Possibilities and concerns of implementing precision agriculture technologies on small farms in Slovenia

Jurij Rakun*, Erik Rihter, Damijan Kelc, Stajnko Denis, Peter Vindiš, Peter Berk, Peter Polič, Miran Lakota

(*Faculty of Agriculture and Life Sciences, University of Maribor, Pivola 10, 2311 Hoče, Slovenia*)

Abstract: Precision agriculture (PA) through the use and utilization of innovative technologies is a concept in agricultural management that enables long-term efficiency gains, control of unforeseen changes, and a reduction of negative impacts on the environment. However, there are even more reasons and benefits to using precision agriculture technologies (PATs) on farms, but the actual use on small farms is often questionable. The main objective of this research was to evaluate and analyze the current state of PA and its potential on a set of small farms. In addition, a comparison was made between small farms located in less favored areas (LFAs) and more favored areas (MFAs) to find if specific characteristics of the surrounding environment affect the (non-) implementation of these technologies by farm owners, with respect to the given regional possibilities. The result shows that 57.5% of respondents on these farms have never implemented PATs before and 20% are beginners in their respective fields. It was found that there were no statistically significant differences in the integration between fewer LFAs and MFAs technologies and their use in this study. The majority of respondents believe that the main changes need to occur on the level of politics. The results show that the level of cost or initial investment is the main reason and the main obstacle in the implementation of PATs on the surveyed farms.

Keywords: precision agriculture, small farm, technological innovations, implementation, situation overview, survey, ICT
DOI: 10.25165/j.ijabe.20221503.6111

Citation: Rakun J, Rihter E, Kelc D, Denis S, Vindiš P, Berk P, et al. Possibilities and concerns of implementing precision agriculture technologies on small farms in Slovenia. Int J Agric & Biol Eng, 2022; 15(3): 16–21.

1 Introduction

Over the last few decades agriculture has undergone tremendous changes[1]. The globalization of the world economy and population growth, with the associated increased demand for food, has increased the negative impact of agriculture on the environment[2]. To address these challenges via creating technological innovations in agriculture over the last two decades, new default concepts have been created in systems that, unlike traditional agriculture, offer a higher level of farming with a less negative impact on the environment[3].

One of these concepts is precision agriculture, which selects processes and analyses individual temporal and spatial data and combines them with other information to support management decisions on the estimated variability of agricultural production[4,5]. The basic principle of PA is to maximize the efficiency of inputs that are intended to increase farm yields and reduce production costs. The efficiency of the inputs is then measured by the output results. In addition to the latter, different authors also cited quality optimization, reduction of environmental impact, and risk reduction[6]. PA involves several technological tools that involve three application processes: collecting information input, processing precision information, and prescribing recommendations for input applications[7]. Precision agriculture technologies focus on the management of in-field heterogeneity[8-11].

A systematic review of studies examining the economic[12-15], agronomic[13-16], and environmental benefits[5] of adopting PATs has revealed that there are at least four main reasons for choosing these technologies. PATs enable selecting processes, analyzing individual temporal and spatial data, and combining them with other information to support management decisions on estimated variability in agricultural production management of spatial variability of fields, providing precise input or addition of nutrients, a more precise application of plant protection products and the automatization of work processes, which reduces labor costs[12].

Economic benefit, according to Adrian et al.[13], plays a major role in the decision of using these technologies. Still, the decision is also influenced by other factors such as socio-economic determinants. Several researchers confirmed that farm size played an important role in PATs adoption. Countries with larger farms are more likely to adopt and use PATs than countries with smaller farms. Paustian and Theusten[17] found that the size structure of the farm (less than 100 hm^2) has a negative impact on adoption decisions. The acceptance of PATs in farms is also related to the economic volume and the volume of agricultural production.

Received date: 2021-04-07 **Accepted date:** 2022-02-11
Biographies: Erik Rihter, MSc, Researcher, research interest: precision agriculture, ICT in agriculture, Email: erik.rihter2@um.si; **Damijan Kelc**, PhD, Assistant, research interest: precision agriculture, irrigation systems, renewable energy, agricultural machinery, Email: damijan.kelc@um.si; **Stajnko Denis**, PhD, Full Professor, research interest: agricultural machinery, precision agriculture, renewable energy, Email: denis.stajnko@um.si; **Peter Vindiš**, PhD, Assistant Professor, research interest: biogas, precision farming, agriculture machinery, Email: peter.vindis@um.si; **Peter Berk**, PhD, Assistant Professor, research interest: precision agriculture, agriculture machinery, Email: peter.berk@um.si; **Peter Polič**, PhD, CEO, research interest: electronic, precision agriculture, agricultural machinery, Email: peter@polic.si; **Miran Lakota**, PhD, Associate Professor, research interest: automatization and digitalization techniques in agriculture, agricultural robotics, Email: miran.lakota@um.si.

