THE ATTITUDE OF AGRONOMISTS AND FAMILY FARMERS ON THE USE OF SATELLITE TECHNOLOGIES IN AGRICULTURE

Ruzica Loncaric
Faculty of Agrobiotechnical Sciences Osijek, V. Preloga 1, Osijek, Croatia
ruzica.loncaric@fazos.hr

Vedran Stapic
Agroklub Ltd., Sv. Leopolda Bogdana Mandića 157, Osijek, Croatia
vedran@agroklub.com

Vinko Bozic
Centre for Applied Life Science Healthy Food Chain Ltd., V. Preloga 1, Osijek, Croatia
vbozic@fazos.hr

Ivona Uzelac
Centre for Applied Life Science Healthy Food Chain Ltd., V. Preloga 1, Osijek, Croatia
ikucera@fazos.hr

Mario Relatic
Agroklub Ltd., Sv. Leopolda Bogdana Mandića 157, Osijek, Croatia
mario.relatic@gmail.com

Sanja Jelic Milkovic
Faculty of Agrobiotechnical Sciences Osijek, V. Preloga 1, Osijek, Croatia
sajelic@fazos.hr

Zdenko Loncaric
Faculty of Agrobiotechnical Sciences Osijek, V. Preloga 1, Osijek, Croatia
zdenko.loncaric@fazos.hr

ABSTRACT

The challenges of food safety, green economy, circular bioeconomy and climate change mitigation have become additional challenges of agricultural production. Overcoming the above mentioned challenges inevitably involves technological, technical, environmental, economic and social aspects of agricultural production. At the same time, the integration of technologies into digital agriculture represents a considerable potential for improving the efficiency, productivity and sustainability of agricultural production at the farm and global level. However, due to large differences in the capacities of applying digital technologies between small and medium-sized farmers and large agricultural producers, the scenario of digitalization of agriculture in rural areas is very uncertain and questionable. Services using satellite systems have a special place in the precise and smart agriculture. For stakeholders in Croatia, several different services are available. The possibility of using satellite services, as well as stakeholders' attitudes about them, are expected to be related to the price, the type and amount of data within the service, the type of production, the size of production areas and the IT literacy of service users. Therefore, a survey was conducted on the possibility of using satellite services and technologies in agricultural production in Croatia. The target group of respondents were agronomists and/or owners of family farms, irrespective of age and agricultural education. In the survey, a series of questions determined their opinion on the possibility and willingness to use the services of satellite technologies in agricultural

production, with special emphasis on the potential advisory role of agronomists and the reasons for possible non-use of satellite technologies. In total, the answers of 229 respondents were collected, of which 56 are agronomists. The conclusion is that there are great opportunities in increasing the use of satellite services, that stakeholders are interested in education, especially in courses and seminars and advisory education, both with an agronomist and with an internet advisory service. In this, the role of agronomists is very important, but there are significant differences in the views of agronomists and other stakeholders, which should definitely be taken into account when creating a strategy and realizing the digitalization of agriculture.
Keywords: *advisory, applications, education in agriculture, extension services, training*

1. INTRODUCTION

In the last few decades, agricultural production has undergone significant positive changes due to information technology along with new challenges, primarily due to climate changes and the depopulation of rural areas. The challenges of food safety, green economy, circular bioeconomy and climate change mitigation have become additional challenges of agricultural production in addition to sufficient and sustainable food production patterns while preserving the soil fertility and environment. This is of particular importance in Croatia due to advanced soil degradation, i.e. soil acidification together with low levels of organic matter and available phosphorus in the soil (Hefer et al., 2023., Lončarić et al., 2023). Overcoming the abovementioned challenges inevitably involves technological, technical, environmental, economic and social aspects of agricultural production. At the same time, the integration of technologies such as the Internet of Things, data science, deep learning, artificial intelligence into digital agriculture represents a huge potential for improving efficiency, productivity and sustainability of agricultural production at the farm and global level (Abbasi et al., 2022, Catal and Tekinerdogan, 2019, Liu et al., 2021, Sott et al., 2020, Wolfert et al., 2107, Zhai et al., 2020). However, due to large differences in the capacities of applying digital technologies between small and medium-sized farmers and large agricultural producers, the scenario of digitalization of agriculture in rural areas is very uncertain and questionable. Thereby, the ability and willingness of agronomists and farmers to acquire and transfer knowledge and competences in the application of digital technologies, play a very significant role in the digitalization of rural areas. Services provided by satellite systems have a special place in digital agriculture, especially in the application of precise and smart agriculture. Satellite images, agrometeorological data, vegetation indices (Bannari et al., 1995), applications for analysis and interpretation of satellite images, applications for decision-making (Aubert et al., 2012) are of great importance in the digitalization of agriculture, and at the same time, they are often included in the data and information offered by satellite services in Croatia. Some of the services are not charged, while more complex and precise services are charged depending on the area of production for which the service is purchased and the type of service. The type, complexity and price of the service are most often correlated with the amount of data and information, and the quality of the service, i.e. the practical applicability of the information in decision-making or the direct implementation of agrotechnical measures. The possibility of using satellite services, as well as stakeholders' attitudes about them, are expected to be related to the price of services, the type and amount of data within the service, the type of production, the size of production areas and the IT literacy of service users. Likewise, we assumed that stakeholders' attitudes and applicability of services depend on the level of education of stakeholders, especially education in the field of agriculture (Nizametdinov Akramovich, 2022) and some other socio-demographic characteristics (e.g. age and gender of service users). We additionally wanted to emphasize the importance of education, since the digitalization opportunities in agriculture might not be fully realized without enhanced education, (Várallyai1 and Szilágyi, 2020) and joint efforts of researchers, technology developers, suppliers, farmers, advisors, digital

