Theses of the PhD dissertation

APPLICATION CHANCES OF ICT TECHNOLOGY IN AGRICULTURE IN SZEKLERLAND

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1. BACKGROUND, OBJECTIVES AND HYPOTHESES OF THE RESEARCH

Agriculture is facing a number of global challenges. These include climate change, producing enough food of sufficient quantity and quality for the world's population, and managing scarce resources optimally. Increasing the output of the agricultural sector is key to ensuring a secure and adequate food supply for the world and to reducing poverty (ALASSAF - SZALAY, 2020). Innovative and modern solutions are needed to increase agricultural productivity in a sustainable way. Digitalisation, of which data and the information derived from data are an integral part, is the basis for the aforementioned innovative solutions. ICT, digital and smart tools are an important element of a competitive agriculture in the 21st century (THAPA et al., 2020). Through the use of ICT tools, farmers can obtain up-to-date data and information on weather, crop conditions, new and innovative technologies, input factor prices and uses of input. The digitisation of agriculture is an important and topical area within the European Union, and the CAP strategy for 2021-2027 sets the objective of introducing digital solutions and technologies in agriculture that reduce environmental footprint and bureaucratic burden, promote generational renewal and make farmers' work easier (GAÁL et al., 2020). The process of implementing the digitalisation of agriculture in the European Union varies from country to country and from region to region, depending on a large number of factors and actors. Key actors in the implementation process are the EU Member States, agricultural organisations and farmers.

The research topic

The fact that I have been an active participant in our family's agricultural business for more than 10 years and that I am daily concerned with the question of how a small or medium sized agricultural business can be competitive in Szeklerland and how digital, ICT tools and solutions can be applied in agricultural work played a decisive role in choosing the present research topic. In addition to the aforementioned personal motivation and interests, the fact that the digitalisation of agriculture is a major issue in the European Union was also an important factor in dealing with the present research topic. This is also proven by the fact that the digitalisation of agriculture is included as a strategic objective in the CAP 2014-2020 budget and 2021-2027 planning period, and that the procurement and promotion of digital tools and technologies is an integral part of the EU agricultural tenders (EUROPEAN, 2019).

Objective

The aim of the research is to present the attitudes and opinions of agricultural workers in the Central Region of Romania, in Szeklerland, regarding the current situation of agriculture, with special regard to the use of ICT, digital tools and solutions, and to formulate a vision of the future, in which the use of new digital technologies and tools is also under investigation. The research was carried out in the Central Region and in Szeklerland (Harghita, Covasna, Mures counties), among farms whose profile is crop, livestock or mixed crop-livestock farming. Simple random sampling was used to collect data.

In terms of questionnaire structure, I focused on two major topics. The first topic is the current situation of agriculture in the Central Region and Szeklerland with special focus on the use of ICT, digital tools and technologies. The second topic is the future of agriculture in the Central Region and Szeklerland, with special regard to the use of ICT, digital tools and drones, robots. In fact, a situation analysis and the concept of a future envisioning are outlined through the analysis and processing of the questionnaire. **After clarifying the objectives, the following research questions were formulated:**

1. In Romania, the average farm size is 4.42 hectares, and the farm structure is characterised by land fragmentation, with a large number of small parcels. How and to what extent does farm structure and land fragmanetation affect the digitalisation of agriculture in the Central Region and Szeklerland?
2. Within the European Union, one of the objectives of the CAP and rural development policy is to make rural areas and settlements more liveable and attractive for young people. Will the use of digital, ICT tools make agriculture more attractive for young people in the Central Region and Szeklerland?
3. The use of digital, ICT tools is influenced by a number of factors that hinder or enhance the spread of digitalisation in agriculture. What are the internal and external factors that help or hinder the use of digital ICT tools in the Central Region and Szeklerland? What is the opinion of those working in agriculture about the positive and negative characteristics of the digitalisation of agriculture?
4. Innovation, up-to-date knowledge and the use of new technologies are the basis for competitive agriculture, so no matter whether we speak about a small or a large farm, these factors are vital. To what extent do age, experience in agriculture and education

influence the use of digital and ICT tools in the agricultural sector in the Central Region and Szeklerland?

5. Sustainable development and reducing pollution are also among the European Union's key objectives. What do Szekler farmers think about the contribution of digitalisation in agriculture to environmental sustainability?
6. In the 2021-2027 planning period, increasing the competitiveness of agriculture is included as an objective in the CAP strategy, one of the pillars of which is digitalisation, and to this end the purchase of digital tools and technologies is a priority in EU agricultural tenders. Are farmers in the Central Region and Szeklerland, who would like to apply for EU funding, really considering the digitalisation of their farms as a priority?

Based on the above research questions, I formulated the following hypotheses:

1. Hypothesis 1: Digitalisation of agriculture in the Central Region and Szeklerland is influenced by the structure of the economy and the farm structures to different degrees. Medium (over 20 hectares) and large (over 100 hectares) farms are more familiar with ICT, digital tools and their use is more widespread, while smaller farms (under 20 hectares) are less familiar with ICT.
2. Hypothesis 2: Young people are motivated to engage in agricultural activities through the use of ICT and digital tools.
3. Hypothesis 3: The proportion of knowledge and use of ICT, digital tools and precision technologies varies according to educational levels.
4. Hypothesis 4: Experience in agriculture (number of years) has a positive effect on the knowledge and use of ICT, digital and precision technologies, i.e. the more experience in agriculture, the higher the proportion of knowledge and use of ICT, digital tools and precision technologies.
5. Hypothesis 5: For higher income farms, ICT, digital tools, precision technologies are known and used, so higher income has a positive impact on the digitalisation process of agriculture.
6. Hypothesis 6: Digitalisation contributes significantly to all three dimensions of sustainability (environmental, economic, social).

7. Hypothesis 7: Strengthening digitalisation in the future economy is essential for business competitiveness. Farmers who are planning to apply for an EU grant in the next 2-3 years should make digitalisation of the farm a priority.

2. LITERATURE REVIEW

Within the literature review chapter of the thesis, I considered it important to present the development of agriculture in Romania, the Central Region and Szeklerland in the last 10 years. Then, I presented the technical and technological development of agriculture, the main milestones and the use of ICT and digital tools in agriculture.

