Precision Agriculture in Hungary: Are percepcions far from the facts?

Abstract

Technological progress can possibly offer multiple solution to the most significant challenges faced by agriculture. Although benefits of precision agriculture are promoted from long period, however its diffusion progressing in slower manner. Percepcions of Hungarian FADN arable farms collected through a survey (2016) is contrasted with the cost-benefit analysis of farms already applying certin parts of precision agriculture technology. The survey revealed the details of the application of different technologies and their impacts as perceived among arable farms. Special subsidies implementing into the "greening" component of CAP will be an incinting factor for supporting the wider spread of PA.

Keywords: **site-specific farming; diffusion; cost-benefit analysis; servay**

1 Introduction

A safe food production and establishing the food security are tasks in which all actors in the food chain should be active involved. Questions of food safety, food traceability, environment pollution or the increasing food demand have been discussed from several aspects by agricultural economists. In our paper we highlight the role of site specific plant production. Any technology – like precision farming – that is in line with the oncept of sustainable intensification can contribute to sustainable food system. However, these possibilities can only be reached if the associated benefits can be shown by facts and clear figures and farmers perceptions and behavior is better understood. Traceability guarantees the food safety from farm to fork. The materials and products flow must be linked with the professional information' flow along the entire chain and they must move together. Stakeholders who cannot suit the requirements based on food security, may drop out from the market. Here appears the role of site-specific – with more common words – precision agriculture (PA).

Number of authors take the initiation in the 1920s of site-specific management that takes into account the heterogeneity within the plot (Franzen and Mulla, 2015). The modern sense of precision agricultural research has started in the 1980s with developing of the yield measuring devices, sensors, variable rate applications and global positioning systems. It has been documented, that young, well-capitalized farmers with large areas and higher level of education, usually more willingly apply these new technologies (Fountas et al 2005; Antolini et al, 2015; DEFRA, 2013, EIP-AGRI, 2015).

PA incidence– international (USA, EU)

Precision agriculture first spread in the US, Europe and Australia, then have become accepted in Argentina, Brazil and some Asian countries (al Fountas et., 2005). Currently, the US has the biggest market share of nearly 50 percent (BIS Research, 2016), where high labor costs encourage the spread of technology. Furthermore, the state subsidy is the highest (Technavio, 2015).

Widmar and Erickson (2015) conducted a survey among American agricultural inputs dealers about high-precision technologies. According to the survey, automatic steering is the most popular, which application already exceeds the use of traditional black lines and also favored the differentiated fertilizing. In recent years, air and satellite images, topographical applications and the logistic use of GPS show increasing tendency.

In Australia, 20 percent of the corn producers applied precision cultivation in 2012 (OECD, 2016), but this rate is much higher among large area farmers. Based on the survey of Ouzman and Llewellyn (2014) 77% of grain farmers who operates more than 500 ha use automatic steering and 33% perform yield mapping. 35% of farmers own machine that is suitable for differentiated scatter, but only 15% of them use it. The effectiveness of technologies indicates that 94% of users would recommend the automatic steering to others, 77% of users would recommend the yield mapping and 80% of users would recommend the differentiated fertilization.
In the last ten years in Europe the precision farming has become a good practice. According to a survey of 2012 (DEFRA, 2013) in England, only 22% of farmers used GPS-based vehicle navigation, 20% of farmers used mapping soil, 16% of farmers used differentiated fertilization and 11% of farmers used yield mapping. In Germany, rate of precision farmers was only 11% in 2006 (OECD, 2016), while in France, 25.4% of farmers used GPS in 2013 (al Vigano et. 2015). According to recent data of EurActiv (2016), 150 000 hectares precision farming is conducted in France, and half of the farms use tractor, equipped with a monitor.

PA incidence – Hungary

The precision farming in Hungary has become practice in the last one and a half decades, but it is still an unknown concept for people. According to a 2015 survey (Tóth, 2015) only half of the crop producers heard about it, 88% of the large scale farms over 500 hectares, 67% of the medium-scale farms between 100 and 500 hectares, while one-third of the small-scale farms less than 100 hectares had heard of precision farming. Survey of Lencsés (2013) showed that adopters of precision farming is primarily younger than 40 years, had higher education, and operate more than 300 hectares area, which is consistent with international experiences. According to Vigano et al. (2015), 23.4% of Hungarian farmers used GPS in 2013.
The site-specific soil sampling, use of the black lines and increasingly the automatic steering are stable as practicable among the technology elements. More than half of the precision farmers use black lines, around 30% of them use autopilot, followed by the machine control, crop and nutrient application (25%). The pest control sensors and drones, and precision irrigation are still in the stage of interest, the rate of their application is only around 5%.