innovation hubs, and start-ups (Hansen et al., 2022, MacPherson et al., 2022). Therefore, a survey was conducted on the possibility of using satellite services and technologies in agricultural production in rural areas of Croatia. The target group of respondents were agronomists and/or owners and employees of family farms and other production entities, irrespective of age, global and agricultural education and preferences for digital technologies. In the survey, a series of questions were included to determine and evaluate their opinion on the possibility and willingness to use the services of satellite technologies in agricultural production. Special emphasis was on the types of different education including extension services, the advisory role of agronomists and the reasons for non-use of satellite technologies.

2. MATERIAL AND METHODS

2.1. Data collection

In this research, the data were collected using an online questionnaire (n = 229) as the research instrument. This online survey method was carried out using the information system Agroklub, an agricultural portal of an informative and educational nature on, agricultural production, rural area and the food industry. The target group of respondents were all stakeholders in agricultural production. The full questionnaire contained a total of 26 open and closed questions, divided into 5 groups. These groups include socio-demographic issues, type and extent of production, frequency of use and attitudes towards satellite services, willingness to use and education about satellite services, and the role of agronomists and advisory activities. Statistical analysis was carried out using Excel, the spreadsheet program from Microsoft and a component of its Office product group for business applications. The collected data were analysed using descriptive statistics (frequency analysis, arithmetic mean, mode, median and standard deviation). Descriptive statistical analysis was used to describe the socio-demographic characteristics of the sample, agricultural production characteristics, and the evaluation and opinions of respondents on the current use and possibilities of using satellite services in agriculture.

2.2. The target group

The target group of respondents were all stakeholders in agricultural production, starting from owners and employees on family farms, up to agronomists employed in agricultural production, agricultural institutions, agencies, educational institutions or agronomists outside agricultural activity. There were no restrictions regarding the type of connection of the respondents with agricultural production, nor their type and level of education. In total, during 3 weeks in August 2023, the answers of 229 respondents were collected, of which 56 are agronomists (24,5 %), while the other 173 respondents (75,5 %) do not have an academic agronomic education. This paper presents an analysis for the entire group of respondents (most often expressed as "all respondents" or "all stakeholders"). Results that specifically show a group of agronomists are labeled "agronomists" and refer to a group of 56 agronomists (unless otherwise noted). The results and characteristics of the responses of other respondents who are not agronomists are marked as "other respondents", "other stakeholders" or "non-agronomist respondents". Characteristics refer to the entire group of 173 respondents who are not agronomists, unless otherwise stated. The group of respondents refers to the entire geographical area of the Republic of Croatia, i.e. it includes the area of all 20 counties and the City of Zagreb.

3. RESULTS AND DISCUSSION

3.1. Gender, age and regional affiliation of the respondents

A quarter of respondents (24.5%) were female, and three quarters (75.5) were male. The gender ratio is very similar among respondents who are agronomists (25.5% vs. 74.6%) and other respondents who are not agronomists (24.1% vs. 75.9%). The average age of all respondents is 42 years, and most respondents (31.9%) are aged 33-42, followed by 43-52 (29.7%) and 23-32

(19.7%). In total, 81.2% of respondents are aged 23-52, which with 14.4% of respondents aged 53-62 makes 95.6% of respondents aged 13-62. The age structure of the agronomist respondents is somewhat different, with an average age of 37.5 years, with the majority of agronomist respondents (40.0%) aged 23-32. Respondents are from all 21 regional units of Croatia, i.e. all 20 counties and the City of Zagreb. The majority of respondents are from Osijek-Baranja County (27.1%) and Vukovar-Srijem County (10.9%), followed by Bjelovar-Bilogora County (7.9%), Brod-Posavina County (6.6%), Virovitica-Podravine County (5.2 %), Koprivnica-Križevačka (4.8 %) and Požega-Slavonia County (4.4 %). In total, there were 54.2% of respondents from the 5 Slavonic counties, 32.3% from the other 9 continental counties and 13.5% from the coastal counties. According to the geographical affiliation of non-agronomist respondents, the dominance of Slavonian counties is slightly lower (51.2%), but the representation of agronomists from Slavonian counties is significantly higher (63.6%), the highest from Osijek-Baranja (38.2%).