2.1. Analysis of agriculture in Romania

Agriculture is a fundamental sector of the Romanian economy. In the years following the fall of communism, the performance of Romanian agriculture declined, as the basic agricultural pillars (agricultural cooperatives, state agricultural enterprises) that had laid the foundations for the sustained development and productivity of agriculture disappeared. The next major milestone in the history of Romanian agriculture was the accession to the European Union, which once again meant a completely new economic, legal and market transformation for agriculture (DACHIN, 2011). The experience of 1989 still played a decisive role in the mentality of farmers, and in this respect, they found it very difficult to accept the concept of the free market and how it worked. In the years after 2007, the main problem for Romanian agricultural operators was competition. The economic crisis that unfolded after accession further weakened Romania's economic position. However, after the crisis, namely, after 2010, the output of Romanian agriculture increased steadily, one of the main reasons being the improvement in agricultural productivity. After accession, farmers received a subsidy for the cultivated parcels under the new support system through area payments. This was an incentive in order to bring land into the production cycle which had not been cultivated and used before the accession. In 2017, Anghel, Anghelache and Panait carried out a study examining the agricultural performance of Romania and some EU Member States. The study highlighted that Romania has a high agricultural potential (TĂBĂRAȘU, 2021). According to EUROSTAT 2021 data, European agricultural production increased by 8% compared to 2020. In this respect, Romania is one of the countries that generated the highest growth in agricultural production, more precisely a 25% increase compared to the previous year. There are favourable conditions in Romania for the development of adequate agricultural production, but there are still a number of factors that hinder the development of agricultural efficiency. These obstacles include the fragmented farm structures, the structure of the economy, the large number of small and very small farms, which in many cases are only self-sufficient and do not produce for sale (MATEOC et al., 2023). Also, there is a lack of an adequate strategy to deal with natural disasters and climate change, which make the agricultural sector even more vulnerable. The weak infrastructure of the supply chain is also a barrier for farmers (CISMAS, 2022). Agricultural cooperatives play a crucial role in the development of agriculture in Romania, providing an opportunity to integrate and strengthen smaller farms in many aspects (ZLATI et al., 2023).

Based on 2020 data, total agricultural output in Romania was €13 086.91 million. According to 2018 data, agriculture, forestry and fishing contributed 6% to GDP production, while in the European Union it contributed with 1.7% (LAURENTIU, 2018). The output of agriculture increased over the period 2007-2020, with an output value of €13 191 000 in 2007, while in 2020 it was €15 341 000. According to data from the 2020 Agricultural Census and the Romanian Statistical Office, the main crops in Romania in terms of crop production were grains, maize, rapeseed (together 73.1%). The share of agricultural land used for grains, maize and sunflower has increased over the last 10 years, with 2% for grains, 20% for maize and 51% for sunflower, while the share of arable land used for potatoes has decreased by 40% and 34% for rapeseed. Potatoes are a staple food, yet the share of potato production has decreased in recent years for several reasons: rising input prices (fertiliser, fuel, pesticides, herbicides, etc.), climate change, especially drought (lack of irrigation equipment) and cheaper imported potatoes, which have put Romanian producers at a disadvantage (POPESCU et al., 2023). In Romania, over a 10-year period (2010-2020), the cattle population decreased by 10% and the pig population by 33%, while the sheep population increased by 15% and the goat population by 4% (INS, 2022a).

2.2. Economic structure, farm structure

Table 1 illustrates the categorisation of farms by their physical size and economic size. In Romania, we can distinguish two types of farms in terms of economic form: agricultural holdings with and without legal personality.

Table 1: Categorisation of farms by size

Economic size of the farm (SO), Euro	Physical size of the farm (land area), hectars
Very small farm: < 2000	Very small farm: < 2 ha
Small farm: 2 000 - <8 000	Small farm: 2 ha- < 20 ha
Medium: 8 000 - < 25 000	Medium: 20 ha - < 100 ha
Large farm: 25 000 - <100 000	Large farm: ≥ 100 ha

Very large farm: ≥100 000	

Source: own editing based on data from EUROSTAT (2017)

Agricultural holdings with legal personality include trading companies (Public Limited Company - PLC, Private Limited Company - LTD, Joint Stock Company - JSC, Limited Partnership Company - LPC., Limited Liability Company - LLC.), associations, foundations, cooperatives. In fact, the aforementioned categories constitute the co-operative enterprises. In Romania in 2020 there were 2 887 000 farms, covering an area of 12 673 000 hectares. Regarding the legal status of agricultural holdings, the number of holdings without legal personality was 2 862 000 in 2020, i.e. a decrease of 25% compared to 2010. The number of holdings with legal personality was 25 000 in 2020, a 17% decrease compared to 2010 (CONSTANTIN, 2018, INS, 2022a, COCA et al., 2023). Looking at the composition of the number of farms, it can be stated that farms with between 1 and 5 hectares accounted for 36% of all farms in Romania and used and cultivated 18% of the total agricultural area in Romania. The share of farms with more than 50 hectares was 1% and the share of agricultural land used by them was 54% (INS, 2022a). In the period 2010-2020, the average agricultural land per farm increased due to the decrease in the number of farms, although despite the increase, the average agricultural land per farm in Romania is only 4 hectares, compared to 69 hectares in France (IONESCU et al., 2019; SĂVESCU – ROTARU, 2021).