2 Material and methods

The survey was conducted among arable FADN farms in 2016 with the goal to obtain clear and up-to-date picture about the penetrartion of PA. Moreover, among the PA farmers we were interested about the application characteristics of precision agriculture and soil conservation tillage in Hungary. This was further expanded with recorded interviews, with three forefront farms, which also filled in the questionnaire. Among the FADN system nearly 656 farms, approximately 70% of the arable farms, responded. Nearly 110 thousand private farms and corporate enterprises operating in 2015 in the Hungarian agriculture, 0.5% of which are private farms, while 1.7% of corporate enterprises responded to the questionnaire. 45 farms among the respondents were proven precision producer (6.9%) in the operating year 2014/2015. 17 of the 45 sample farms (37.8%) took some (based on subscription, data volume) correction signal. Based on data from suppliers approximately 2,500 firms are buying RTK signal in Hungary. Since the 2.6% of the surveyed arable crop farms are registered user of companies that ensurs RTK signal and based on the suppliers'data, the rate of RTK users among agricultural enterprises is 2.3% and thus the sample of questionnaire was proven to be representative.

The aim of the study was to statistically proofthe economic benefits of the precision arable cropping. At the same time we were looking for farmers perception related to differenet aspects of PA, e.g. whether it is worth the application of precision technology for the Hungarian producers. All responses to the questionnaire were provided by farmers could be matched to the FADN databasefor cost and profit data.

The answers given to the questions were connected to the balance sheet and account plant level data the year of 2015. Since the aim of the study was to detect only the benefits of a site-specific production of arable crops, hereafter the examination is continued at the sector (crops) level, filtering the distorting effect of subsidies and land lease. The cost and income calculations are based on the national extended FADN database from 2015 maintained by the Sector Expenditure and Income Information department of the Research Institute of Agricultural Economics.

We studied re 13 cultivated plants and 45 farms. Among these farms12 produced winter wheat, 10 farms produced maize and 8 farms produced sunflower. 17 out of 45 farms had information available for a longer period, at least three years prior to the introduction of precision farming technology, and 2 years afterwards. 3-year average of 17 farms' data was the basis for the calculations in order to minimize the bias causedby weather effects. During the test, the before and after results were compared; the average of the years before the period of introduction compared to the average data for the years after the application. In case no natural data were available (pesticides, seeds) the cost of production was used as second best proxy, and in these cases the effect of price changes had to be taken into account. The pesticide and seed costs were deflated on the basis of input price index data. The adjusted data more accurately illustrate the the evolution of input costs.

Various statistical indicators were tested in case of the cultivated plants grown by the 17 precision farms compared with the control farms', to verify the hypotheses criteria (yield, production value per unit cost of production, overhead cost, sectoral profit). The indicators are: average, mode, median, the scale of standard deviation, standard deviation, minimum and maximum values, in addition, the interquartile range has also been delineated. Then, main variables were tested under asymmetry, kurtosis, and finally normality. During the normality, the significance level was determined by Shapiro-Wilk test, if it is greater than 0.05, the normality is confirmed. The result of the normality test allowed the perform of variance analysis (ANOVA), we examined the hypothesis so the use of precision technology for main cultivated plants (wheat, corn, sunflower) have additional yield and profitability advantages, in addition the production is more efficient compared to conventional cultivation.

During the research, we made the following hypotheses:

H1: The most important hindering factors for the penetration of precision farming in Hungary are the high investment costs, lack of appropriate information and advisory service.

H2: The widespread switch to the appliaction of precision fertilization and pest management would cause a decrease in the input use, which decrease the environmental pressure.

H3: Precision farming in case of the main arable plants (wheat, corn, rapeseed, sunflower) increases yield, with cost and profitability benefitscompared to current standard agronomy practices.

3 Results

Rate of application, standards, expectations

During the survey, we were intereseted about the different information sources farmers used to gain knowledge about precision- and soil conservation management.

During the interview, we touched upon the judgement for contribution of sustainability of farming technologies' environmental/economic/social, the agronomic equipments, the activity carried out with PA practices, the agronomic, technology effect on the farm, and the change of plant production. The farmers provided informations about the area cultivated by crops, using precision farming and about the technological elements applied to the plants during the season 2014/2015.