3.2. Level of education of the respondents

The largest number of respondents (49.3%) have completed secondary school as their final level of education, 10.5% have completed professional higher education, 26.6% university, 10.9% a master's degree or doctorate, and 2.6% of respondents have only completed elementary school. The most common level of education of agronomists (63.6%) is completed undergraduate or graduate studies at universities, 12.7% of agronomists completed professional studies, and 23.6% of the agronomists surveyed have a master's or doctorate degree. Among respondents who are not agronomists by profession, i.e. other stakeholders, the majority have completed secondary school (63.4%), 3.5% only primary school, 10.3% professional higher education, 14.9% university graduate studies and 6 .9% master's degree or doctorate (but not in the field of agriculture).

3.3. Type and degree of agricultural education of the respondents

A total of 70.7% of respondents have some agricultural education (night school, course, high school or higher education), and among producers and other stakeholders who are not agronomists, 62.2%. Family tradition, which we do not count as an official form of education, is the most common form of acquiring skills, a total of 149 respondents, i.e. 65.1% (40.4% of agronomists and 72.3% of other stakeholders who are not agronomists). At the same time, for 54 respondents (23.6 %) it is the only form of agricultural education, but 95 respondents (41.4 %) have some official education in agriculture in addition to family tradition.

		Non-agronomist respondents		Agronomists		All respondents	
No.	Types of agricultural education	No.	(%)	No.	(%)	No.	(%)
1	Family tradition	126	72,8	23	41,1	149	65,1
2	Night schools, courses and seminars	71	41,0	12	21,4	83	36,2
3	High school	51	29,5	16	28,6	67	29,3
4	Incomplete studies	12	6,9	-	-	12	5,2
5	Professional studies	-	-	11	19,6	11	4,80
6	Undergraduate university studies	-	-	34	60,7	34	14,9
7	Graduate studies	-	-	42	75,0	42	18,3
8	Master's and doctorate degrees	-	-	5	8,9	5	2,2
	TOTAL	173		56		229	

Table1: Types of agricultural education of respondents

Following a family tradition, the most common types of agricultural education are night schools, courses and seminars, then high school, graduate, undergraduate or professional studies, incomplete studies, and master's and doctorate degrees (Table 1).

However, the structure of the respondents' final agricultural education is somewhat different, i.e. the highest level of education in agriculture achieved by individual respondents (Table 2). In addition to 23.6% of all respondents (31.2% of non-agronomists) who state only family tradition, there are 25.8% of all respondents (34.1% of non-agronomists) with night school or courses as the highest level of agricultural education. This means that 49.4% of all respondents (as much as 65.3% of respondents who are not agronomists) have no high school or academic agricultural education (Figure 1). High school agricultural education is the highest level of agricultural education for 21.0% of all respondents (27.8% for non-agronomists). If we include in this group respondents with incomplete studies in agriculture, there are a total of 116 respondents with secondary or higher education in agriculture, i.e. 50.6% (Figure 1).

		Non-agronomist respondents		Agronomists		All respondents	
No.	Types of agricultural education	No.	(%)	No.	No.	(%)	No.
1	Family tradition	54	31,2	-	-	54	23,6
2	Night schools, courses and seminars	59	34,1	-	-	59	25,8
3	High school	48	27,8	-	-	48	21,0
4	Incomplete studies	12	6,9	-	-	12	5,2
5	Professional studies	-	-	7	12,5	7	3,1
6	Undergraduate university studies	-	-	8	14,3	8	3,5
7	Graduate studies	-	-	36	64,3	36	15,7
8	Master's and doctorate degrees	-	-	5	8,9	5	2,2
	TOTAL	173	100	56	100	229	100