***Corresponding author: Jurij Rakun**, PhD, Assistant Professor, research interest: digital signal processing, computer, vision, pattern recognition, field robotics. Faculty of Agriculture and Life Sciences, University of Maribor, Pivola 10, 2311 Hoče, Slovenia. Tel: +386-2-3209000, Email: jurij.rakun@um.si.

Farms with higher yields are more likely to accept PATs than farms with lower yields[13-15].

Farm owner characteristics also influence the adoption and implementation of PATs. As age increases, the likelihood ratio of accepting PATs decreases, while higher education among farmers makes them more likely to accept PATs. Familiarity with computers is also important in explaining PA adoption[18]. In the study by Daberkow and McBride[19] it was found that factors such as computer literacy, full-time farming job, farm size, farm type, and farm location collectively represent a measure of perception that PA is a profitable technology. Meanwhile, younger farm owners often have a higher level of formal education. They are more skilled in farm management and often more technology development-oriented, which affects the introduction of new technologies and their experimentation with PATs[17]. Similar conclusions were also reached by researchers in Poland[20], where 100 farm owners were surveyed. They found that PATs are more popular among farmers who are less than 40 years old, have a higher level of education, and manage larger farms.

Many studies in Europe have evaluated the level of implementation and perception of PA in relation to a specific region. Studies have also focused on the functionality of PATs. Paustian and Theuvsen[16] studied PAT adoption in Germany, Van der Wal et al.[21] analyzed the development of PA in the Netherlands, and Barnes et al.[11] conducted an interregional study on the introduction of PATs in five European countries (Belgium, Germany, Greece, the Netherlands, and the United Kingdom). Their common research question was which factors significantly influence the adoption and implementation of PA. The European Parliamentary Research Service[22] concluded that the use of PATs has increased since 2000 in European agriculture. Despite a wide range of technological solutions, only 25% of farms in Europe included PA components. One of the critical questions has arisen about the correlation between farm size and the benefits of these technologies. An obstacle to more mass implementation in the European Union (hereafter EU) and the creation of an appropriate common agricultural policy is the wide diversity of European agriculture and its specific structures[22]. The experts also stressed the question of the image of future agriculture and PA[22]. Studies have mentioned the current gap in farm modernization, innovative approaches, and the use of PATs, which remains below expectations and is spreading unevenly across the EU[23,24].

The awareness and implementation of new technologies in agriculture, which also includes PAT, is reflected in numerous factors in a specific smaller area, such as on a farm, at the national or even international level[25]. Based on the reviewed scientific research, the following factors also influence the level of adoption and implementation of PAT on farms. In addition to the features of the farm (size, type, ownership, specialization)[9,15,16,25], social interaction also plays an important role at the local level. The authors[22,25-27] mention that regional cooperation and more favorable human relations (e.g. trusted friends) significantly impact using of new technologies in agriculture. The European Parliamentary Research Service[22] highlight the importance of the features (availability of technologies, easiness of use, systems compatibility) of PATs. Studies mention the impact of adoption as a relation to the number of supporting institutions and firms[25,28], political support (legislation, measures, strategic plans, vision)[25,29], and multidisciplinary cooperation (active participation of all stakeholders in PA)[25,29]. For the faster implementation of PATs, farmers and cooperatives must play an important role in research and innovation where the use of technologies needs to be validated and demonstrated in practice in different agricultural activities and geographical areas of farms. PATs must be developed or adapted to assess economic benefits, taking into account the geographical region, the method of production, and socio-economic variability. PATs should be easy to use, affordable, robust, and designed for both small and medium-sized farms. Regional training and awareness-raising are essential for the achievements of farms, advisers, and other actors[30]. According to official statistics[31], the average farm owner is old and not keen on new technologies. Moreover, in most cases, these farm owners already have a younger succeeding farm manager who helps to run the farm or has already unofficially taken over. As they grew up with technology, they have a better understanding of PATs and the supporting technologies. Thus, including the exact demographic pool in the survey could cause a bias and give a false impression.

