Some ideas of economic aspects of precision plant production (protection)

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Abstract— **Precision farming – besides other aspects – enables the reduction of use of chemical substances in crop production while decreases farming risks, contributes to specific field-crop-plant applications, makes production processes more designable and increases profitability. The introduction of a new technology requires complex farm-management decisions, including the consideration of economic correlations (costs-yield-income). Considering the three basic meanings of sustainability, the farming strategies have to meet these requirements. There are several alternatives to reduce artificial chemical use (applying new chemicals with lower doses, chemical-free ways like organic farming, negative environmental taxes, precision farming, etc.).**

In Hungary the farm structure is polarized, there are large crop producing farms (operating over 1000 ha), a lot of small farms (working less then 50 ha), but the number of middle sized farms is growing up, fortunately. Precision plant production could be a real alternative for them in their efforts to optimize chemical use, but the capital investment required for shifting to this technology, should also be considered. It is necessary to examine the conditions under which it will be a viable decision from economic point of view. It can be stated that the extra investment will be returned above 150-160 ha crop producing farm. Risk of return depends on soil conditions, weed coverage and could be decreased by increasing the utilization of machinery.

The objective of the study is to examine the economic consequences of precision plant protection, to find the answers to the questions which may occur when the farmer turns to precision farming.

Keywords— **changes in profitability, viable size**

I. INTRODUCTION

The basic task of sustainable agricultural production is to find and use such technologies, methods and processes which can maintain the environment and also keep the economical level of production under given ecological and social circumstances. Besides agriculture's primary producing function, the importance of multifunctionality has been increased. Parallel with this process the limitation or elimination of artificial chemicals has become general. The social need for the decrease of chemical use in agriculture and its environmental impacts is growing.

Due to the above mentioned tendencies, the strengthening of society, new directions have appeared in the agricultural production of developed countries which have moved farming towards reduced chemical use, during the recent decades. These include the following:

- reduction of plant protection chemical use in general (long-lasting, curing agents) with which less treatments are needed during vegetation. The reduction of active ingredient doses results that the quantity of agent per area unit is dropped. This is one element of agricultural technical development and chemical industry is interested in it (Husti, 2006)
- chemical-free (banning the use of artificial chemicals) trends (types of organic farming, rejecting the use of most artificial chemicals), or total banning of chemical use for the sake of environmental safety. The extension of this trend slowed down in 2005 in Europe, the primary reason for which was the decreasing bonification following the market saturation processes. This resulted a drop of producers' income. (Willer - Yuseffi, 2005; Járási, 2006; Takács, 2007) During the last decades the market of organic products has grown steadily, the extra-price has decreased slowly and nowadays those products can be clearly categorized which have future. Járási and Takács (2008) examined organic products in Hungarian market by BCG analyses. They got winter wheat and sunflower as cash-cow products, rapeseeds, fodders and other cereals as star products. Question marks were given to grapes, medical and culinary crops, and dogs to fresh vegetables and potatoes. (Járási – Takács, 2008)

- implementation of integrated crop production systems that is reasonable farm management (Integrated Pesticide Management), that could be considered as "conventional production";
- precision farming – which enables targeted agent spraying via spot treatments – results rational chemical use besides – or instead of – chemical reduction.

The conditions of economical agricultural production have to be maintained with a decreasing level of supporting. At the same time the most important step is to determine the strategy which can be applied and supported in the countries at different development levels. However, in areas where the agricultural excess production is usual, dead stock is accumulated, the dose of fertilizers per hectare is high (450-500 kg per hectare), the average number of plant protection treatments is high (8-9 for autumn wheat), it is necessary to investigate the impact of chemical reduction. Certainly, these investigations should cover not only the change in cost and yield due to chemical reduction but also the extra expenses of its implementation (costs of transformation, necessary investment, quality assurance). Every case when a farmer changes his former farming technology and needs to make some changes in main inputs, the conditions of profitability will change. It would change the level of inputs, the input – output relations, cost structure, investment return and so on. The investigations must be carried out not just on farm level, but we also have to deal with its impact at the level of the sector and the national economy. An analysis, based on years of data collecting in Denmark, stated that at the level of national economy the 33% decrease of chemical application in the past decade did not reduce significantly the income level of farmers. Income supplements for producers were not necessary. (Ørum et al., 2002)

For preserving sustainability in agriculture we need to reduce the level of industrial inputs as much as possible without substantially lowering the profitability of farming (not talking about organic production in this case). (Christensen, and Huusom, 2001; Anselin et al., 2004; Takács, 2003)

„Precision agriculture“ has several definitions. Most commonly it means locally specified treatments of different factors such as soil, insects, pests and weeds. Through this method the fields and the production can be influenced in different places and also in heterogeneous spreading. Practically the precision (locally specified) weed control means that chemical treatment is being applied only to certain spots of the field as emerging weeds demand it [Maxwell and Luschei 2005; Swinton, 2005]. On the other hand, we can state that precision crop protection enables the development of rational and reasonable chemical use. Therefore not the chemical use alone, but the „unnecessary" chemical spraying can be decreased and, at the same time, the profit of the farm can be increased.