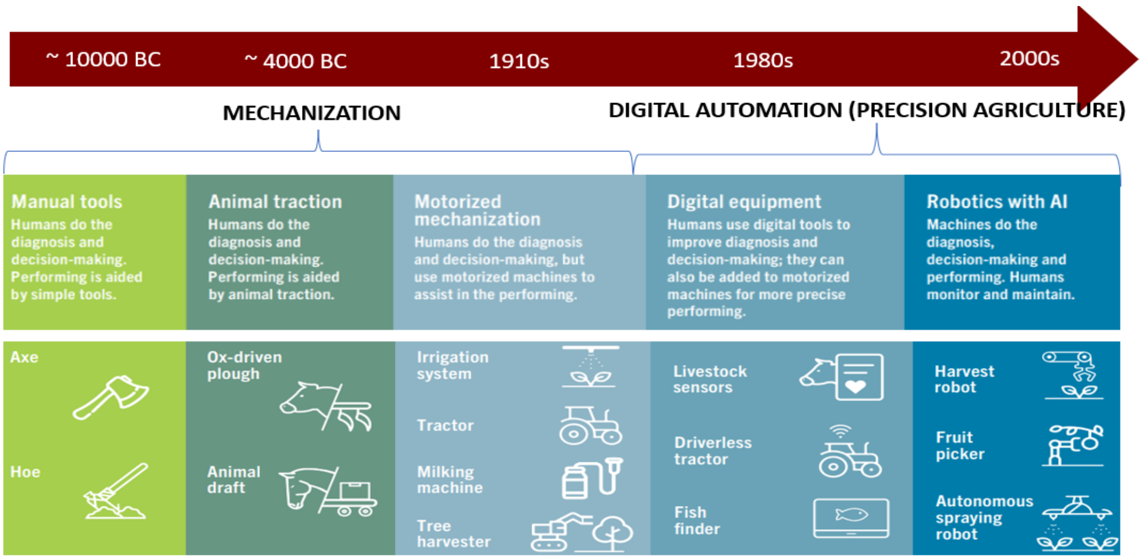
2.3. The agricultural situation in the Central Region and Szeklerland

The Central Region includes 6 counties: Alba, Brasov, Covasna, Harghita, Mures, Sibiu, of which Szeklerland is an integral part (Mures, Harghita, Covasna counties). The total area of the Central Region is 34 100 km^2, which represents 14.3% of the country's territory. From a regional perspective in Romania, the Central Region has the highest share of mowing and pasture lands, with 54% of the total agricultural area of the Central Region. By county, the highest share of mowing and pasture was found in Szeklerland (53% in Covasna, 86% in Harghita, 42% in Mures). 43% of the total agricultural area is arable, 54% is pasture and mowing, 0.81% is kitchen garden, 2% is orchard and vineyard and 0.02% is greenhouse. Potatoes are the main crop in the eastern and western parts of the Central Region, but the hillier areas are also suitable for fruit growing. In 2010, the area used for potato production in the Central Region was 56 282 hectares, compared to 27 961 hectares in 2022, with a 50% decrease. The counties of Harghita and Covasna are the main producers of potatoes. Among the counties of Szeklerland, Covasna County accounted for 53% of the Central Region's potato production, while Harghita County accounted for 24% and Mures County for 6%. Wheat, sugar beet and rapeseed are also widely grown in the central and southern parts of the region. In 2010, the area used for grain production in the Central Region was 92 715 ha, while in 2022 it was 91 227 ha, a decrease of 1.6%. In 2010, the agricultural area used for grain production in Harghita County in Szeklerland was 9 325 hectares and in Covasna County 17 283 hectares, while in 2022 it was 14 278 hectares in Harghita County and 23 488 hectares in Covasna County, i.e. in both cases the area used for grain production increased. Livestock production is important in all counties of the region, especially in the hilly and mountain areas. In Romania, the cattle population decreased by 8% compared to 2010, but increased by 18% in the Central Region, with a significant increase in the Szekler counties. In Harghita County the increase was 27%, in Covasna County 26% and in Mures County 13%. The sheep population increased by 22% in Romania compared to 2010 and by 19% in the Central Region (INS 2022b, INS 2022a).

2.4. Agricultural development

Agricultural development has taken place and is taking place in different parts of the world at different rates and intensities. *Figure 1* illustrates the evolution of technologies used in agriculture, with examples ranging from the use of simple tools to robotisation and AI. The concept of automation in agriculture is understood as the use of different machines, tools and equipment to simplify processes, increase productivity, facilitate decision making and achieve precision. According to this definition, agricultural automation includes precision agriculture, which is a management strategy that collects, processes and analyses data to improve farming decisions.

Figure 1: Evolution of agricultural automation



Source: own editing based on FAO (2022)

The first field, marked in blue, contains the motorised agricultural machinery operated by people/farmers (tractor work, irrigation, milking). The diagnosis(s), i.e. collecting information (internal, external) for decision making, is made by people (in most cases the farmer). In the second part of *Figure 1*, the fields marked in darker blue cover the tools and technologies of digital automation, which may be software-based, multifunctional, interdisciplinary. With the development of digital automation technologies, robots, artificial intelligence, all three phases can be automated, diagnosis, decision making, implementation, so that human resources are only needed for monitoring and maintenance (FAO, 2022).

2.4.1 ICT, digital tools, farm management software and mobile applications in agriculture

Through mobile applications and farm management software, farmers can receive up-to-date data and information on the state of the crop, market prices (input and product prices), weather conditions, which help farmers in their daily and all kinds of decision-making. Based on the above, the digitalisation of agriculture creates the opportunity for data-driven decision-making in farming processes and management.

The term agricultural software includes websites, mobile apps and computer programs that help farmers with production, marketing, sales and processing. Using farm management software, it is possible to plan crop rotation, tillage processes, timing, determine yields, forecast weather, monitor crop development and needs, and by real-time data analysis, make informed, efficient application of inputs (pesticides, fertilizers, water, etc.), thus increasing the yield and reducing the cost of the business.

In the 21st century, the use of ICT (Information and Communication Technology) tools plays a crucial role in all economic sectors, enabling more efficient production and operation. ICT tools enable (agricultural) business managers to make decisions, produce and manage their businesses faster and more efficiently. Information also plays a crucial role in production and sales, in production it helps to improve efficiency, while in sales a lack of information can lead to a competitive disadvantage. According to CSÓTÓ, the concept of ICT includes software (applications, decision-support systems), hardware (smartphones, computers, laptops, tablets, etc.) and the Internet (source of information) (CSÓTÓ, 2013). According to NAGYNÉ, communication technology is part of IT (NAGYNÉ HALÁSZ - GUBÁN, 2016). In the course of agricultural activity, information is one of the main pillars of the farmer’s decision-making processes and actions. In this respect, it is very important that the information is relevant and up-to-date for the farmer, on the basis of which he can make his decisions. Data is one of the most important components of a smart farm. In addition to the level of mechanisation, the fundamental difference between conventional and smart farms is the possibility for farmers to continuously collect up-to-date information on a given plot or crop. One of the tools for presenting the collected data in a consistent form is the map (vegetation index map, weed map, yield map, etc.), which provides the basis for farmers' decision-making processes. The maps enable farmers to delimit management and intervention zones. The next step after data consolidation is the interpretation of the data, which informs the decision amker on how and why to intervene. Data management software helps farmers to make decisions, but also allows them to monitor what is happening on the farm, to plan all agricultural processes and interventions, from sowing to harvesting, and to obtain the necessary inputs. These agricultural softwares have basic record-keeping functions such as planning of agricultural tasks, crop and yield forecasting, weather forecasting, monitoring of crop and land conditions, and through the controlling function, accounting, inventory, employee tracking.