On a European scale, Slovenia is one of the countries with the most challenging production conditions in terms of areas with limited factors for production, as the location of many farms is in less favored areas[31]. Compared to the vast majority of EU countries, farms in Slovenia are small. The average farm size in Slovenia in 2016 was 6.9 hm^2. According to statistics, in 2016, the average age of a farm owner was 57 years. Regarding the educational structure: the share of farmers with various forms of formal agricultural education is increasing, as is the percentage of those who have completed a professional qualification in agriculture[32].

With these facts in mind, the main objective of this research was to evaluate and analyze the current state of PA and its potential on a set of different small farms in Slovenia with a special focus whether farm locations in less favored areas (hereafter LFA) or more favoured areas (hereafter MFA) play a role in the adaptation of PATs. This research is also set to answer why farm owners are reluctant to invest in PATs and how certain specific characteristics of the country's agriculture affect the (non-) implementation of these technologies by farm operators. It is assumed that most of the surveyed farmers, mainly due to the specific characteristics of the area, do not yet use innovative PATs on their farms nor are they beginners in this field. Given the special features of the area, it is assumed that farm owners believe that agricultural policy should be changed and adapted to make PA more established.

2 Materials and methods

2.1 Study design

The data of the respondents was collected with an online survey as part of the Interreg Central Europe project Transfarm 4.0 in the period from 12 August to 18 October 2019 from forty random farms in Slovenia, that provided insight into the condition or position of farm owners with regard to implementation and PA. Online surveys were also conducted by partner countries (Austria, Hungary, Poland, and parts of Italy). The online survey, done with the help of Google Forms, was chosen in order to sample the current state and opinion of farm owners who are information and communication technology (hereafter ICT) literate, which is usually one of the prerequisites to use PATs.

Due to the scale of the project survey, which was generally related to farm owners' requirements for technological innovation in agriculture, the focus is only on issues that are relevant to this

research. The first part of the survey included nine questions about the characteristics of farm owners and their farms. There were seven close-ended expert questions where farm owners were surveyed about views on PA. Three more open-ended questions were added to the survey. It should be pointed out that farm owners were surveyed in this study. However, due to the area's specific characteristics under consideration, farm owners perform several functions on their farms simultaneously (managers, operators, owners, administrators). The main reason for this is that Slovenia is dominated by family farms, where, for financial reasons, farms cannot afford to have one person performing just one function on the farm. Thus, functions remain primarily at the level of family members, with younger members - who are more computer literate, assisting older members, especially in the use of ICT and new technologies on the farm.

With the help of SWOT analysis, the current situation, and the guidelines for the development of PA in the research area are summarized. To answer these, the survey included questions looking for proposals for a faster, better, and more efficient implementation of PA in the study area. The purpose of the survey analysis is to help decision-makers in making strategic decisions on the use of PATs in the future and to support further research in this area.

2.2 Statistical analysis

The answers to the survey were exported and processed in MS Office Excel and statistically processed with the IBM SPSS 25 software package. The results are presented in 2-dimensional contingency tables, structural circles, and columns and were processed via a fundamental statistical analysis (descriptive statistics).

3 Results and discussion

Forty farm owners from different regions responded and completed the online survey. The sample was dominated by male farm owners (67.5%). Most of the respondents belong to the age group of 20-49 (70%), and 6 (15%) were in the 50-59 and 60-69 years age groups. As Table 2 shows, out of a total of 40 respondents, 33 (82.5%) have university degrees. 23 (57.5%) of farmers own farms smaller than 10 hm^2. 8 (20%) farms belong to the size group of 10-19 hm^2. 4 (10%) farms are in the 30-49 hm^2 size group and 3 (7.5%) farms are in the 50-99 hm^2 size group. The average size of the surveyed farms is 19.68 hm^2.

Table 1 shows that out of a total sample of forty farms, 12 (30%) respondents are full-time employees on their farms, out of which 66.7% have already implemented PATs, according to the additional questions from the survey. The remaining 28 (70%) respondents are only part-time employees on their farms and 17.9% of them have already implemented PATs. Paustian and Theusten[17] found in their research that 34% of full-time employees on their farms were PATs adopters and only 11% of part-time farmers were PATs adopters.

