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Article

Precision Farming Technology like the Tool of the Sustainable Agriculture in the Hungarian Practice

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Abstract: Modern plant production systems are faced to numerous challenges, for example, they have to satisfy the growing food necessity with moderate environmental damage and to produce quality product with profit. The support of the food needs cannot be solved by giving up the chemicals. Many new or rediscovered technologies have appeared against the harmful effects of the chemicalization of the agricultural production without yield loss or with yield similarity (for example ecological, mid-tech farming and precision farming technologies). Precision farming technology should not be considered as only a modern plant production technology or only a new agro-management tool. In our opinion the precision farming technology is achieved only when the results of electronic and IT equipment are realized and can be differentiated in the variable rate treatments zone-by-zone. The biggest problem with the precision farming technology according to our opinion is that the possible advantages and disadvantages of the technology highly depend on the professional knowledge and attitude of the manager and the staff. Between the autumn 2010 and spring 2011 the own data collection was made for examining the knowledge about the precision farming technology among Hungarian farmers producing field crops. Some

interviewed farmers have used precision farming technology for years, some have planned to adopt this technology and some have heard about the technology but does not want to use it. Adaptation of precision farming technology may bring both advantages and disadvantages. According to the scientific literature sources the most important advantage of precision farming technology is the decreasing of the negative environmental impacts. In the survey, non-precision farmers placed this advantage in the 1st place, according to the precision farming planners it was in the 2nd place, while according to the precision farmers this impact was only on the 8th place. Furthermore we examined the opinion of the farmers about the changes in percentages of operational cost, herbicide cost, fertilizer cost and human resource cost resulted by the adaptation of precision farming technology compared to the conventional technology. I used the box-plot analysis for this examination. In summary the biggest cost saving were in the fertilizer cost and herbicide cost according to the opinion of precision farmers.

Keywords: cost-saving, site-specific plant production, environmental impact

1. Introduction

Modern plant production systems are faced to numerous challenges, for example, they have to satisfy the growing food necessity with moderate environmental damage and to produce quality product with profit. All over the world the common challenges of the agriculture is to satisfy the growing food necessity on the smaller and smaller agricultural area.

In our opinion, the future of the agricultural production is to keep the input (artificial or natural) usage within a reasonable level and spread out only that amount which is really necessary for the produced plant considering the heterogeneous conditions of the field. Many new or rediscovered technologies have appeared against the harmful effects of the chemicalization of the agricultural production without yield loss or with yield similarity (for example ecological, mid-tech farming and precision farming technologies).

The central idea of the precision farming technology is to rationalize the inputs differentiated on plot-to-plot of the field and not on the average of the whole field. These smallest treatment plots are called management zones. Management zones are the base of map-based fertilizer distribution: The advantage of site-specific treatments can be achieved by using high technical level and in a responsible way, when the farmer faces with the fact that when there is a rapid rate change, the applicator needs time until it is able to distribute the target fertilizer amount. [MILICS et al., 2012]. They carried out that the size of the treatment units (grid-cells of equal size), multiples of the required working width have to be taken into account. This underlines the role of management, the role of planning The question concerning the size of management zone (in the case of soil samples or weed management) is hard to answer. It depends on the heterogeneity, the size of the farm and many times on the financial conditions. The professionally established weed management assumes the exact knowledge of the weed infestation of a given area. [BAROSSO et al., 2004] The weed sampling techniques provide the

opportunity to obtain the information on the weed species and their dynamic of development. [MAXWELL and LUSCHEI, 2005]. Other authors underline the importance of taking into consideration of the type of the crop and the fact whether only the site specific fertilize use is introduced into the technology or the site-specific weed management, too. [PANTEN at al., 2005]

It was carried out in Hungary that the most widespread sample density was one sample of size 2x2 metres per 0.5 ha. [BARKASZI et al., 2007] The reliability of information attained by this manner depends to a great extent on the spatial distribution of the given weed species and the heterogeneity of the weed spectrum inside the parcel. The authors found out the weed density of the large size parcels is a serious task for the plant protection expert as a great number of samples are necessary to reliably map a parcel with heterogeneous weed spectrum. That requires significant amount of work and time increasing the cost of herbicide treatments. Under continental climate conditions the most typical weed sampling period is before the application of weed control treatments, in the spring when weeds are just starting up. It is possible to do sampling some weeks after the herbicide treatment in order to observe the efficiency of the treatment and also in the autumn in some cases if autumn herbicide application becomes necessary for autumn sown crops. Based on field experiences BARKASZI et al. (2007) concluded the sampling method is reliable only for surveying the frequent weed species in the parcel, while more rarely found weeds (e.g.: spots of perennials) are to be sampled only by means of going over the parcel and GPS recording them. Otherwise, in the case of a traditional sampling process, the number of sampling cells required for acceptable reliability is unnecessarily high. These extra costs of weed sampling needs to be taken into account besides savings from herbicide reduction. The sample sizes can be the base of herbicide treatments, regarding the costs of sampling. [TAKÁCS-GYÖRGY – TAKÁCS, 2009]

Due to the zone-to-zone input rationalization and treatments the environmental damage effects of the production will decrease and the profitability of the production may increase.