2.4.2. Precision farming

Precision agriculture uses ICT tools to obtain data that help properly apply factors that influence agricultural production (input factors) (GEBBERS et al., 2010). The main aspect of precision agriculture is to adapt the operations and processes to the current land conditions and needs, and accordingly, the interventions and the different work processes are carried out in the right place at the right time. Nowadays, the concept of PA is changing, as we can talk about smart farming through the use of IoT. While PA monitors changes within a given parcel, smart farming goes beyond that, i.e. it integrates the collected data with other real-time data, all this happens simultaneously, thus supporting decision making (BUCCI et al, 2019).

2.4.3. Drones in agriculture

Nowadays, the use of drones and robots are becoming more and more diverse in all industries, including agriculture. Drones and sensor technology are an integral part of agriculture 4.0. A drone is an unmanned aerial vehicle capable of remotely piloted or programmed flight for information retrieval, logistics or special operational tasks (BAKÓ, 2014). Drones have been used primarily in the military industry, but technological advances have expanded their scope of application, so that today they can be used in all industries. Drones have been used for precision spraying in Japan since the 1980s. Spraying and fertilisation using drones offers farmers many advantages: no trampling damage, no fuel costs, high area coverage (10-17 hectares per hour), optimisation of water requirements, pesticide savings of up to 30% (TÓTH, 2021). Drones also allow farmers to monitor the condition of their fields, which includes: soil condition assessment (e.g. soil moisture status), plant counts, determination of actual number of tillers, monitoring crop health, nutrient status, crop estimation, plant stress control, drought extent, monitoring the ripening process, leaf area index, determination of the extent and nature of weed infestation, assessment of wildlife damage. With advances in imaging technology, it is possible to determine with an accuracy of up to centimetres which plants are at risk of dehydration, or whether all plants have received sufficient sunlight and nutrients, and to identify pests and diseases. From an agricultural point of view, the importance of drones lies in the fact that different types of body-mounted cameras (infrared, thermal, and conventional) provide the possibility to scan and analyse the area in real time (WOLFERT et al., 2017). The use of drones in agriculture is various, they are an integral part of agriculture 4.0 and are constantly being developed by drone companies. One of the objectives is to bring fully automated drones into agriculture.

2.5. Digitalisation and its conditions in the agriculture of Romania and Szeklerland

Digital technologies are now widely available in all EU Member States, but there is a huge gap in the way these technologies are used. There are several reasons for this, the first is the capital required for the initial investment, the second is the digital competences and skills needed to use these technologies and, in many cases, farmers perceive them as complicated to use and apply, which discourages them from adopting new and innovative technologies (EUROPEAN COMMISSION, 2019). In Romania, the digitalisation of agriculture is a very complex issue. On the one hand, small farms dominate in terms of farm structure, and the basic problem with land as a factor of production is the large number of fragmented agricultural areas with small parcels, which hinders efficient production. In any case, farm structure poses a major problem, i.e. Romania has a high proportion of small and medium-sized farms, which lack the financial resources and expertise to apply precision and smart farming. A specific environment and medium are needed for the use of digitalised agricultural equipment, an integral part of which is broadband internet access and the digital competence of agricultural workers and entrepreneurs. In terms of human capital, the main problem is the lack of digital literacy, with 28% of individuals having at least basic digital skills, compared to an EU average of 54% (EUROPEAN COMMISSION, 2022c, b). 45% of farmers in Romania use a so-called "*virtual diary*" to monitor changes in the economy, economic events, input and output movements and trends. Regarding the tools and methods used, 20% of farmers use Excel, 17% use other computer programs and applications, and 14% do not use such tools and methods. In the EU, 44% of French farmers and 40% of German farmers use software or farm management applications for record keeping (CIUREA, 2020, RFI, 2018). Based on 2022 data, the AgriTech sector in Romania is growing, with more AgriTech businesses being founded and more investments being made in the development of these types of businesses, which farmers can use to produce more efficiently and effectively (ACTIVIZE, 2022).

Romania has a high agricultural potential, which can only be exploited in a conscious and sustainable way if farmers also recognise the importance, usefulness and relevance of digitalisation of agriculture and demand the use of innovative technologies. In order to create an environment that adopts new agricultural precision and smart technologies, there is a need for government help, as is the reform of agricultural training and higher education.

3. MATERIALS AND METHOD

The present paper involves both primary and secondary research. An integral part of my research was a review of the relevant literature, both national and international. Following the literature review, empirical research was carried out in Romania, in the Central Region. As a first step, I considered it important to have an in-depth literature review on the Romanian, and within that the Szeklerland agriculture, because when performing the causal analysis, this comprehensive literature review provided relevant information for the formulation of numerous conclusions later on.

3.1. Presentation of the secondary data

The secondary data focuses on two major topics. The first topic was the study of agriculture in Romania, including the Central Region and Szeklerland, using Google Scholar as the primary source. The sources for the secondary data collection were the Romanian Statistical Office (INS) website, Eurostat, FAO, EMIS, World Bank. The second topic was the use of ICT, digital tools, precision technology in agriculture, also an integral part of the secondary data collection was the exploration and study of relevant literature. The sources of relevant literature were Google Scholar, Research Gate, Web of Science, Science Direct. The keywords used in the search were *digitalisation of agriculture, ICT tools in agriculture, conditions for digitalisation of agriculture, precision agriculture, agriculture 4.0, drones in agriculture, farm management software in agriculture, mobile apps in agriculture* and their combinations. In addition to the above keywords, I also considered it important to use only relevant and relatively recent articles and studies. After the literature analysis, I formulated the hypotheses, tested their validity and relevance in my questionnaire research, and after the questionnaire research, I selected the statistical methods for the analysis.