The results of the online survey are comparable to the results of the partnering countries. The sample size for each country was between 33 and 77. The situation regarding the age of farm owners in other surveyed countries is similar. This may point to the fact that farm owners in the age groups 50-59 and 60-69 are slowly losing interest in adopting PATs and they belong to a generation that is slowly retiring. Reasons, why online surveys were not completed by several farm owners in the mentioned age groups may also be that digital technologies on farms are managed/used by younger members who are more ICT literate.

Table 1 Structural percentages of respondents

Item	Group	F (%)
Gender	Male	27 (67.5)
	Female	13 (32.5)
Age	20-29	6 (15)
	30-39	14 (35)
	40-49	8 (20)
	50-59	6 (15)
	60-69	6 (15)
Education	Primary school	1 (2.5)
	High-school education	5 (12.5)
	University education (University degree, Bachelor, Master, PhD)	33 (82.5)
	Other: Professional, Master (not university)	1 (2.5)
Farm size	Under 10 hm^2	23 (57.5)
	10-19 hm^2	8 (20)
	20-29 hm^2	1 (2.5)
	30-49 hm^2	4 (10)
	50-99 hm^2	3 (7.5)
	100-200 hm^2	1 (2.5)
Less favored areas (LFA)	Yes	24 (60)
	No	16 (40)
Farm type	Full-time	12 (30)
	Part-time	28 (70)

3.1 Use of precision agriculture technologies

One of the questions was related to the level of use of PATs by farm owners. The question was: "to what extent do you agree with the following statements about PATs?" The respondents had to self-evaluate the use of PA and they had to choose 1 out of 6 survey statements shown in Table 2.

Table 2 Distribution of respondents, according to the interest or use of PATs

Questions	F (%)
I am not interested in PA	3 (7.5)
I do not use PAT yet, but I probably will in the near future	23 (57.5)
I have been using PA applications on my farm recently	5 (12.5)
I am a beginner at PA, but I want to become a professional in the field	8 (20)
I am an advanced user of PA applications but not a professional	1 (2.5)
I have been a professional user in the field of PA for many years now	0 (0)

The highest percentage (57.5%) of responses indicate that the participants do not use PATs yet, but they will probably use them soon. Almost a fifth (20%) of respondents used these technologies, but they are barely beginners. As shown in Table 3 (12.5%) respondents have used PA applications on their farms recently. There are no professional users in our research.

Comparing these results to the average results of the whole Interreg Central Europe project Transfarm 4.0 group; 15% of the partner countries are beginners in the use of PATs but want to become professional users, in comparison to 20% in this pool of respondents, so the results are very comparable. Also, when asked about interest in implementation, on average 10% of respondents in all partner countries answered that they were not interested in using these technologies at all, compared to 7.5% in this pool of respondents.

The results of frequency use of PATs are also comparable with the results of the research by Paustian and Theusten[17] wherein the group of small farms (1-99 hm^2), only 9% were adopters of PATs. The study of Borusiewicz et al.[20] on the other hand, analyses the necessity of PA, where 64% of the respondents think PA is necessary and 10% that it is not, out of which the majority are older than 50 years of age.

3.2 Methods and potential of precision agriculture

To evaluate the potential of specific methods in PA, we listed seven PA methods in a survey question. Respondents were able to select or determine the level of potential among the four options of specific PA methods. The question was: "how would you evaluate the potential of the following PA methods for the future management of your farm; to have no potential, to have low potential, have high potential, or have very high potential?".

Table 3 Methods of precision agriculture and their potential according to the respondents (%)

PA method/process	a	b	c	d
Site specific organic fertilization	8	20	42	30
Site specific mineral fertilization	13	15	34	38
Site specific tillage	10	10	47	33
Site specific sowing	10	18	44	28
Site specific chemical plant protection	5	18	37	40
Site specific mechanical plant protection	15	30	35	20
Adequate irrigation	20	23	29	28

Note: a: No potential; b: Low potential; c: High potential; d: Very high potential.

According to the respondents, all PA methods generally have potential. The "Site specific tillage" method had the highest potential in terms of survey results. As shown in Table 3, respondents see the potential in the "Site specific chemical plant protection method". Respondents are most sceptical when it comes to "Site-specific mechanical plant protection" and "Adequate irrigation". Other methods generally have the same percentage of potential according to respondents.