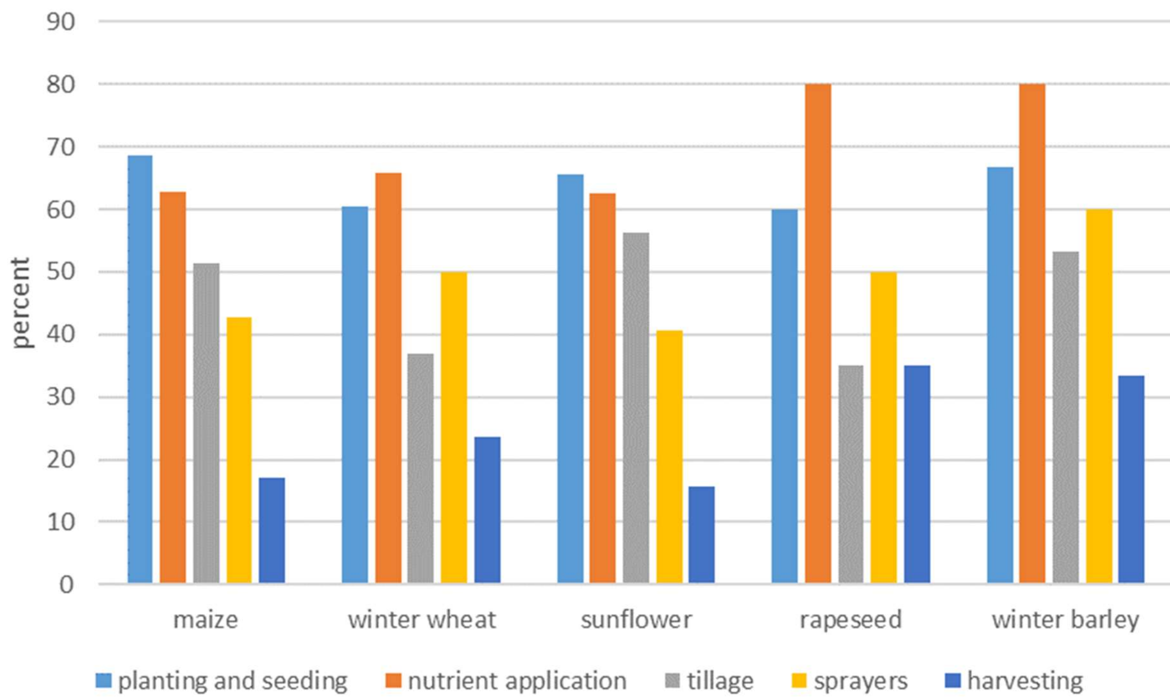
6.9% of 656 respondents (45 farms) engaged in precision farming. 31.1% of precision arable crop farms did not use GPS correction, so not capable of ± 2 cm cultivation (sowing, fertilization, etc) accuracy, 26.7% of the respondents buy annual RTK signal subscription, and 13, 3% have their own RTK base station, additional 15.6% are using different corrections from RTK. The remaining holdings (8.9%) are paid on the basis of the amount for correction, or have subscription during the campaign period (2.2%).

29.6% of the available machinery (tractors) are equipped with robot steering and 45.6% are suitable touse on-board computer. 5.7% of the tillage machines can be connected with an on-board computer and only 2.1% is suitable with depth changed cultivation workflow. 56.6% of wide row spacings drills can be connected with on-board computer, a quarter of them are suitable for variable-rate sowing, and 27.6% suitable for non-overlaping cultivation. More than half of manure-dispensing devices can be connected to a computer, 23.0% of them can rule out the overlaps, and 36.1% are enabled for variable-rate. 26.4% of the harvesters are capable for robot steering, while 15.1% for yield mapping. The number of trailed sprayers were higher than the self-propelled sprayers, whereas the ratio was reversed in precision ability. 84.2% of the self-propelled sprayers can be connected with on-board computer, 57.9% is suitable for overlap free ingredient spraying, whereas 47.4% is suitable for variable-rate (Figure 1).

88.9% carry out parcell contour recording, primarily via external services. 82.2% carry out soil sampling and soil mapping whereas 64.4% make nutrient plan. 42.2% of the farms make plant protection using drones or by walk, while only one-third of the respondents use yield mapping, which might indicate that not the yield level optimization is the only goal in general. The prevalence of precision technology in winter wheat is the highest (area, farm number).