Here we mention – without trying to cover the whole literature on the importance of site-specific chemical treatment in sustainability – that all technologies applying herbicides at a lower doses have great influence on reducing environmental burden, and minimize risk to the environment. The application of precision technology in crop production may ensure more efficient production for the grower along with a lower environmental impact. [AUERNHAMMER, 2001; NEMÉNYI et al., 2001; BLACKSHOW et al., 2006; BATTE and van BUREN, 1999; PECZE, 2006; RIDER et al., 2006]

Precision farming could result in a reduction in the amounts of agrochemicals distributed in the environment, and it also could be one of the basic pillars of efficient agriculture while large-scale production structure, investments, organisational structures and operational mechanisms remain. Earlier studies estimated 20-60 per cent pesticide savings owing to precision plant protection and 0-30 per cent savings in fertiliser use depending on the yield homogeneity [LOWENBERG-DeBOER and SWINTON, 1997; BATTE and van BUREN, 1999; PECZE, 2006; RIDER et al., 2006]. Also, for the producer this method of farming can be a tool for reducing the production risk.

Precision farming technology should not be considered as a modern plant production technology or a new agro-management tool. In my opinion the precision farming technology is achieved only when the results of electronic and IT equipment are realized and can be differentiated in the variable rate

treatments zone-by-zone. Furthermore, application maps are necessary for it, which are based on soil sampling with DGPS, yield mapping and the tractor guidance system, which decrease the overlapping and the extra input under the treatment. This equipment is the basis of precision farming technology but in itself, we do not consider as precision farming technology function.

Numerous international and Hungarian research works were published with the technology elements of precision farming technology (yield mapping, precision sowing, precision nutrient supply, and precision weed management) from its introduction in the early 1990s. The precision farming technology is older than 20 years but it is still evolving and boarding. The focus points of the development are the precision of the treatment and the wider scale of the adaptation. Many farmers know about or at least have already heard about the advantages and disadvantages of the precision farming technology. Numerous farmers think that they not able to introduce and operate the precision farming technology because of the high investment cost of technology. Another barrier of the fast spread of the precision farming technology among the farmers is that the theoretical advantages of the technology in the practice may highly depend on the heterogeneity of the field, the knowledge and skill of the operational staff and the commitment of the management.

If we would like to understand the reasons of the slow expansion of the precision farming technology, firstly we have to analyze the diffusion of innovation in agriculture, Precision farming – as an innovation in agriculture – can be considered as ‘technology push’ innovation. According to some economic theories, demand-creating innovations can be expected to diffuse if using the limited resources with the new technology results in economic efficiency. 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, 2001].

Based on ROGERS’ (1962) typology of the diffusion of innovations, precision crop production as an agricultural innovation can be described as follows, including some of the reasons for its slow diffusion in practice [TAKÁCS-GYÖRGY, 2012]:

1. In the launch phase, it had an advantage over the technological elements widely used in farming, which could have made rapid diffusion possible.
2. Precision technology is less compatible, as farmers greatly vary in knowledge, skills and attitude to innovations, as well as in farm size and financial background. Due to lack of counseling support, the process of proliferation of the new technology is slower. In this respect, the Hungarian practice has several positive features, such as the successors of the production systems set up several decades ago, and the counseling networks.
3. 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.

4. The key figures of letting farmers learn more and test the new technology are the participants of agriculture and providers. (There are several specialist, scientific shows and presentations organized annually in order to achieve wider diffusion.)
5. Some of the benefits of precision technology can be observed directly (material saving, improved cost-effectiveness, yield growth), similarly to extra costs and investments. However, its indirect impacts, such as 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, and the perceived risk of its introduction is high, the technology will diffuse slowly, even when the financial background is sufficient. (This phenomenon can be observed both in the United States of America and in Europe.)