3.3 The impact of advantages and disadvantages of PATs properties

For the evaluation, we prepared questions for the respondents about the advantages and disadvantages of PATs properties. The respondents had to choose between five answers. They determined the level of inhibition or the level of promotion for the use of PATs. The question was "how do you assess the impact of the following properties of PATs on the better promotion of PA?".

Table 4 The impact of advantages and disadvantages of PATs according to the respondents (%)

Properties	a	b	c	d	e
Initial investment	38	49	5	8	0
Compatibility of different systems	15	34	20	28	3
Operation costs	15	59	23	3	0
Manufacturer service	15	47	23	15	0
User friendliness	5	27	5	55	8
Reliability of the systems	5	27	5	45	18
Data handling	8	29	10	40	13
Traceability of working processes	5	15	20	50	10
Facilitation of documents	3	16	10	38	33
Improving the quality of work	3	19	2	38	38
Reduced workload	8	11	3	18	60

Note: a: Strongly inhibiting; b: Slightly inhibiting; c: Undecided; d: Slightly promoting; e: Strongly promoting.

The results show that respondents are most undecided in "Operation costs" and "Manufacturers service" with a tendency of being strongly or slightly inhibiting. According to the respondents, the "Initial investment" is the highest-ranked reason for the decision not to use PATs. "Operation costs" is also an important obstacle. Respondents are also sceptical about the manufacturer's service. As shown in the table, "Reduced workload" is the greatest motivation to use PATs. Generally, respondents are of the opinion that "User-friendliness", "Reliability of the systems", "Data handling" and "Traceability of working processes" accelerate PATs use.

Looking beyond the presented group of respondents, the situation is generally similar in all the partner countries in the Transfarm 4.0 group, where it is necessary to point out that the most significant inhibiting constraints are "Operation costs" and "Initial investment" for farm owners to undertake the purchase.

By comparing this study to other works, similar conclusions can be observed. The study by Fountas et al.[9] focuses on the PA's current status for farmers in Denmark and the Eastern Corn Belt, USA. They found that the respondents think that high costs, lack of time, and technical knowledge are the most important factors in the (non)-implementation of PATs.

3.4 Differences between farms located in less favorable areas and farms in more favorable areas

Less-favorable areas (LFA) is a term used to describe an area with natural handicaps, such as lack of water, climate, short crop season, tendencies of depopulation, hilliness, or mountainous terrain, as defined by its altitude and slope, within the EU[33]. LFAs affect the production capacity of a farm, which is less competitive due to its natural characteristics and has less flexibility. In Slovenia, up to 75.4% of surfaces are defined as LFAs[30]. In this study, 60% of farms are located in LFAs and 40% in MFAs. The question was "Which of the following PATs do you use to manage your farm?". Table 5 shows the differences in the use of PATs in the mentioned areas.

Table 5 Connection between the use of PATs with less or more favored areas

Precision agriculture technologies	Use of precision agriculture technologies/%	
	LFAs	MFAs
Platforms (applications)	15.0	10.0
GPS systems	2.5	2.5
Sensors	5.0	2.5
Precision irrigation systems	2.5	2.5
Precision spraying technologies	2.5	2.5
Precision fertilization technologies	2.5	2.5
Precision tillage and planting technologies	0	0
Farm management and information systems	5.0	2.5

Note: LFAs: Less favored areas; MFAs: More favored areas.

In general, the results show that respondents from all PATs, most often use platforms or applications. The reason why farm owners use platforms (applications) the most out of all given technologies may be because they can use them in all agricultural processes and activities. Precision tillage and planting technologies were not used by anyone participating in the research, but have the highest potential according to subsection 3.2. The usages of other technologies, as shown in Table 5, are very similar to each other. Table 6 indicates that there are no statistically significant differences between the use of PATs in LFAs and MFAs in the study. This means, that the area of use does not affect the adoption of PATs but in general lies in the interest of the current/future user(s) that perceive at least some advantages of PATs in the area where they farm.

3.5 Impact of individual participating stakeholders

The listed participating stakeholders have a major impact on the adoption and implementation of PATs. There were multiple questions with several different responses offered. The question was "which of the following stakeholders do you consider to have the major impact on the adoption and implementation of PATs?".

The answers of the respondents are shown in Figure 1.