According to the difference following the introduction, 31.1% reported a slight decrease of the specific cost, 20.0% realized more a significant decrease, 20.0% reported a slight increase. 53.3% of the respondents gave an account of a slight increase of profitability, whereas 8.9% greater increase occurred due to the technology. The labor input was not a substantive change. The labor hour cost per hectare dropped significantly at 22.2% of the sample farms. Regarding the yield 46.7% of the farms reported a slight, 13.3% reported higher increase, whereas 26.7% see no difference.

Figure 1 The share of precision technology components used in agro-technical factors in major crops



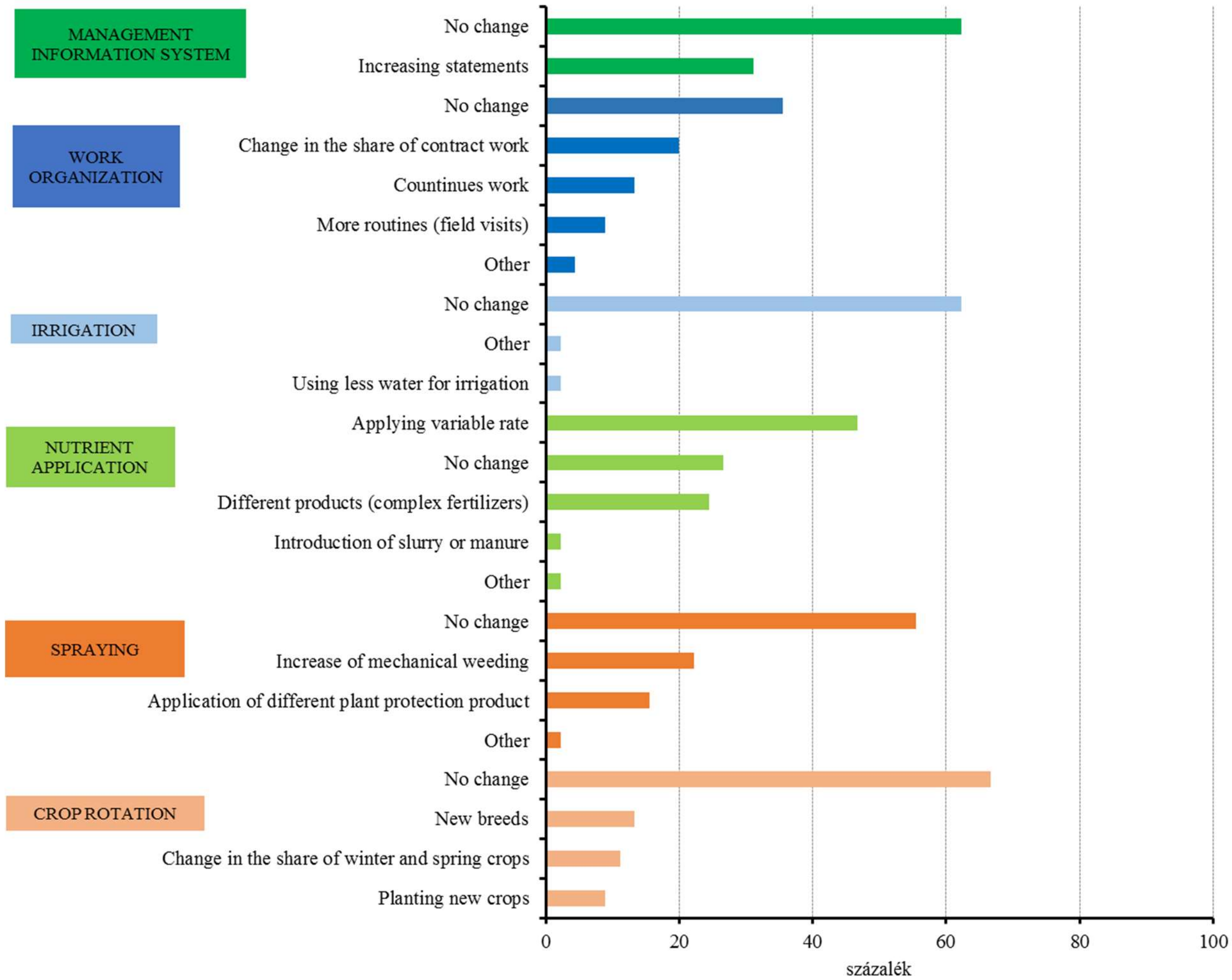
source: Own construction, based on survey data, Research Institute of agricultural Economics, Horizontal Analysis Department