To use this highly developed technology, the farmer must change his farming strategy – which could mean mainly increasing intensity of farming – and implement several technical investment.

II. MATERIAL AND METHODS

In this paper the economic aspects of precision plant protection, especially weed management were examined. Precision weed management in wide spread crops is a usual method in those farms which apply precision nutrition.

Based on former model calculations a cost-margin analysis was made in order to show how the viable size – covering the simple capital replacement, too – is modified by the introduction of precision farming with average crop production structure under Hungarian conditions. Then it was examined how the return on investment changes when new machinery and technology is built up from the beginning.

The precision weed management means that weed species, their density and soil conditions should be taken into consideration together. The empirical basis of this examination were given by the experimental data collected by Reisinger in 2002. The size of the examined plot was 40 ha, where 80 of 0.5 ha units area were marked out for sampling and observation. The sampling cells were rectangles with approx. 1 to 4 side proportions and the side length of these was 35 x 140 m. The following data were available: parameters affecting soil productivity (pH, clay content, humus content, nutrient (N, P, K, microelement) supply); weed recording at different times (37 species at the autumn, 13 species at the spring, 44 species altogether); average yield realized on the area unit; and the description of the applied precision crop production (fertilizing and weed control) technology. Out of the weed species, 14 were not found at all, in case of further 20, the weed coverage did not reach 1 %.

During the examination, the calculations were made with finite element method, by dividing the permanently changing surfaces into symmetrical $\Delta l \bullet \Delta w$ size cells, with discrete values identical equal with the area integral of the cell. The sampling cell is determined by a couple of factors. The width of the cell depends on the territorial distribution of soil sampling, 0.5 ha unit was used. After defining the needed number of cells, the task was to determine the threshold value of treating the cell. It depends on the weed coverage (per m^2), the nutrient supply of the soil (N, P, K), the clay content (K_A) and relationship between yield and the inputs (especially nutrition) and the price of inputs and yield as well. So the treatment of cells and the dose of herbicide will depend on the above mentioned factors.

It is presumed that the required machinery is developed parallel with the introduction of the new farming technology and the purchase of basic instruments is not delayed, therefore only the extra investment costs should be defined. Thus the extra investment need of a farm having the basic equipment (including corn harvesting machine) is 22.000 EUR.

Production costs include costs corrected with income expectations from the invested assets. The production structure is relatively simple (30% winter wheat – where precision crop protection is not significant – 15% sunflower, 35% maize and 20% alfalfa). In the calculations, the material cost saving of precision farming was 10%, the cultivation cost was higher by 5%, and the yield was higher by 10%. Later a finite element method was adapted in order to elaborate a stochastic simulation model which divided a sample plot into small parcels. It modelled the risk on return of investment depending on the treated area. (Table 1)

The precision weed management needs several extra investments from farmers. Examination of returns were made on farm level with net present value (NPV) calculation in relation to the investment need of means required for precision farming (completed with spraying machine as well) and the area integrated into precision farming. The calculation period was 10 years, as regard the long term use of precision machinery, the discount interest rate was 6% (which is characteristic under Hungarian economic conditions).

Table 1: General features of simulated model versions

Sign of model version	Features of version		
	Area treated with precision technology	Soil features	Weed coverage
A	<50 ha	balanced	balanced
B	>100 ha	balanced	balanced
C	<50 ha	balanced	changing
D	>100 ha	balanced	changing
E	<50 ha	changing	changing
F	>100 ha	changing	changing

Source: own construction

The size of area served with precision technology, the variability of soil parameters and the weed coverage variability, as probability (random) values were used in the model varieties with Monte Carlo simulation in order to examine the risk of returns of turning to precision farming. The size of risk was given by the proportion of unfavourable (NPV ≤ 0) cases. The environmental impacts (precipitation, temperature, etc.) on the yield and the effects of market prices were not examined.