Table 2: Types of final agricultural education of respondents

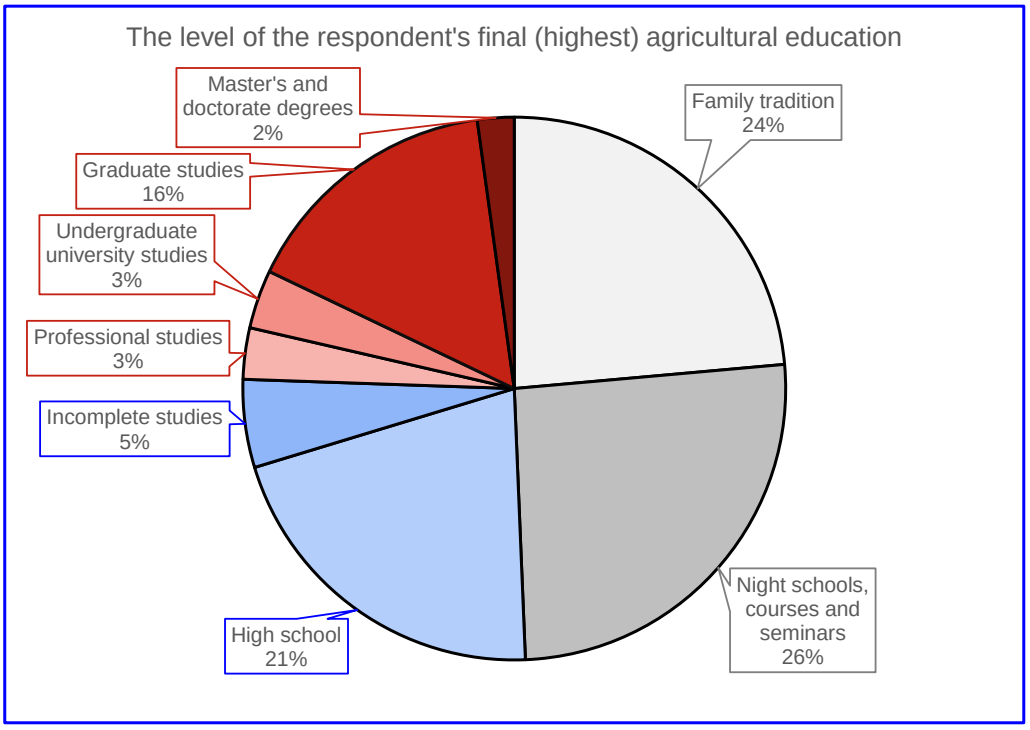

Figure 1: The level of the respondent's final (highest) agricultural education

3.4. Frequency of use of satellite services

Less than 50% (47.6%) of respondents declared that they do not use satellite services, 31.4% do, and 21.0% are not sure, i.e. they use services but do not know if they are connected to satellite technologies. Just slightly more agronomists (37.5%) use satellite services.

There are even fewer users who pay for satellite services (8.7%), 47.2% of respondents declared that they use such services for free, and the other 44.1% also do not pay because they do not use such services. Among agronomists, there is a slightly higher proportion of respondents who pay for services (10.7 %) and who use these services for free (53.6 %) than among respondents who are not agronomists (8.1 % and 45.1 %). Respondents evaluated the frequency of use of five different types of services with grades in the range of 1-5. They most often use agrometeorological data (rating 3.35), followed by satellite images of production areas (2.66), and much less often applications to help in decision-making (1.90), vegetation indices (1.87) and applications for processing and interpreting satellite data and images (1.73) (Figure 2). Respondents who are agronomists use agrometeorological data, satellite images and vegetation indices somewhat more often than other respondents.