3.2. Presentation of the empirical research

The empirical research was based on a questionnaire survey, processed using the SPSS program, involving classical descriptive statistics and complex multivariate analysis. To create the questionnaire, the QuestionPro online interface was used, so the questionnaire was created and shared online and the response were also formulated and collected online. The questionnaire survey was carried out in the Central Region and Szeklerland, Romania, among farmers whose activity is crop production, livestock production or mixed farming (crop production and livestock production). Based on the secondary data, it became evident that in

Szeklerland both mixed farms and small farms are dominant, therefore, regarding the content of the questionnaire, I tried to formulate questions that are relevant for small farmers in the field of digitalization of agriculture, and the knowledge of digital tools, so the focus of the questionnaire was not only on the use of digital technologies.

For the questionnaire I used the QuestionPro online interface, and the questionnaire survey was relised online between 25 March and 27 August 2023. In total, my questionnaire was sent to 1 285 farmers, I received 500 responses, of which after data cleaning I was able to evaluate 300 and use them in the analysis.

The objectives of the dissertation were to assess the situation, from the farmers' point of view, regarding the current knowledge and application of ICT, precision and digital tools, and to outline a future perspective, including the application of ICT, precision and digital tools. In the first part of the results section, I described the knowledge and use of ICT and digital tools among farmers based on the questionnaire research, and then the future vision and goals of farmers based on the results of the questionnaire research. The results are presented and illustrated by graphs, charts and tables. The hypotheses are then analysed. Cross-tabulation, ANOVA and two-step cluster analyses were carried out by using the SPSS program, and the hypotheses were tested by applying these methods.

Overall, the socio-demographic characteristics of the sample indicate that the majority of the respondents were male (84%), the average age of the respondents was 40 years, and the average level of education was secondary (45%). Based on the responses received, I found that the majority of the farmers in the sample had a permanent address in a rural settlement (87%). The majority of the responding farmers, 53%, have a mixed farm (crop and livestock), while 39% have a crop farm and only 8% have a livestock farm. The average agricultural land used by the average respondent was 46 hectares. 57% of the farms fall in the small farm category (2-20 hectares), followed by the medium farm category (20-100 hectares) with 37% and 7% in the large farm category (> 100 hectares). 81% of the responding farmers carry out agricultural activities without legal personality, 38% of the respondents in this category are private entrepreneurs, 29% have the status of authorized natural person and 14% are family businesses. The proportion of farmers with legal personality is 8%. 11% of the farmers responding do not have entrepreneur status, they only have a producer's licence. 52% of farmers are not members of any cooperative, while 32% are and 16% would like to become members in the future. The majority of the respondents fall into the category of less than 25 000 RON in terms of annual net turnover, followed by the category of 25 000-50 000 RON

I used cross tabulation, ANOVA analysis and cluster analysis to process the results of the questionnaire research. The analyses were carried out using SPSS software, which was used to examine the correlations between the data and information collected by the questionnaire, to see if there is any correlation between the variables and responses and to draw conclusions and test hypotheses.

The most commonly used method was cross tabulation, because most of the variables in the database are ordinal or nominal variables and cross tabulation analysis nicely outlines the correlation, the relationship, the closeness and the degree of closeness between the variables under study.

4. RESULTS AND DISCUSSION

The objectives of the dissertation were to assess the situation from the farmers' point of view regarding their current knowledge and application of ICT, precision and digital tools, and to outline a future perspective, in which the application of ICT, precision and digital tools was also in the focus. In the first part of the results section, I will describe the knowledge and use of ICT and digital tools among farmers based on the questionnaire research, and then I will describe farmers' future vision and goals based on the results of the questionnaire research. The results are presented and illustrated by graphs, charts and tables. The hypotheses are then analysed and the results are presented. Cross tabulation, ANOVA and cluster analyses were carried out using the SPSS program, and the hypotheses were tested by applying these methods.

4.1 Knowledge and use of ICT and digital tools based on the questionnaire survey

The introductory questions focused on farmers' ICT literacy and knowledge. 36% of farmers, the majority, had received computer education at secondary school, 22% at university and 18% had attended a course.

24% of respondents had not received any computer education. The majority of respondents (38%) rated their computer/internet skills as good, 35% as medium, 14% as poor and 12% as very good. I further examined the ICT tools used by farmers in their work, which revealed that the majority of the respondent farmers (91%) use smart phones in their farming work, followed by laptops 59%, desktop computers 21%, GPS 17% and tablets 16%. In terms of the use of professional mobile apps, 89% of farmers use a mobile app on the farm for weather forecasting and 80% for market information, while 59% use Microsoft Excel spreadsheet software and 21% use electronic invoicing/accounting software and spray diaries. Farmers who regularly use ICT tools say that ICT tools facilitate daily work and administration, and the majority of farmers use the data and information collected by ICT tools for future planning. 65% of farmers have no problems using ICT tools while for 16% using ICT tools poses a challenge. In the latter case, the category of difficulties cited by farmers included: lack of expertise in the use of ICT tools, finding and using the right applications, difficulty in keeping up with the use of modern tools, lack of advice and knowledge transfer.

4.2. Knowledge and use of precision technologies and drones based on the questionnaire survey

51% of the farmers surveyed had heard of or were familiar with the concept of precision farming, but did not use it on their farm. On the other hand, 17% use some precision farming technology on their farm and 31% have not heard of/are not familiar with and do not use it. The majority of farmers (46%) had come across the term precision farming on a professional website. In terms of sectors, 76% of farmers who use precision farming technologies are growing crops. In terms of tools used, the majority of farmers use precision plant health monitoring. Within livestock farming the most used tool is the milking robot. Looking at the areas of application of drones, the majority of farmers have used or would be willing to use a drone on their farm. Through the questionnaire, I further sought answers to the questions related to factors that hinder and help the adoption of digitalisation and precision technologies in agriculture. According to the responding farmers the three major factors chosen as barriers were: *lack of expertise, financial burden and lack of confidence in efficiency*. Among the facilitating factors, the three most important factors identified by farmers were *more or more detailed information, professional advice and training*, *skilled labour* and *higher profitability*. Based on farmers' opinions, it can be concluded that they see the usefulness and importance of digitalisation in agriculture and believe that it will be indispensable for the future, but there is still a sense of uncertainty and fear towards digitalisation. In the latter case, as farmers have expressed, education, training and consulting services can help in learning about and familiarising with digital and precision technologies. Among the disadvantages of using drones and precision technologies, the adjective "expensive" appeared in the answers of several farmers, for which the solution could be to use current EU tenders and to develop a communal precision machinery fleet for smaller farmers by integrating them into cooperatives.