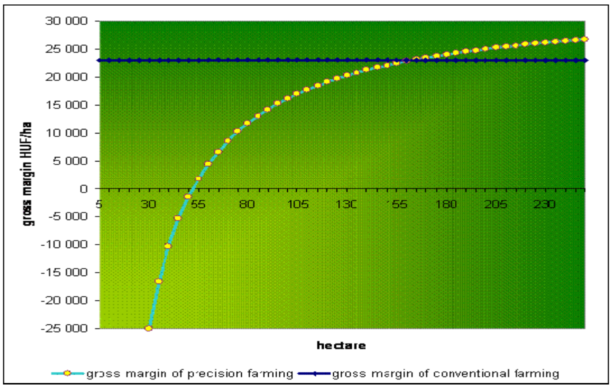
Examinations were made with Monte Carlo simulation (Rubinstein–Kroese, 2007), which is a computer simulation method based on numerous random number generation: which orders probability dispersion to the input quantities of the mathematical model ($Y= G(X_1, X_2, \ldots, X_M)$) X_i as probability variables, and N as random number is generated to each input quantity, according to the dispersion ordered to X_i. The calculation of probability/probability range from the N values on Y measurable quantity is made either directly from the statistics of the Y values or on the basis of approximate permanent dispersion function. Simulation is made with N = 100 runnings.

III. RESULTS

The result of our former calculations was that the viable farming size of crop producing farms is about

160 ha, when the development of own precision farming equipment is manageable and the farm can become self-financing with different production structure. (Takács-György, 2008) This is the point when this technology is at the same profitability level than conventional one under Hungarian conditions (Figure 1).

It means that this type of farming can be viable for medium-size farms. Others should find some ways of co-operation – common machinery use, machine lending, machine leasing – that can help to avoid significant extra investment and similarly to precision crop production they can apply the same environmentally friendly and efficient technology in economic sense. (Takács, 2007)



Source: Takács-György, 2008

Figure 1. Viable size determination in case of precision vs conventional farming

With the help of precision weed management, according to the data measured on the experimental plot, the relative dispersion of yield is smaller than it would be expected from the nutrient balance of the soil and the unevenness of weed coverage. F-test proves that on the basis of variances of the examined variables, the multitudes are different and it can be proved with 95% reliability that the variables are significantly different. The simulation model – for estimating the risk of return on necessary investment of precision machinery – helps to examine great number of combinations of factors (heterogeneous soil and weed conditions, farm sizes etc.). According to the results (Figure 2) some typical combinations could be determined (Table 2), the transition to precision farming/weed management is reasonable only in case of great variability of soil qualities, soil nutrient supply and weed coverage, and in case of high utilization level of precision technology equipment which is rather expensive.

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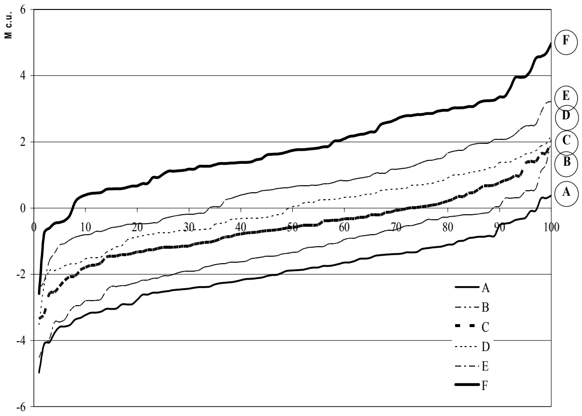
Table 2. Estimation of certainty of return in relation to soil features and distribution of weed coverage

		Changeability of soil features		
		Small	Medium	Large
Changeability of weed coverage	Small	▨	▥	▤
	Medium	▥	▥	▤
	Large	▥	▤	▤

Source: Takács-György et al., 2008

Remark: ▨ big risk no return ▥ medium risk uncertain return ▤ low risk probable return



Source: own construction

Figure 2. Estimation of risks on returns with Monte Carlo simulation

IV. CONCLUSIONS

The implementation of precision crop protection is reasonable only in wide-spaced cultures. Payback on complementary equipment can be expected when these crops are in higher proportion in the production structure. Shift of smaller farms to precision farming is possible if they apply the technology as a leased service, or the investment is made in the frames of joint machine utilization, like machinery rings.

The introduction of a new technology requires complex farm-management decisions, including the consideration of economic correlations (costs-yield-income, return on investment). Stochastic models help the estimation of investment risks. Differentiated nutrient supply will increase yield safety under changeable soil conditions, and it can result cost savings by avoiding unnecessary chemical use. The safety of returns is increased when precision farming can be pursued with high equipment exploitation due to horizontal integration.

The positive environmental impacts of precision farming (nutrient supply, crop protection) as a technological alternative to sustainable agriculture are inevitable, and resulting positive outcomes affect everyone involved.

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