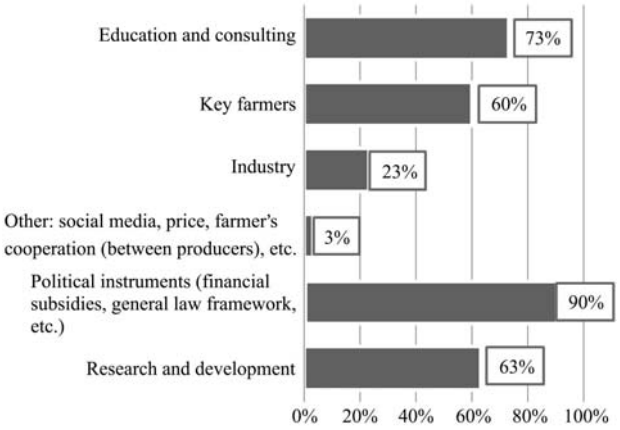

Figure 1 Impact of individual participating stakeholders on the wider (non) implementation of PATs in practice

The majority of respondents (90%) believe that for mass implementation of PATs, the biggest change needs to occur within policies. Furthermore, a large percentage (70%) of respondents believe that appropriate education and counselling would contribute to a more successful implementation of PAT. Just over half of the respondents believe that research, development (63%), and key farmers (60%) have a significant impact on the adoption and implementation of PATs. Key farmers (see Figure 1) are farmers that are educated in the area of PATs and know the technology. Their knowledge is passed on to other farmers that intend to learn and implement the knowledge in their work process.

The results of this survey are comparable to those of the other partner countries. Respondents in partner countries had similar views as the respondents participating in our study. The impact of education and counselling was chosen by 60% of the respondents, and the same percentage applies to the impact of policy instruments.

3.6 SWOT analysis

Table 6 lists the SWOT analysis created based on the study. Four aspects are presented in the analysis, where four benefits are listed as strengths and opportunities, and weaknesses and threats are listed as barriers to PA in the research area according to the respondents.

Table 6 SWOT analysis of precision agriculture in the research area

Strengths	Weaknesses
Farm owners are becoming more aware of the potential of PATs. The research area does not significantly lag behind the average of other partner countries in the use of PATs. More than 75% of farm owners are already educated about PATs. There is more and more research development and talk about PATs.	Do not know all the benefits of PATs PATs require a high initial investment. Complex and unreliable PATs.
Opportunities	**Threats**
Accelerate sustainable agriculture through technological development. Interaction of farm owners with ideas/solutions. Optimization of agricultural work, processes, reduction of environmental impact, management of uncontrolled changes, and support decision-making.	Questionable willingness and maturity of farm owners for the implementation of PATs. Complex quantification of PATs advantages. Questionable knowledge about open opportunities or fear of farm owners' interactions. Prejudices of farm owners about the maintenance costs of PATs.

Based on the literature review, there are a lot of positive policy changes and development programs for PATs in the research area. There are positive EU guidelines for funding in this area for the coming period (2021-2027). The development concepts (action plans, strategies, resolutions) are also proactive. Threats and weaknesses in the research area represent the likelihood of the farmers using subsidies only as a source of income and not exploiting the real benefits of PATs.

4 Conclusions

This study provides insights into the state of PATs in small farms with characteristics such as being located in LFAs or non-LFAs and fragmented farms in the country. The study identifies which farmers are implementing PATs and what are the main reasons that they may not use these technologies. The results show that 57.5% of respondents have never implemented PATs before, but plan to use them in the near future. Out of all respondents, 20% are beginners in this area, so they have already started to implement it. The level of costs or initial investment is the main reason and the main obstacle in the implementation of PATs on farms. If start-up costs were lower, farm owners would be more likely to implement innovative PATs on their farms. Respondents in this study are sceptical about the cost of operating or maintaining these technologies. In comparison, the results show that the main advantages of PATs, according to the respondents, are a reduced workload, improved quality of work, and the facilitation of documents. While determining the potential of individual methods of PATs, it was found that, according to the respondents, all methods have a similar potential. Still, the methods of the site-specific tillage and the site-specific chemical plant protection stand out in terms of potential for use.

The majority of respondents believe that the most should be changed in political instruments, the latter as many as 90% of all respondents. According to the respondents (73%), non-implementation is also influenced by education and consulting. At this point, it is assumed that farmers are being made aware of and involved in many programs and incentives implemented at an agricultural policy level to develop PA. 60% of farms in this research are located in LFA and 40% in MFA. There were no statistically significant differences in the integration between fewer LFAs and MFAs of technologies and their use in the study. Respondents use approximately all the given PATs technologies in the survey to the same extent, but mostly use different platforms (applications) for agricultural activities.

