4260 EUR (34% is the cost of fertilization). *(Table 6.)*

Table 6. Costs of precision farming technology on the examined 30 hectares

	Nutrient supply			Total cost of production*		Total variable cost (EUR)
	Material cost (EUR)	Operatio-nal cost (EUR)	Total (EUR)	Material cost (EUR)	Operatio nal cost (EUR)	
Winter wheat	1 576	193	1 768	1 414	236	3 418
Maize	1 941		2 134	3 536	366	6 036
Sunflower	1 261		1 453	2 443	364	4 261

Source: AERI, own calculation * without nutrient supply

Considering variable costs of precision fertilization and other elements of precision farming technology *(Table 6.)* positive income is realized even in case of the lowest examined sales price. If the yield price increases by 18 EUR the income per hectare increases by 99 EUR in winter wheat production, 138 EUR in maize production and 41 EUR if the cost of production does not change. *(Table 7.)* The income of winter wheat production increases by 39% if the yield-price grows by 25%. In case of maize the income change is 44% in the same yield-price change and in the sunflower production it is 21%.

Deviation in the extra incomes is the same on different yield-price compared precision farming technology to traditional technology. This is the reason why Table 8 does not contain the extra incomes on different price. In the model calculation on the half of the plot we can calculate material cost decrease with the precision fertilization compared to the traditional fertilization in all the three crops. Because of the basic conditions the fertilizer savings on the total 30 hectares is 0 EUR. The extra income of precision farming technology compared to the traditional technology is 2639 in case of EUR winter wheat production, 5012 EUR in case of maize production and 4268 EUR in case of sunflower production. (*Table 8.)*

Table 7. Incomes of precision farming technology at different price-levels*

		Winter wheat	Maize	Sunflower
Planned yield (tons)		**166**	**228**	**68**
Yield price (EUR/ton)	71	7 681	9 343	
	89	10 650	13 423	
	107	13 618	17 502	
	125	16 587	21 582	
	143	19 555	25 662	
	161			5 913
	179			7 129
	196			8 345
	214			9 562
	232			10 778

Source: own calculation * on 30 hectares

Table 8. Fertilizer cost savings and extra income by precision farming technology *

Number of parcel	Winter wheat		Maize		Sunflower	
	Fertilizer cost saving (EUR/ parcel)	Extra income**	Fertilizer cost saving (EUR/ parcel)	Extra income**	Fertilizer cost saving (EUR/ parcel)	Extra income**
1/1	-5 077		-5 077		-5 077	
½	4 062		4 062		4 062	
1/3	5 889		5 889		5 889	
¼	2 234		2 234		2 234	
1/5	-1 422		-1 422		-1 422	
1/6	-5 686		-5 686		-5 686	
Total	**0**	**2 639**	**0**	**5 012**	**0**	**4 268**

Source: own calculation * on 30 hectares
** with the total production technology

4. Conclusions

It can be stated that some form of fertilization cannot be left out from production process even in case of soils of relatively good nutrient supply, because positive income can be achieved by applying nutrient supplying technologies even in case of lower price levels.

We have not found any difference in the total amount of applied fertilization between traditional and precision farming technology, but on half of the parcels we can calculate material savings in all the three crops (winter wheat, maize, sunflower). This is true only for the basic terms, namely when we do not calculate yield-potential on different parcels. In the same time, when applying precision fertilization we should calculate higher operational cost so in economic terms, it is not expedient without other precision production elements. If we combine precision fertilization with other elements (for example precision weed management) the extra income is notable. The price-sensitivity of precision farming technology is smaller than that of the traditional technology, so there is smaller fluctuation in the income change and the process is more calculable. Besides economic considerations, the ecological aspect should also be highlighted: the soil damage effects of the plant production can be reduced by applying precision fertilization.

In the future it is worth examining how the profitability changes if yield-potential on parcel level is also considered.

The aim of future research can be to define the optimal sowing structure from the aspect of profitability of precision farming technology calculating with price-sensitivity (both the input and the output price changes).

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