4.3. Assessment of future ideas and needs

The final part of the questionnaire contains questions on farmers' future plans, outlining the direction of development and the issue of farm transfer, i.e. succession. In terms of future plans, the majority of farmers would like to develop and expand the farm. There are few farmers who want to sell the farm. The issue of succession is considered to be solved by 51% of the farmers and the question remained unsolved by 49%. In the latter case, the following reasons were given for succession: no successors to take over the farm, young people are not interested in farming, no desire to work in agriculture, no male successors, farming is not a profitable sector.

According to the questionnaire results, 69% of farmers would like to take part in future training courses to learn how to use ICT and digital tools and 31% do not want to take part in such courses. The majority of the farmers who completed the questionnaire (44%) believe that in the future it will be possible to gain a competitive advantage through the development of modern machinery, followed by market cooperation (42%), skilled labour (42%) and vocational qualifications, professional knowledge and training (41%).

4.4. VALIDATING HYPOTHESES

1. ***Hypothesis: Digitalisation of agriculture in the Central Region and Szeklerland is influenced by the structure of the economy and the farm structures to different degrees. Medium (over 20 hectares) and large (over 100 hectares) farms are more familiar with ICT, digital tools and their use is more widespread, while smaller farms (under 20 hectares) are less familiar with ICT.***

Testing hypothesis 1. was performed by using multiple cross-tabulation analysis, including and using multiple questions as appropriate, and the most important variable was the variable called the property size categories. The results showed that there is a significant relationship between farm size and the use of weather and temperature check apps ($\chi 2=7.12$; $p=0.028$). While larger farms use weather and temperature check apps, medium and smaller farms use these apps less. There is a significant relationship ($\chi 2=8.97$; $p=0.011$) between farm size and the use of mobile apps to assess crop condition, since smaller farms are less likely to use mobile apps to assess crop condition. There is a significant relationship ($\chi 2=6.09$; $p=0.047$) between the variables of farm size and the use of mobile apps to obtain market information (input prices, sales prices, etc.), with smaller farms less likely to use mobile apps to obtain market information. Based on the cross-tabulation analysis, the relationship between variables was not significant in two cases. One case is farm size and monitoring irrigation by using mobile app ($\chi 2=3.56$; $p=0.168$), the other case is farm size and monitoring nutrient supply by using mobile app ($\chi 2=1.52$; $p=0.467$). There is a significant relationship between farm size and knowledge and use of precision farming ($\chi 2=74.58$; $p=0.00$). Large farms have higher knowledge and use of precision farming technologies, medium farms have knowledge but not use of precision farming technologies, while smaller farms have less knowledge and use of precision farming technologies. Farm size therefore influences the knowledge and use of precision farming. The results show that there is a significant relationship between farm size and the variables of willingness to use and adopt agricultural drones ($\chi 2=29.21$; $p=0.00$). Smaller farms tend to be more reluctant in adopting or willing to adopt agricultural drones, while medium farms and large farms have higher rates of adoption and willingness to adopt. This implies that farm size has an impact on the adoption and willingness to adopt agricultural drones. When examining the relationship between farm size and adoption of ICT tools, there were two cases where the relationship was not significant – the variables having a smartphone and having none of the ICT tools. The descriptive statistics revealed that the most commonly used ICT device is the smartphone. For larger farms, the range of ICT tools used is more varied. Therefore, it can be said that the first hypothesis is valid in almost all cases. In two cases there was no significant relationship: one was farm size and the monitoring of irrigation using mobile apps, and the other was farm size and the monitoring of nutrient supply using mobile apps. In the cross-tabulation analysis of the ICT tools and farm size categories, there was also no significant relationship between the variables: 'smartphone' and 'I do not use any ICT tool'. Overall, it can be stated that the **first hypothesis was partially validated.**

2. ***Hypothesis: Young people are motivated to engage in agricultural activities through the use of ICT and digital tools.***

One of the questions within the survey asked: *Do you think ICT, digital tools and software make agriculture more attractive for young people?* The majority of respondents, 90%, said yes and only 10% responded negatively. In this regard, **hypothesis 2 is validated**, which states that young people are motivated to engage in agricultural activities by the use of ICT and digital tools.

3. ***Hypothesis: The proportion of knowledge and use of ICT, digital tools and precision technologies varies according to educational levels.***

Hypothesis 3 was tested using one-way ANOVA analysis of variance and cross-tabulation. The basic question and the basic variable is level of education, for which I also created categories: primary, secondary and tertiary education, described in the descriptive statistics section. Moreover, four categories were created for evaluation, described in the descriptive statistics section.

Table 2: Results of one-way ANOVA analysis of variance (Descriptives and ANOVA table)

	N	Mean	Std. deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Primary education	119	3.7983	1.75914	.16126	3.4790	4.1177	1.00	7.00
Secondary	136	4.6544	1.39512	.11963	4.4178	4.8910	1.00	7.00
Tertiary	45	5.6667	1.43019	.21320	5.2370	6.0963	1.00	7.00
Total	300	4.4667	1.67678	.09681	4.2762	4.6572	1.00	7.00
	Sum of Squares	df	Mean square	F	Sig.			
Between Groups	122.750	2	61.375	25.391	.000			
Within Groups	717.917	297	2.417					
Total	840.667	299						

Source: own editing (2023)