Agricultural innovation generally is not generated by farmers in Hungary. The main reasons are the polarized and highly fragmented farm structure, the lack of capital. He also underlined the lack of entrepreneurial affinity. The attitude of farmers to cooperate can be characterized by the lack of willingness and most of the Hungarian farmers want to own their machinery and if they do not have the needed capital for investing to buy the new technology they gave up it. [TAKÁCS – BARANYAI, 2010] 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; BARANYAI – TAKÁCS, 2008; SZABÓ, 2006; BAKUCS et al., 2008; SZABÓ, 2011]. The cooperation of several different actors in the food chain is necessary in the case of precision technology, although the process is different from the market-focused technology development system proposed by FENYVESI and ERDEI-KÉSMÁRKI-GALLY (2012).

Secondly, we should explore the motivation factors of users because it plays key role in the adaptation of the technology. Based on the scientific literature, the most impending factors of adaptation of precision farming technology are the high investment cost (which is sometimes true, but sometimes just supposed) and the knowledge and the behaviour of the farmers with the information science and technology equipment. Following the initial phase, the role of interpersonal communication channels increases (e.g. discussions between experts), the farmer shows also can help to increase the farmers knowledge on new technology. [PECZE, 2006; CSIZMADIA, 2009; MACIEJCZAK, 2012]. We must also bear in mind the IT skills, the important role of extension services and communications, the communication of economic and other usefulness of novelty in the diffusion of precision technology. [GRIFFIN et al., 2004; KALMÁR, 2010; KUTTER et al., 2011] The causes of the slow spreading process also include lack of education and expertise [ATTANANDANA et al., 2007; TAKÁCS 2008; MAGDA et al. 2008; NÁBRÁDI 2010].

Nevertheless, ensuring the financial background of the precision farming technology adaptation is not enough for the successful operation, the active participation and positive attitude of the farmer and the full staff is also necessary.

Otherwise the application of the precision farming technology elements depend on the plant, on the field, on the weed and pest population and on the management. [TAKÁCS-GYÖRGY et al., 2002] The biggest problem with the precision farming technology according to our opinion is that the possible

advantages and disadvantages of the technology highly depend on the professional knowledge and attitude of the manager and the staff. This is the reason why sometimes the farmers think that the investment for precision farming technology will not give the expected advantages so they do not buy other additional elements of the technology or start to use their precision equipment in a conventional way.

SWINTON and LOWENBERG-DEBOER (2001) said that key factor of the spreading of precision farming technology was the increasing efficiency of input use. It means that the more efficient input use makes the spread of the technology faster. In contrast with their opinion, the most impressionable factors of its spread are the following [DABERKOW and McBRIDE,2003]:

- size and geographical situation of cultivated land;
- quantity and quality of human resources;
- risk-sensitivity of the manager.

There are many literature sources about the scientific results of economic viability of the precision farming technology. According to some researchers, precision farming technology is profitable only above 250 hectares [SZÉKELY et al., 2000]. According to others, the farmers need a minimum of 1500 hectares for precision weed management or fertilization. (Table 1.) In my opinion, the reason of these differences is that the economical threshold level highly depends on the correlation between savings and additional costs, which is strongly determined by the heterogeneity of the given plots. If the farmers can use precision farming technology on bigger field, they could experience more advantages of the technology.

Table 1. Break even areas of precision farming technology

Technology elements	Break-even area (ha)	Country
Precision farming technology	250	England
Precision farming technology	800	England
Yield mapping, soil sampling, variable rate fertilization	2018	USA
	430	
	589	
Precision farming technology	250	Hungary
Precision weed management	1500	Germany
Precision weed management	500-200	USA, Canada
Precision farming technology	1000	Hungary
Precision farming technology	300	Greece, Denmark
Precision farming technology	500	Denmark
Precision fertilization	1500	Hungary
Precision plant protection	250	Hungary
Precision farming technology	250	Germany

Source: [KALMÁR, 2010]

2. Material and methods

The main aims of this paper to examine awareness of the precision farming technology (by structured interviews) and to explore the features of the adaptation process of precision farming technology. In the first step of the researches, the following hypotheses were formulated:

Hypothesis (H1): The adaptation of precision farming technology depends on economical and personal factors.

H1/a: The precision farming technology elements are mostly used in the farms with bigger cultivated land.

H1/b: The precision farming technology elements are used in farms with bigger economic size.

H1/c: The adaptation of precision farming technology highly depends on the age of farmer.

Hypothesis (H2): The opinion of precision and non-precision farmers about the advantages and disadvantages of precision farming technology is clearly distinguishable.