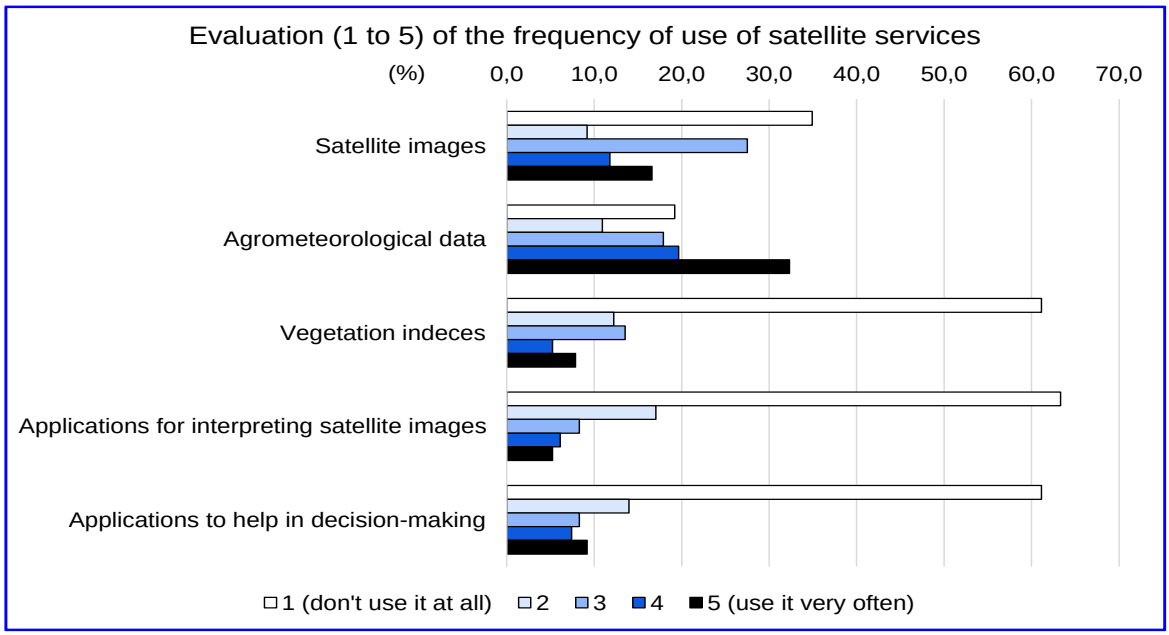

Figure 2: Evaluation of the frequency of use of different satellite services

3.5. Evaluation of the necessary IT literacy and the price of the service

14.9% of the respondents could not answer whether there is a need for a high level of IT literacy to use the satellite services, while the rest rated the need as 3.25. At the same time, 10.9% of respondents do not agree at all or agree to a small extent (11.8%) that a high level of IT literacy is necessary, and to a large extent (24.0%) or completely agree with that (15.3 %) of respondents. Thus, almost twice as many respondents (1.7 times more) believe that using satellite services requires a high level of IT literacy. 33.6% of respondents could not evaluate the justification of the price of satellite services. However, a significantly larger number of respondents (25.8%) disagree, and a smaller number (16.2%) agree with the statement that the prices of services are in line with the expected benefit and success in production. At the same time, almost a quarter of respondents (23.7%) do not know whether they would recommend the use of satellite services to small and medium-sized farmers, 34.5% of respondents would recommend, and 24.0% of respondents would not recommend the use of satellite services to small and medium-sized farmers.

3.6. Possible reasons for non-use or less use of satellite services

Respondents were asked to what extent they agree with certain reasons for lower use or generally not used satellite services. The offered reasons for not using these services are: 1) using them requires too much time, 2) using them requires too much training and IT skills, 3)

using them is too expensive, 4) using them cannot significantly help production, 5) the scope of the respondent's production is too small to use the satellite services. Respondents to the greatest extent (45.9%) agreed with the reason that the scope of their production is too small to use the satellite services, 28.4% of respondents disagreed with this, and 25.8% chose a neutral answer. More respondents agree (39.8% vs. 30.6%) that the price of services is unjustifiably high. In their research, Linsner et al. (2021) also found that farmers identify lack of knowledge, lack of availability, high prices that are not affordable for owners of small and medium-sized farms as problems in the digitalization of agriculture. At the same time, in this research, only 25.3% of respondents believe that the use of these technologies requires too much time, and 44.%% disagree, while 38.9% of respondents disagree and 29.3% believe that it requires too much training and IT skills. Finally, 31.0% of the respondents believe that the use of these technologies cannot significantly help them, while 38.6% of the respondents believe that using satellite services can help them.

3.7. The probability of using certain satellite services in the future

Assuming that the problem or obstacle that prevents them from using satellite services is solved, regardless of what the problem is, the respondents would use satellite services to a significantly greater extent than they currently do. They would use agrometeorological data to the greatest extent (71.6% of respondents), followed by satellite images of production areas (52.8%), applications to help in making decisions (50.7%), vegetation indices (49.3%) and the least (48.5 %) applications for processing and interpreting satellite images. Nevertheless, despite the presumed removal of the problem, agrometeorological data would still not be used by 13.5% of the respondents, and other services by about a quarter of the respondents (22.3% for satellite images, 27.7% for decision-making applications, 28% for vegetation indices and 26.2 % for applications for processing and interpretation of satellite images). A significantly higher percentage of agronomist respondents would use the above services: 80.4% agrometeorological data, 60.7% vegetation indices, 58.9% satellite images of production areas, 55.4% decision-making support applications and 53.6% of agronomist respondents would use applications for process and interpreting satellite images.

3.8. Readiness for education or training, payment for services and engagement of agronomists in the future

A total of 21.8% of respondents have no interest in being educated in the field of using satellite services, and 23.6% are currently not interested, but they might decide to do so if they had more information about this type of service. The majority of respondents (54.6%) are ready for education or training, where 16.6% are ready to attend a course, 12.7% are for a lifelong education, 14.9% want training using an online advisory service, 9.6% by working with an agronomist consultant, and 0.9% by attending studies (Fig. 3). A significant difference was found between agronomists and other respondents (Fig.4), as a smaller share of agronomists than other respondents stated that they had no interest in education at all (19.6% vs. 22.5%) or currently (17.9% vs. 25.4%). At the same time, a larger share of agronomists is ready for lifelong education (19.6 % vs. 10.4 %) and with an agronomist consultant (17.9 % vs. 6.9 %). Other respondents in larger proportion than agronomists (17.3% vs. 7.1%) are ready for training using an online consulting.