In case of plant protection, more than half of the farms did not change their practice, 22.2% of the farms increased the mechanical weed control rate, 15.6% switched over to a different pesticide use. The technology resulted a various amounts active ingredient use in the nutrient supply for the majority of farms, and more farms turned to the use of different products, whereas 26.7% of respondents did not change their nutritional usage practices. (Figure 2)

Cost and profitability

Examining the results of precision technology adopters at the crop level, we found that the yields exceedsthe control group for each crop. The average total income of precision farms, with the exception of wheat and rape, are higher – by 13% in case of maize, 25% in case of winter barley, and 50 % in case of sunflower – compared to conventional farms. Both the quantity and cost of fertilizer used were higher forprecision farms, supported by literature findings, that the technology does not necessarily entails a reduction in production costs, rather results in an increase in efficiency, which implies a yield leveland associated nitrogen use that is optimal. The pesticide cost exceeded the conventional producers (ranging between 8-56%). Thus, the H2 hypothesis could not be verified (based on farming conditions of the sample examined in Hungary).

Figue 2 The effect of the introduction of precision farming



source: Own construction, based on survey data, Research Institute of agricultural Economics, Horizontal Analysis Department

The production cost exceeded the values of the control farms at different rates. In contrast, the gross margin rate surpassed the traditional farms in case of all included arable crops. The results by crops, appart from maize, also showed positive trends. For winter wheat 23%, sunflower 2%, barley 30% surplus was resulted by the use of technology, while the highest sectoral income gap was resulted at winter rape (40%). Sample farms using PA, achive 17% less income from maize. The cost of production for each farm was lower or equal. (Table 1)

Table 1. Impact of the application of PA on the most important financial figures among the 45 farms

Indicators	Winter Wheat	Maize	Sunflower	Rapeseed	Winter barley
Yield	107%	109%	110%	111%	105%
Output	113%	116%	111%	124%	113%
Total revenue	**97%**	**113%**	**150%**	**100%**	**125%**
Cost of inputs					
of which:					
seed	*86%*	*112%*	*108%*	97%	*114%*
fertilizer	*129%*	*141%*	*91%*	*131%*	*123%*
pesticide	*110%*	*156%*	*125%*	*137%*	*108%*
machinery	102%	86%	89%	100%	87%
from which:					
tractors	*96%*	*75%*	*85%*	*97%*	*78%*
Cost of production	**109%**	**123%**	**103%**	**119%**	**109%**
Gross margin	112%	101%	112%	121%	105%
Crop income	**123%**	**83%**	**128%**	**140%**	**130%**
Unit cost of main product	93%	100%	90%	99%	94%
Return on costs	110%	64%	123%	102%	124%

source: Own construction, based on sectoral FADN data, Research Institute of agricultural Economics, Horizontal Analysis Department

In case of the selected 17 farms based on the time spent on precision farming, examining the three-year average, we stated that the yield and output exceeded the values of the control group by 3-11%. The production cost of the main product was lower in case of winter wheat, corn and sunflower (17, 13 and 17%).

In all the cases, the precision cultivation technology users reached a higher gross margin and crop profit. The profit in case of maize and wheat was distinguished (44% and 59%), whereasfor sunflower the gain was 34%. Similarly to the crop income, the return on cost is significantly higher for the PA farms; by 41% at wheat, by 70% maize, and by 34% at the sunflower.

During the research, we assumed, that the introduction of precision farming results in an extra yield, cost saving and profitability advantage for arable crop producers (H3). The control of hypothesis was selected by statistical methods. The study covered 12 PAfarms and 12 conventional arable farms growing winter wheat.

The analysis included three years' data in the case of certain crops, such a multitude of sample is 36. 8-8 cases constituted the range of multitude to be tested at corn, that 24 cases can been analyzed, wheras in the case of sunflower likewise a wheat was no comparable data in one case, thus statistical analysis is realized 24 and 23 value in case of eight crops grown by precision technology.