Between the autumn 2010 and spring 2011 the own data collection was made for examining the knowledge about the precision farming technology and the spread of this technology among Hungarian farmers producing field crops. The own data collection contained 72 farmer's opinion about the precision farming technology. In my survey, the farmers were chosen with random sampling in different agricultural exhibitions. Some interviewed farmers have used precision farming technology for years, some have planned to adopt this technology and some have heard about the technology but does not want to use it.

Different statistical methods were used for the efficient processing of the database. Cross-table analyses were used to identify the correlation between two non-metric variables. In case of cross-table analyses the Chi-square (χ^2), the Cramer's V value, and their significance level were examined. The variance analyses help to identify the effect of the non-metric independent variables on the metric dependent variable. In case of the statistical analyses, the validity criteria like the probability of mistake (α) was 5% which is generally admitted in social sciences. [SAJTOS and MITEV, 2007] In both statistical analyses the null-hypothesis is the lack of the dependence of the variables.

3. Results and Discussion

The examined database includes the data of 72 farms. All farms produce field crops. Thanks to the personal interviews, nobody was excluded from the examination because of missing data. The available sample database was divided into three sub-samples according to the used farming technology:

1. non-precision farmers ($n_1=48$)¹
2. precision farmers ($n_2=8$)²
3. farmers planning to introduce precision farming ($n_3=16$).

¹ Include farms which use net-based soil sampling or rd but the treatments do not act on the management-zones.

² Include farms which use at least one from the following elements: precision fertilization, precision plant production, precision tillage, precision weed management, precision sowing, sensors (soil, leaves, etc.).

3.1. Adaptation of the precision farming technology in the examined sample

The databases of Hungarian Central Statistical Office or Research Institute of Agricultural Economics do not include information about the adaptation frequency of the precision farming technology elements. The primary aim of the structured interviews was to identify the factors which have effects on the adaptation decision of precision farming technology.

Precision farming technology used in 11% of the interviewed farmers, the rate of non-precision farms was 89% (7% of these farms used ecological farming). Some of the non-precision farmers used GPS based soil-sampling (7%) or GPS tractor guidance (12%) which is part of the precision farming technology, but did not use any other elements which lead to the site-specific production. 25% of the conventional farmers planned to adopt precision farming technology in the future. The frequency of the use of precision farming technology in the database may be distorted, because the structured interviews mostly happened in agricultural exhibitions where particularly those farmers take part, who are more open to novelties.

Based on the frequency of the application of precision farming technology elements the first in the rank among farmers using precision farming technology was precision fertilization, the next was precision plant protection. The tractor guidance GPS tractor guidance and the soil sampling were not in the most common elements in the precision farmers sub-sample, while GPS tractor guidance was a widely used element among conventional farmers. The reason for that so many conventional farmers use tractor guidance may be that the operation of this element does not need additional work and its advantages may be detected in a short time.

Two third of the precision farmers have used more than one elements of the precision farming technology. These farmers have started the technology with grid soil sampling. The farmers who used three or four different precision farming technology elements have bought all elements at the same time.

3.2. Opinion of farmers about the advantages and disadvantages of the precision farming technology

Adaptation of precision farming technology may bring both advantages and disadvantages. Advantages of the precision farming technology are the following: higher yields, better yield quality, income increasing, decreasing environmental impact, decreasing chemical use. Disadvantages of the precision farming technology are the increase of working time and operational costs.

The respondents of the interviews could tell their opinion about the advantages and disadvantages of precision farming technology on a list which included 11 possible changes. They could use the Stapel-scale³ to classify the changes resulted by the introduction of the precision farming technology. Table 3 summarizes the result of these answers.

There was no significant difference between the average values of the three sub-samples according to the ANOVA-test. Otherwise, the ranking of the possible changes based on the average value (in

³ Stapel-scale: scale from -5 to +5. If there is no changes compared to the conventional farming 0 was used. Negative numbers means decreasing, positive numbers means increasing. [SAJTOS and MITEV, 2008]

absolute value) were completely different. Only the changes in the income and in the labour need showed significant differences between opinions of the interviewed sub-samples.

In the rank of changes the most remarkable differences could be observed in the yields the organization of work according to the opinion of precision farmers. Otherwise the improvement of the organization of work was in the 6th or 7th place in the other two sub-samples. The higher yield was on the 4th place in these two groups. All these experiences suggest that besides the realized extra yield and cost saving, the organizational change is may be also noticeable by the farmers in the practice.

According to the scientific literature sources the most important advantage of precision farming technology is the decreasing of the negative environmental impacts. In my survey, non-precision farmers placed this advantage in the first place, according to the precision farming planners it was in the second place, while according to the precision farmers this impact was only on the 8th place. There were similar changes in the area of the chemical changes, which has a strong link with the decreasing of environmental damage. The precision farmers put the chemical changes only on the 9th place. (Table 2.)