The use of PATs on small farms is often questionable. There are usually some hesitations regarding the introduction of PATs usage and their financial eligibility. There is often a lack of financial resources, cooperation, and knowledge of these technologies. Implementation will certainly increase gradually in the future. The implementation will slowly become self-evident, not only on large farms but also on small farms. More and further research will be needed in this area to follow these trends and act accordingly in order to support PATs in real use.

This study can help future research and development activities, especially in countries with small farms. This can provide information for better and cheaper technological solutions. The greatest efforts will focus on integrating and launching more mass use of available PATs on farms. In the future, we plan to re-explore and compare the state of implementation of PATs in the region. Based on this research, one of the priority pillars of the Smart Specialisation Strategy (S3/S4) is being prepared, which represents

one of the key roles for strengthening and upgrading the Slovenian innovation ecosystem.

This study had some limitations, e.g. the number of respondents, but still, the results are comparable to the results of the surveys done by the project partners in the participating countries.

Acknowledgements

This work was funded by the INTERREG CE program, Transfarm 4.0 project, under the index number CE1550.

[References]

[1] Wang M H. Possible adoption of precision agriculture for developing countries at the threshold of the new millennium. Computers and Electronics in Agriculture, 2001; 30(1–3): 45–50.

[2] Weick C W. Agribusiness technology in 2010: Directions and challenges. Technology in Society, 2001; 23(1): 59–72.

[3] Robertson M J, Lewellyn R S, Mandel R, Lawes R, Bramley V, Swift L, et al. Adoption of variable rate fertiliser application in the Australian grains industry: status, issues and prospects. Precision Agriculture, 2012; 13(2): 181–199.

[4] Raza U, Salam A. Zenneck waves in decision agriculture: An empirical verification and application in EM-based underground wireless power transfer. Smart Cities, 2020; 3(2): 308–340.

[5] Kviz Z, Kroulik M, Chyba J. Soil damage reduction and more environmental friendly agriculture by using advanced machinery traffic. Agronomy Research, 2014; 12(1): 121–128.

[6] International Society for Precision Agriculture. ISPA Forms Official Definition of 'Precision Agriculture', 2019. Available: https://www.precisionag.com/market-watch/ispa-forms-official-definition-of-precision-agriculture/. Accessed on [2020-07-02].

[7] Earl R, Wheeler P N, Blackmore B S, Godwin R J. Precision farming - the management of variability. The Journal of the Institution of Agricultural Engineers, 1996; 51: 418–423.

[8] Hrubovcak J, Vasavada U, Aldy J E. Green technologies for more sustainable agriculture. Agriculture Information Bulletin, No. 752, Economic Research Service, US Department of Agriculture, Washington, DC, 1999.

[9] Fountas S, Blackmore S, Ess D, Hawkins S, Blumhoff G, Lowenberg-Deboer J, et al. Farmer experience with precision agriculture in Denmark and the US eastern corn belt. Precision Agriculture, 2005; 6: 121–141.

[10] Reichardt M, Jürgens C. Adoption and perspective of precision farming (PF) in Germany: Results of several surveys among the different agricultural target groups. Precision Agriculture, 2009; 10(1): 73–94.

[11] Barnes A P, Soto I, Eory V, Beck B, Balafoutis A, Sánchez B, et al. Exploring the adoption of precision agricultural technologies: A cross regional study of EU farmers. Land Use Policy, 2019; 80: 163–174.

[12] Koutsos T, Menexes G. Economic, agronomic, and environmental benefits from the adoption of precision agriculture technologies. International Journal of Agricultural and Environmental Information Systems (IJAEIS), 2019; 10(1): 40–56.

[13] Adrian A M, Norwood S H, Mask P L. Producers perceptions and attitudes toward precision agriculture technologies. Computers and Electronics in Agriculture, 2005; 48(3): 256–271.

[14] Smale M, Heisey P W. Simultaneous estimation of seed-fertilizer adoption decisions: An application to hybrid maize in Malawi. Technological Forecasting and Social Change, 1993; 43: 353–368.