The normality ofdifferent variables was checked using Shapiro-Wilk test, where the null hypothesis, that the completion of normality of variables, has been accepted. Since the variables followed normal distribution within the group, we had the opportunity to carry out the variance analysis. Using the ANOVA test we checkedwhether there is significant relationship between precision and non-precision multitudes under the following variables: average yield, outpute, production costs and crop profit or income. The effect of the production technology to the yield

and production cost in case of wheat and to the yield, output, crop income and production cost in case of maize and sunflower is significant (Table 2).
Accordingly, the use of precision technology has a clear impact on yield and production costs in the case of wheat. However, in case of sunflower and maize, PA has clear effect on yield, output, crop income. The yield and the production cost changed due to the application of precision technology, wherasfor outputsignificant deviation was not shown.

Table 2. ANOVA test results

Crop	Avg. yield		Output		Cost of production		Crop income		Unit cost	
	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Winter wheat	5,17	0,03	2,057	0,16	0,18	0,68	1,52	0,22	3,99	0,05
Maize	4,24	0,05	13,902	0,00	0,03	0,86	9,96	0,00	6,86	0,01
Sunflower	14,02	0,00	8,56	0,01	0,00	0,97	11,08	0,00	21,33	0,00

source: Own construction, based on sectoral FADN data using SPSS, Research Institute of agricultural Economics, Horizontal Analysis Department

Table 3. Variation explained (eta)

Crop	Avg. yield		Output		Cost of production		Crop income		Unit cost	
	η	η^2	η	η^2	η	η^2	η	η^2	η	η^2
Winter wheat	0,27	0,07	0,17	0,03	0,05	0,00	0,15	0,02	0,24	0,06
Maize	0,29	0,08	0,48	0,23	0,03	0,00	0,42	0,18	0,36	0,13
Sunflower	0,49	0,24	0,40	0,16	0,01	0,00	0,45	0,20	0,57	0,33

source: Own construction, based on sectoral FADN data using SPSS, Research Institute of agricultural Economics, Horizontal Analysis Department

The wheat producers using PA realized a higher yield per unit, and experianced lowe unit cost compared with conventional farms. Those farms who apply precision technology during corn and sunflower production, harvest significantly higher yields per hectare and relize higher profit compared to conventional arable crop farms. The production cost for this crop is also lower.
Overall, the assertion, that the precision technology, results higher return and higher profitability, while increase the efficiency thereby, that higher yield can be achieved with lower unit costis verified in the case of sunflower and corn. Lower production cost and higher yields can be observed in wheat production, the crop income is not increased significantly, so the higher profitability hypotheses was rejected.

Contributing/ impeding factors to the uptake of PA

According to the survey, the main barrier of the PA penetration is the excess investment cost (52%). 15% of the respondenzts indicated, that the technology cannot work effectively for their farm size and according to 12% of the respondents there are no adequate financialpossibilities for the additional expenditures. According to the farms response, those farms, who could not imagine the succes of the precision technology's introduction for their farm size, mostly (77.8%) cultivate smaller than 200 hectares of land. 83.6% of respondents emphasizing the lack of financing opportunities are member of small family farm, private entrepreneurs or licensed traditional small-

scale producers. The H1 hypothesis was confirmed that in the producers' view, the biggest barrier of the PA diffusion, is the high investment costs.
425 evaluable questioner arrived about the contributing factors that contributes the introduction of precision arable farming. 28.2% of the respondents indicated, that higher profitability would be the highest impetus for PA diffusion A quarter of the respondents think that more detailed informations are the most important factor. According to our survey, any benefit related to subsidy would also contribute to the broader use of PA.

Diffusion of PA – theories of innovation diffusion

Based on Rogers' (1962) typology about the diffusion of innovations, precision farmingcan be seen as an agricultural innovation and its diffusion can be described by the following steps (exploring some of the reasons for its slow diffusion in practice, based on the results of literature and our survey):

1. In the launching phase, it had an advantage over the technological elements currently 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 possibilities. Due to lack of advisory support, the process of difussion is slower. In this respect, the Hungarian practice has several positive signs, such as the successors of the production systems set up several decades ago, and the advisory networks.
3. The application of precision crop production must be considered from two views. Although the adoption of the different elements of the technology is not complex, it requires far more attention, a more complex information base and also more accurate work.
4. An important aspect letting farmers learn more and test the new technology provided by input providers. (There are several specialist, scientific exhibitions and conferences, 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.)