Table 2. The opinion of the different subsamples about the changes resulted by the adaptation of precision farming technology

The most important effects of precision farming technology	User of precision farming technology		Planner of precision farming technology		Non-user of precision farming technology	
	average (n=8)	rank	average (n=16)	rank	average (n=48)	rank
yield change	2,75	1.	2,81	4.	2,26	4.
income change*	2,12	6.	4,44	1.	2,45	2.
change of chemical use	-0,63	9.	-2,87	5.	-2,36	3.
change of environmental damage	-1,38	8.	-4,19	2.	-2,70	1.
change of labour force needs*	2,37	3.	0,62	9.	0,7	9.
change of work time	2,25	4.	0,44	10.	0,57	10.
change of operational costs	0,37	10.	2,50	6.	2,02	5.
change of organization	2,75	1.	2,44	7.	1,74	6.
change of yield quantity	2,25	4.	2,13	8.	1,66	7.
change in planning process	2,00	7.	2,88	3.	1,57	8.

Note: large-scale increase: +5; large-scale decrease: -5; corresponding to conventional farming: 0;

* the results of sub-samples are significantly different based on the ANOVA test

Source: own construction based on the structured interviews

According to the farmers who have already used precision farming technology the changes after the introduction of precision farming were smaller in practice than it was expected from the theoretical knowledge. In my opinion, it shows the information about the precision farming technology given in newspapers or agricultural exhibitions emphasize more advantages of the technology.

3.3. *Sentiment of the variable cost of the precision farming technology*

I examined the opinion of the farmers about the changes in percentages of operational cost, herbicide cost, fertilizer cost and human resource cost resulted by the adaptation of precision farming technology compared to the conventional technology. I used the box-plot analysis for this examination.

According to the correlation analysis there were no significant differences between the judgment of the cost changes and the adaptation of precision farming technology. In summary it can be stated, that the biggest cost saving were in the fertilizer cost and herbicide cost according to the opinion of precision farmers. The precision farmers also mentioned the increase of the operational costs and human resource costs.

4. Confirmation or rejection of hypotheses

Based on the results of the cross-table analysis, I determined that only the size of cultivated are and age of farmers had significant effects from the examined factors on the adaptation of precision farming technology in the practice. According to these results, the H1/a and the H1/c hypotheses were verified. There were no significant correlation between the adaptation of precision farming technology and the economic size unit of farms. Therefore, if the farms belonged to the bigger European Size Unit it did not mean that they used the precision farming technology. Based on these results, the H1/b hypothesis were disproved. In summary, I may be stated that according to my exploratory survey, precision farming technology was adapted in the farms with more than 300 hectares by younger than 40 years old farmers.

The farmers who have already used the precision farming technology assessed the changes resulted by the adaptation of the technology less significant, than the farmers who know the technology only from theory. According to my opinion, it suggests that the information about the precision farming technology in newspapers or agricultural exhibitions is more optimistic than the advantages in the practice. Based on the cost calculations, the average opinion of the non-precision farmers and the planners are very similar, but the opinion of non-precision farmers moved in wider interval. Based on these the H2 hypothesis was verified.

5. Conclusions

The positive impacts of the precision farming technology – which are well communicated towards the farmers – may be experienced in the agricultural practice. One of the observations of my research, namely that there were no significant differences between the average opinion of precision and non-precision farmers has also confirmed this opinion. A great part of the farmers knows the advantages and disadvantages of precision farming technology but most of them thinks that the investment costs of the technology is too much for them or the commitment of management for the technology is missing. Nevertheless, the commitment of the management for the precision farming technology is not enough if the working staff do not pay enough attention for the settings of equipment or the maintenance.

I defined that the rankings of effects of precision farming technology are different in the group of user, group of planners and group of non-users of precision farming technology. For the precision

farmers the most important advantages of this technology are the better organization and yield increase (in quantity and in quality) and the increase of the profit. The most important disadvantages are the increase of human resource needs and working time.

According to the answers of interviewed farmers the most adopted element of precision farming technology is the tractor guidance (it was used in 6 farms, precision and the conventional farms together). The using frequencies of the net-based soil sampling and of the off-line precision nutrient supply (which get strong link with soil sampling) and of the off-line precision plant protection were similar. In my opinion the reason of lack of on-line precision farming technology elements are that the investment cost of these technology elements are much higher than the off-line equipment and the possible savings are the same.

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