I started testing hypothesis 3 with a variance analysis, in which I examined the relationship between farmers' level of education and their self-assessment of computer/Internet user skills. The mean score of the computer/Internet user knowledge of those with primary education was 3.79, 4.65 for those with secondary education and 5.66 for those with tertiary education, while the mean score of the computer/Internet user skills of the total sample was 4.46. The same rule applies when examining the results of the F-test, i.e. if the estimated p-value is greater than 0.05 then the relationship is not significant. *Table 3* shows that it is significant, which in this case means that there is a significant difference between level of education and computer/internet user knowledge. In order to see the relationship between level of education and computer/Internet user knowledge, a cross-tabulation analysis was also performed. 43% of farmers with tertiary education rated their computer/internet user knowledge as very good, while 58% of farmers with secondary education rated it as good and 76% of farmers with primary education rated it as poor. The cross tabulation and ANOVA analyses indicated that farmers with higher education also had higher computer/internet user knowledge. The results show that farmers with primary education do not use laptops, while farmers with secondary and higher education do, and farmers with higher education use tablets in their agricultural work. Examining the relationship between the use of professional mobile apps by farmers and the variables of farmers' level of education, the relationship was significant in only one case using cross-tabulation analysis, for mobile apps used for temperature check ($\chi2=21.60$; $p=0.001$). The majority of farmers with tertiary and secondary level of education are aware of the concept of precision agriculture and have heard of it and it can be stated that they use it at a higher rate than farmers with primary level of education, the majority of which are neither aware of it nor use it. There was a significant relationship ($\chi2=17.85$; $p=0.00$) between the variables of educational level and willingness to use and apply agricultural drones, which implies that farmers with primary education did not use and were not willing to use agricultural drones, while farmers with tertiary education used and were willing to use agricultural drones. **Hypothesis 3 was partially confirmed by** the analyses. Knowledge and use of ICT, digital tools and precision technologies varies according to educational level. I highlight that it is partial, because, as shown by the hypotheses above, it is not always possible to state that there is a significant relationship between the variables under study.

4. ***Hypothesis: Experience in agriculture (number of years) has a positive effect on the knowledge and use of ICT, digital and precision technologies, i.e. the more experience in agriculture, the higher the proportion of knowledge and use of ICT, digital tools and precision technologies.***

The fourth hypothesis was investigated by examining the question of age and the new variable of age categories by several cross-tabulation analyses. The results show that there is a significant relationship between the variable age and the use of weather forecasting mobile app ($\chi2=14.04$; $p=0.001$). The older age group does not use weather forecasting mobile apps, while the younger age group does. There is also a significant relationship between age and the use of mobile apps for checking temperature variable ($\chi2=13.36$; $p=0.001$), in case of which the young age group uses such mobile apps while the middle and old age group do not use them. The results suggest that the younger age group is more likely to use mobile apps, hence age/experience in agriculture does not have a positive effect on the use of professional mobile apps, thus the opposite of those stated in the fourth hypothesis was shown based on the aforementioned cross tabulation analysis. In the following, I will continue to test the fourth hypothesis through the age category variable, including new variables in the analysis. There was only one case where a significant relationship between the age variable and the use of ICT tools was found, namely, the use of a laptops ($\chi2=45.73$; $p=0.00$). Interpreting the results, the older age group does not use the laptop for farming purposes, while the younger age group uses laptops regularly (daily or weekly). The young age group uses/would use a farm drone, while the majority of the middle age group and the older age group (72%) do not use and would not use a farm drone. This implies that the number of years of experience in agriculture does not have a positive effect on the adoption of agricultural drones. Based on the results of the cross-tabulation analysis, **I reject the fourth hypothesis.** The analyses (cross-tabulation analyses) proved that the older age group is less familiar with ICT, and hardly uses any digital and precision farming tools, while the younger and, in some cases, the middle age group is more familiar with and uses ICT, digital and precision farming tools.

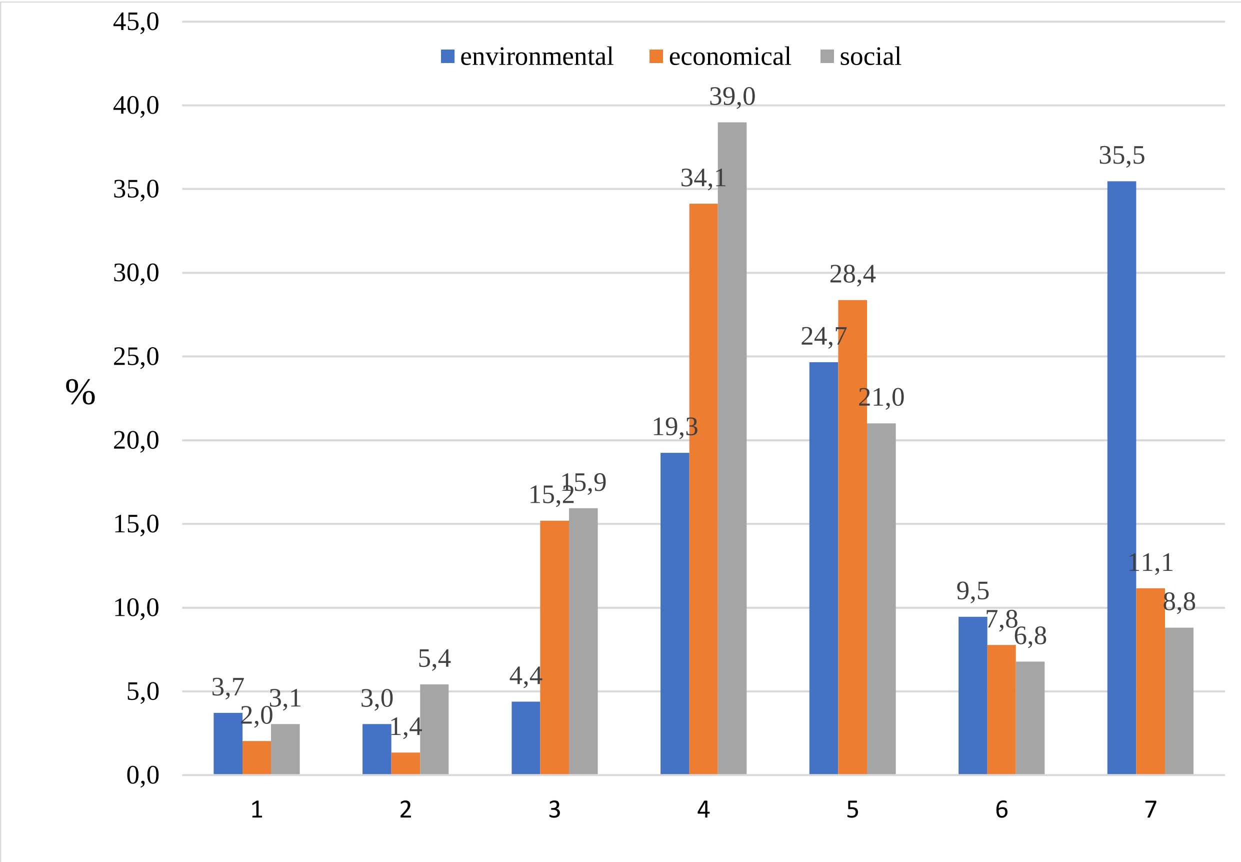
5. ***Hypothesis 1: For higher income farms, ICT, digital tools, precision technologies are known and used, so higher income has a positive impact on the digitalisation process of agriculture. This hypothesis was also tested using cross tabulation analysis with income categories as the underlying variable. The table below illustrates the questions included in the cross-tabulation analysis and the main results.***