[15] Isgin T, Bilgic A, Forster L, Batte M T. Using count data models to determine the factors affecting farmers' quantity decisions of precision farming technology adoption. Computers and Electronics in Agriculture, 2008; 62(2): 231–242.

[16] Paudel K, Pandit M, Mishra A, Segarra E. Why don't farmers adopt precision farming technologies in cotton production? 2011 AAEA & NAREA Joint Annual Meeting, 2011; pp.24-26. doi: 10.22004/ag.econ.104828.

[17] Paustian M, Theuvsen L. Adoption of precision agriculture technologies by german crop farmers. Precision Agriculture, 2017; 18(5): 701–716.

[18] McBride W D, Daberkow S G. Information and the adoption of precision farming technologies. Journal of Agribusiness, 2003; 21(1): 21–38.

[19] Daberkow S G, McBride W D. Farm and operator characteristics affecting the awareness and adoption of precision agriculture technologies in the US. Precision Agriculture, 2003; 4(2): 163–177.

[20] Borusiewicz A, Kapela K, Drozyner P, Marczuk T. Application of precision agriculture technology in Podlaskie Voivodeship. Agricultural Engineering, 2016; 20(1): 5–11.

[21] Van der Wal T, Vullings L A E, Zaneveld-Reijnders J, Bink R J. Doorontwikkeling van de Precisielandbouw in Nederland. Wageningen Environmental Research Rapport, 2017; 94p.

[22] European Parliament. Precision agriculture and the future of farming in Europe. European Parliamentary Research Service (EPRS). Scientific Foresight Unit (STOA), 2016. Available: https://www.europarl.europa.eu/RegData/etudes/STUD/2016/581892/EPRS_STU(2016)581892_EN.pdf. Accessed on [2020-04-01].

[23] European Commission. The Common Agricultural Policy at a Glance. The Common Agricultural Policy Supports Farmers and Ensures Europe's Food Security, 2018.

[24] Massot A. The common agricultural policy (CAP) and the Treaty, 2019. Available: https://www.europarl.europa.eu/factsheets/en/sheet/103/the-common-agricultural-policy-cap-and-the-treaty. Accessed on [2020-04-09].

[25] Say S M, Keskin M, Sefri M, Sekerli Y E. Adoption of precision agriculture technologies in developed and developing countries. The Online Journal of Science and Technology, 2017; 8(1): 41–49.

[26] Rogers E M, Singhal A, Quinlan M M, Stacks D W (Ed.), Salwen M B (Ed.), Eichhorn K C (Ed.). Diffusion of innovations. An Integrated Approach to Communication Theory and Research (3rd ed.). Abington: Routledge, 1983. Available: https://doi.org/10.4324/9780203710753-35. Accessed on [2020-05-02].

[27] Burgess P J, Morris J. Agricultural technology and land use futures: The UK case. Land Use Policy, 2009; 26(1): 222–229.

[28] Edwards-Jones G. Modelling farmer decision-making: Concepts, progress and challenges. Animal Science, 2006; 82: 783–790.

[29] Bahr C, Forristal D, Fountas S, Gil E, Greiner G, Hoefarter R, et al. EIP-AGRI Focus Group Precision Farming. Final Report, 2015. Available: https://www.researchgate.net/publication/289345187_EIP-AGRI_Focus_ Group_Precision_Farming_FINAL_REPORT/references, 1993. Accessed on [2020-05-20].

[30] Travnikar T, Bedrač M, Bele S, Brečko J, Cunder T, Kožar M, et al. Slovensko kmetijstvo v številkah. Kmetijski inštitut Slovenije, 2019. Available: https://www.kis.si/f/docs/Slovensko_kmetijstvo_v_stevilkah_OEK/KIS_Slovensko_kmetijstvo_v_stevilkah_2019_SLO_splet_.pdf. Accessed on [2020-05-16].

[31] SURS Statistični urad Republike Slovenije. Število in sestava prebivalstva, Slovenija, 2016. Available: https://www.stat.si/StatWeb/Field/Index/17/104. Accessed on [2020-05-27].

[32] SURS Statistični urad Republike Slovenije. Struktura kmetijskih gospodarstev, Slovenija, 2016. Available: https://www.stat.si/StatWeb/News/Index/6742. Accessed on [2020-05-28].

[33] Glossary of Statistical Terms. Less-favoured area (LFA), 2011. Available: https://stats.oecd.org/glossary/detail.asp?ID=1520. Accessed [2020-04-17].