Figure following on the next page

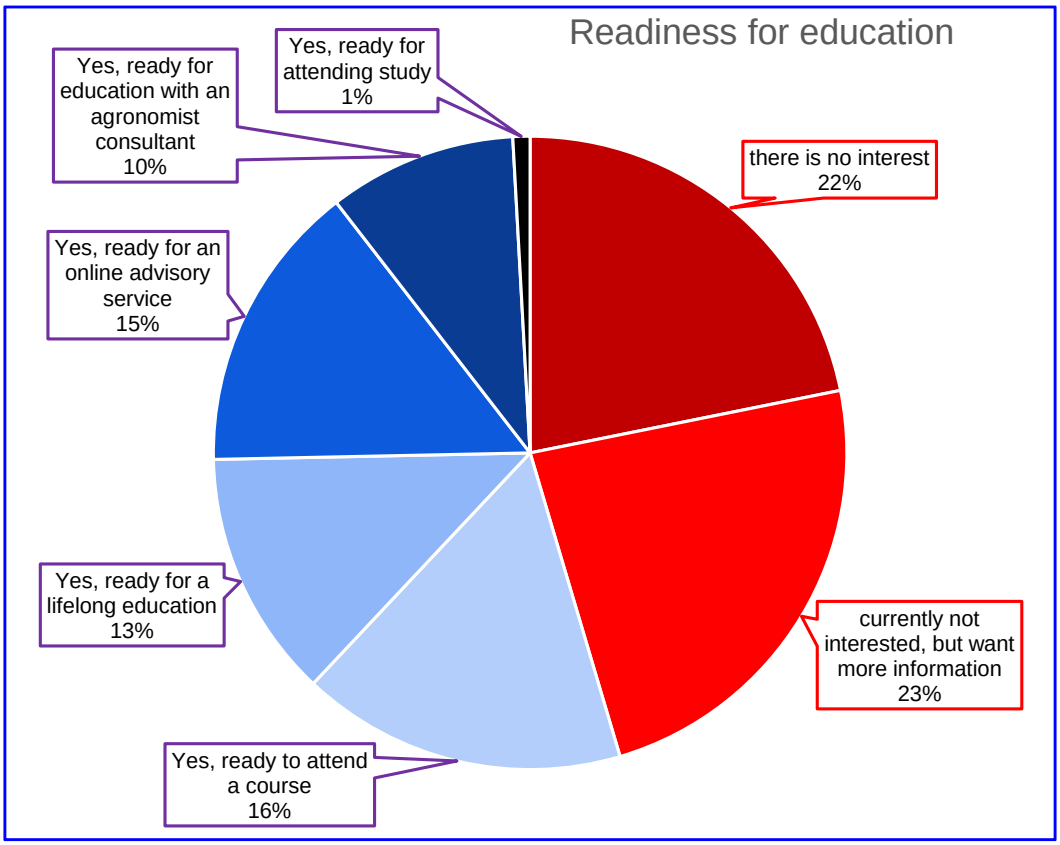

Figure 3: Readiness of respondents for different types of education about satellite services

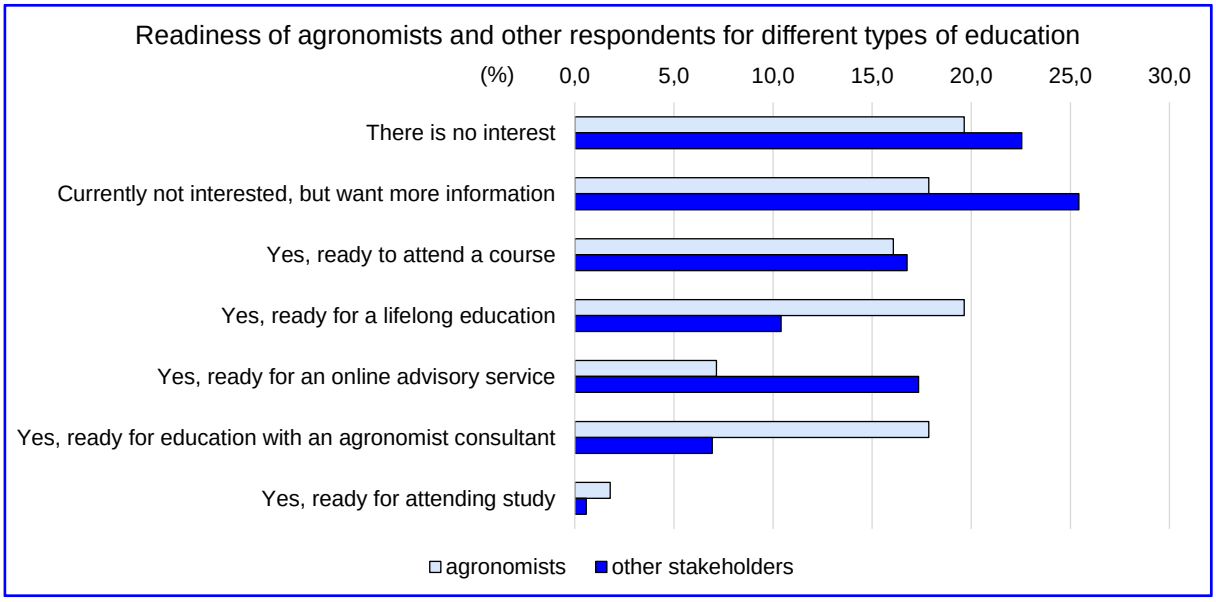

Figure 4: Readiness of agronomists and other respondents for different types of education on satellite services

As many as 58.1% of respondents believe that the organized advisory role of agronomists would significantly increase the use of satellite technologies, i.e. satellite services, 30.6% cannot estimate, and only 11.4% of respondents answered negatively. It was expected that a higher proportion of agronomists answered positively (66.1%) than other respondents (55.5%), and that a larger proportion of other respondents than agronomists could not estimate (34.1% vs. 19.6%), but it is interesting that a larger share of agronomists (14.3%) than other respondents