The motivation factors of users play 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), 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 exhibitions also can help to increase the farmers' knowledge on new technology. (Batte, M. and VanBuren, 1999; Maciejczak, 2012) Do not forget about 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, 2004; Kutter et al., 2011) The causes of the slow spreading process also include lack of education and expertise. (Attanandana, et al., 2007; Nábrádi, 2010)

In connection with the spread of innovations, particularly in the field of info-communication Gartner hyper-cycle curve is often used. Appearance of a new technology is usually associated with an increased interest, and due to the often excessive expectations after the peak of interest is almost followed by a temporary disillusionment. Its applicability is improving after refinement of the technology, benefits come to the fore instead of risks, leading to the spread of production. Looking at the Hungarian diffusion we stated, that it follows the deceleration indicated by Blackmore (2016), except that site-specific fertilizer use in Hungary widely applied, due to the complex services provided by suppliers (soil mapping, soil testing, counseling). Vehicle navigation, yield mapping and site-specific soil sampling is accepted in practice, to machinery steering, differentiated sowing and auto-section control is spreading, but the rate of spreading has not exceeded the critical mass (chasm), yet. Although the technology is already passed the innovator stage, its development is constantly going on nowadays, so there are still in R&D activities related to technology. The main reason for the differences is that the components of precision plant production technology can be used separately and connected to each other. The drones are on the peak of the current interests, the researchers are focusing on developing robots and integration opportunities of plant development models.

4 Conclusions

According to the results of our survey on the diffusion of PA in Hungary, farmers' expectation among the FADN farms and the comparision of their costs, profitability data we proved our hypothesis that one of the barriers of the low spread is the high investment (surplus) costs. This result correlates to the literature. The potential increase in profitability will facilitate the wide application of PA – if it can be observed directly –, but more and precise information is also important factor. Due to the respondents, the positive role of special agricultural grants in helping the spreading of the technology must be highlighted. Plant contour inclusion is the most frequently used item, after it the site-specific soil sampling and the nutrition.

Comparing the results of the survey to the theories of innovation diffusion it can be stated that the spreading of PA slowed despite the expectations and economic and environmental advantages (literature speaks about). The fact that most of the farmers have not realized direct increase in their profitabilty is a real barrier in wider application of more items of PA. Based on the examinations of produtction data of Hungarian FADN farms we could confirm sidnificant increase in profitability only in those farms (17) that apply high, intensive, up-to-date technologies and the optimization is the aim of PA in managgement zones. The advantages of precision technology depend on weather conditions of the certain cropping year, the soil conditions (heterogenity) and the level of production and management in a big way. The advantages of more precise cropping are traceable in unfavorable periods and fields, where limited yield and profitability can be realized with conventional farming comparing the potential yield. The increase in yield goes hand in hand with the increase in input use (i.e. cost increase). The main reason is the relatively low input use in fertilizers, pesticides in Hungarian FADN farms.

The cost of wheat production is exceeded the conventional production technologies users by -3-+47 %, in corn -5-+30 % and in the case of sunflower by -8-+26 %. The increase in input chemical use can be the interest of the distributors in supporting the spread of the technology beside the machinery distributors. We should also mentione that this higher input use – due to the optimized usage in management zones – is applied and utilized by the crop, so the rate of environment pollution can be decreased.

From the factors affecting the diffusion of PA the direct advantages should be emphasised, like in cost efficiency in the context of profitability, resepectively. The communication to farmers of the indirect, less visible effects and the quantification should be the task of all participant, including the distributors, experts, members of extension services, farmers who have good experiences and ag politicians. The site-specific farming can be applied in medium sized or in small farms with success, partly based on own equipment or partly in the frame of shared economy, common machinary usage (i.e. machinary rings) and of course by services.

The implementation of special sudsidies of site-specific crop production into the "greening" component of CAP will be an incinting factor for supporting the wider spread of PA, wider usage of more components of the technology. Innovative organizational behaviuor goes ahead that indicates that with appropriate information the producers the advantages and importance of site-specific crop production (teaching, extension, experiences spread by "unwritten tradition"), strengthening the trust of cooperation and feeling for the novelty needs new managarial skills and thinking. More services at acceptable price, different common machinary usage forms also support wider spread of PA.

Our opinion is that precision crop production can be one of the means of enhancing the green component, as environmentally friendly farming practice, drafted within the direct subsidy system of Common Agricultural Policy proposed for the coming planning period. The greening impact – the decreasing substance use measured in chemicals – can be greater than savings that can be reached by leaving the land fallow, because this prefers marginal areas where chemical use is originally lower.

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