(10.4%) believes that an organized advisory role of agronomists would not increase the use of satellite services. Only 15.3% of respondents (21.4% of agronomists and 13.3% of other respondents) would hire an agronomist for help in the use of satellite technologies, i.e. satellite services, and the largest share of respondents (44.1%) would maybe hire an agronomist, but they are not sure (26.8% of agronomists and 49.7% of other respondents). Only 2.2% of respondents' business entities have already engaged an agronomist for satellite services. 38.4% of all respondents would not hire an agronomist, of which 17.5% because they do not need the services of satellite services at all, and 21.0% because they personally already know enough. Also, 37.5% of agronomists would not hire an agronomist for help because 30.4% of all agronomists already know enough, and 14.3% believe that they do not need satellite services. Among the other respondents (who are not agronomists), there are 17.9% of those who would not hire an agronomist for help because they already personally know enough about the services of satellite services. Regarding the willingness to pay for the satellite services in the future, 50.2% of respondents (69.6% of agronomists and 43.9% of other respondents) would pay for the services if the price is appropriate for the benefit achieved, 28.4% of respondents (10.7% of agronomists and 34.1% of other respondents) want to use, but do not want to pay, and 21.4% of respondents (19.6% of agronomists, 22.0%) do not want to use or pay for satellite services. There is a very significant difference between agronomists and other respondents, agronomists to a greater extent (1.6 times) are willing to pay for services, and other respondents to a greater extent (3.2 times) want to use, but do not want to pay for the satellite services.

4. CONCLUSION

The conclusions were drawn based on the responses of 229 respondents from all over Croatia, although most of them were from the Eastern Croatian region (54.2%). Among the respondents, 24.5% are agronomists and 75.5% of stakeholders do not have an agronomic education, and 75.5% of the respondents are male. The average age of all respondents is 42 years, and 49.3% of respondents have completed high school, 2.6% only primary school, 10.5% higher school, 26.6% college, and 10.9% have a master's degree or doctorate. However, 49.4% of all respondents have no high school or academic agricultural education, with 23.6% only having a family tradition, and another 25.8% attended certain seminars or night schools in the field of agricultural education. 21% of the respondents have an agricultural secondary school as the highest degree, and 24.5% of the respondents have an academic degree in agricultural education. According to the results of the survey, we can conclude that almost a third of stakeholders in agricultural production use satellite services, half of the stakeholders do not use satellite services, while a fifth of stakeholders are not sure whether the services they use are related to satellite services. A very small number of stakeholders, less than a tenth pay for satellite services, and slightly less than half of the stakeholders use only free services. Relatively satisfactory is only the current use of agrometeorological data and, to a lesser extent, the use of satellite images. The most frequently used are agrometeorological data, which more than half of the stakeholders use often while a third of stakeholders use satellite images often. Stakeholders use vegetation indices and applications the least, almost two-thirds do not use them at all, and often use them less than a fifth of stakeholders. Agronomists use agrometeorological data, satellite images and vegetation indices more often than other stakeholders in agriculture. According to the majority of stakeholders, a high level of IT literacy is necessary to use the satellite services. More than a third of stakeholders would recommend the use of satellite services for small and medium-sized farmers, a quarter would not recommend it, while another quarter of stakeholders do not know. Almost half of the stakeholders believe, and a quarter do not, that the scale of their production is too small to use the satellite services. Stakeholders rated the unjustifiably high price of services as a significant obstacle.

About a quarter of stakeholders believe that using these technologies requires too much time and too much training and IT skills. It is possible to significantly increase the use of the services by solving existing problems and obstacles. Thus, agrometeorological data in that case would be used by almost three quarters, and all other services by about half of the stakeholders. There would be an even greater increase in the use of services by agronomists than by other stakeholders. But, even if the problem is removed, the services would still not be used by about a quarter of the stakeholders. Interest in education in the field of satellite services is on average very good, although a fifth of the stakeholders have no interest at all, and a quarter are currently not interested. However, those currently not interested for education are interested in obtaining additional information about satellite services. More than half of the stakeholders are interested in education, mostly in courses, and somewhat less by an advisory internet service or working with an agronomist consultant. Agronomists are to a greater extent ready for additional education than other stakeholders, especially in the framework of lifelong education and with agronomist advisors, and other stakeholders are to a greater extent ready for training using the advisory internet service. More than half of the stakeholders believe that the organized advisory role of agronomists would significantly increase the use of satellite technologies, and only a tenth of them disagree. However, an almost negligible number of agronomists are currently engaged in tasks related to satellite services. Just a fifth of the stakeholders are ready to engage an agronomist in relation to satellite services, and almost half of the stakeholders might still engage an agronomist. More than a third of the remaining stakeholders would not engage an agronomist, a smaller part because they do not need these services at all, and a fifth of the stakeholders because they believe that they already know enough about the satellite services. Also, more than half of the stakeholders would pay for satellite services if the price is appropriate, more than a quarter would use but not pay for the service, and a fifth of the stakeholders neither want to use nor pay for satellite services. Agronomists are willing to pay for services to a greater extent (1.6 times) than other stakeholders, and other stakeholders are to a greater extent (3.2 times more than agronomists) willing to use, but not to pay for satellite services. Finally, the general conclusion is that there is a lot of room for increasing the use of satellite services, that stakeholders are interested in education, especially in courses and advisory education, both with agronomists and by an Internet advisory service. In this, the role of agronomists is very important, but there are significant differences in the views of agronomists and other stakeholders, which should definitely be taken into account when creating a strategy and realizing the digitalization of agriculture.

ACKNOWLEDGEMENT: *The paper is the result of research within the project SatelitFoto@Agro - Application of available online services of satellite photos within the possibilities and needs of local food producers funded by the European Union from the European agricultural fund for rural development (EAFRD).*

LITERATURE:

1. Abbasi, R., Martinez, P., Ahmad, R. (2022). The digitization of agricultural industry – a systematic literature review on agriculture 4.0. Smart Agricultural Technology, 2: 100042.
2. Aubert, B. A., Schroeder, A., and Grimaudo, J. (2012). IT as enabler of sustainable farming: an empirical analysis of farmers' adoption decision of precision agriculture technology. Decis. Support Syst., 54: 510–520.
3. Bannari, A., Morin, D., Bonn, F. (1995): A Review of Vegetation Indices. Remote Sensing Reviews, 13: 95-120.
4. Catal, C., Tekinerdogan B. (2019): Aligning Education for the Life Sciences Domain to Support Digitalization and Industry 4.0. Procedia Computer Science, 158: 99–106.

5. Hansen B. D., Leonard E., Mitchell M. C., Easton J., Shariati N., Mortlock M. Y., Schaefer M., Lamb D. W. (2022): Current status of and future opportunities for digital agriculture in Australia. Crop & Pasture Science, Special Issue.
6. Hefer, H., Andrišić, M., Zegnal, I., Mikulić, D., Rašić, D., Lončarić, Z. (2023): Agrochemical indicators of soil fertility in the Republic of Croatia in 2021. 58th Croatian & 18th international symposium on agriculture Book of abstracts, Carović-Stanko, K., Širić, I. (ed.). Zagreb: Sveučilište u Zagrebu Agronomski fakultet, Zagreb, 2023: 17.
7. Linsner, S., Kuntke, F., Steinbrink, E., Franken, J., Reuter, C. (2021). The Role of Privacy in Digitalization – Analyzing Perspectives of German Farmers. Proceedings on Privacy Enhancing Technologies, 3: 334–350.
8. Liu, Y., Ma, X., Shu, L., Hancke, G.P., Abu-Mahfouz, A.M. (2021): From Industry 4.0 to Agriculture 4.0: current status, enabling technologies, and research challenges. IEEE Transactions on Industrial Informatics, 17(6): 4322–4334.
9. Lončarić, Z., Rastija, D., Hefer, H., Andrišić, M., Rašić, D., Zegnal, I., Lončarić, R. (2023): Decreasing Content of Soil Organic Matter as Direct Loss of Nitrogen and Money from Soil. Economic and Social Development. 95th International Scientific Conference on Economic and Social Development. Book of Proceedings, Ribeiro, H. N., Fotova Cikovic, K., Kovač, I. (ed.). Varazdin Development and Entrepreneurship Agency, Varaždin, Croatia, 2023: 259-267.
10. MacPherson, J., Voglhuber-Slavinsky, A., Olbrisch, M., Schöbel, P., Dönitz, E., Mouratiadou, I., Helming, K. (2022): Future agricultural systems and the role of digitalization for achieving sustainability goals. A review. Agron. Sustain. Dev. 42: 1–18.
11. Nizametdinov Akramovich, A. (2022): The priority of using innovative technologies in the agricultural education system. Journal of Academic Research and Trends in Educational Sciences, 1(10): 185–191.
12. Sott, M.K., Furstenau, L.B., Kipper, L.M., Giraldo, F.D., Lopez-Robles, J.R., Cobo, M.J., Zahid, A., Abbasi, Q.H., Imran, M.A. (2020): Precision techniques and agriculture 4.0 technologies to promote sustainability in the coffee sector: state of the art, challenges and future trends. IEEE Access, 8: 149854–149867.
13. Várallyai, L., Szilágyi, R. (2020): Is it essential the digitization in agriculture? Experiences in Curriculum Development for Agri-digitalization engineer at BSc level. Journal of Agricultural Informatics, 11(2): 34–40.
14. Wolfert, S., Ge, L., Verdouw, C., and Bogaardt, M.-J. (2017). Big data in smart farming–a review. Agric. Syst., 153: 69–80.
15. Zhai, Z.,Martinez, J.F., Beltran, V., Martinez, N.L. (2020): Decision support systems for agriculture 4.0: survey and challenges. Computers and Electronics in Agriculture, 170: 105256.