There is a significant relationship between the income category variables and the use of ICT tools variable, except for one ICT tool, there is no significant relationship between the use of smartphones and income category variables ($\chi2=11.31$; $p=0.079$). However, it was also found that farmers with higher income have a richer and more colourful use of ICT tools than farmers with lower income. There was a significant relationship between the income variable and the knowledge of the concept of precision farming and the use of its technology ($\chi2=81.43$; $p=0.00$). There is a larger proportion of farmers with higher income who have knowledge of and who use precision farming technology. More specifically, 64% of farmers in the category above 300 000 RON income, know and use precision farming technology, while there is only 5% of farmers in the category below 25 000 RON income. At the same time, 52% of farmers in the income category below 25 000 RON have not heard of or do not use it. Based on the cross-tabulation analysis, it is clear that income has an impact on the use of precision farming technologies, with higher income having a positive impact. The results show that there is a significant relationship between the income category variable and the variables of willingness to use agricultural drones ($\chi2=27.36$; $p=0.00$). The majority of farmers in the higher income category use of agricultural drones, more specifically 91% of farmers in the income category above RON 300 000 know and use precision agriculture technology, while 33% of farmers in the income category below RON 25 000 know and use such precision agriculture technology. Based on the cross-tabulation analysis, it is clear that **income has an impact on the use of agricultural drones, with higher income having a positive impact**.

6. ***Hypothesis: Digitalisation contributes significantly to all three dimensions of sustainability.***

The last question of the questionnaire was the following: *To what extent do you think that digitalisation in agriculture contributes to sustainable (environmental and/or economic and/or social) farming? 1 to 7, where 1: no contribution, 7: significant contribution.*

Figure 2: The contribution of agri-digitalisation to sustainable (environmental and/or economic and/or social) farming



Source: own editing (2023)

Figure 2 shows that 36% of the responding farmers consider that agri-digitalisation contributes significantly to environmental sustainability, 11% consider it contributes significantly to economic sustainability and 9% consider it contributes significantly to social sustainability. Therefore, the responses suggest that digitalisation contributes significantly only to environmental sustainability, and **I reject the sixth hypothesis** that digitalisation contributes significantly to all three dimensions of sustainability.

7. ***Hypothesis: Strengthening digitalisation in the future economy is essential for business competitiveness. Farmers who intend to apply for an EU grant in the next 2-3 years should make the digitalisation of the farm a priority.***

In the 4th section of the questionnaire, I formulated questions referring to the future state of the economy (plans, goals, ideas) and in this part one of the questions was whether respondents intend to apply for an EU grant in the upcoming 2-3 years, and the type of improvements and innovations they plan to make in their farming business. Among the alternatives that could be chosen, the digitalisation of farming (purchase of digitalisation tools, software, drones) was also mentioned. Hypothesis 7 was tested by looking at the answers provided to the above questions. The majority of the farmers (54%) would like to purchase machinery/tools through grants and 33% of the responding farmers would like to implement digitalisation on their farm through grants. Based on the responses, the first priority for farmers in terms of future improvements is to purchase machinery/tools and the second priority is digitalisation of the farm. This means that **I can only partially validate Hypothesis 7,** as farming digitalisation did not turn out as a top priority based on the responses received.

Table 3: Hypotheses tested within the thesis, methods and results

Hypothesis	Validation method	Result
H1. Digitalisation of agriculture in the Central Region and Szeklerland is influenced by the structure of the economy and the farm structures to different degrees. Medium (over 20 hectares) and large (over 100 hectares) farms are more familiar with ICT, digital tools and their use is more widespread, while smaller farms (under 20 hectares) are less familiar with ICT.	empirical research, cross -tab analysis	**Partially validated** Result: farm size has an impact on and influences the adoption of ICT, digital and precision agriculture technologies on farms, but there is no significant relationship in all of the cases.
H2. Young people are motivated to engage in agricultural activities through the use of ICT and digital tools.	descriptive statistics	**Validated**
H3. Knowledge and use of ICT, digital tools and precision technologies varies according to famers' level of education.	ANOVA cross-tab analysis	**Partially validated** Result: Hypothesis 3 was partially confirmed, because, as shown by the cross-tabulation analyses above, it is not always possible to conclude that there is a significant relationship between the variables under study, especially between the variables of educational levels and the use of different ICT tools.

H4. Experience in agriculture (number of years) has a positive effect on the knowledge and use of ICT, digital and precision technologies, i.e. the more experience in agriculture, the higher the proportion of knowledge and use of ICT, digital tools and precision technologies.	Cross-tab analysis	**Rejected** Result: the opposite was found to be true, with the older age group being less familiar with and using ICT, digital and precision farming tools, and the younger and, in some cases, middle-aged age groups.
H5. For higher income farms, ICT, digital tools, precision technologies are known and used, so higher income has a positive impact on the digitalisation process of agriculture.	Cross-tab analysis	**Validated** Higher income has a positive impact on the knowledge and use of ICT, digital tools and precision technologies.
H6. Digitalisation contributes significantly to all three dimensions of sustainability.	Descriptive statistics	**Rejected** Result: agri-digitalisation contributes significantly only to environmental sustainability.
H7. Strengthening digitalisation in the future economy is essential for business competitiveness. Farmers who intend to apply for an EU grant in the next 2-3 years should make the digitalisation of the farm a priority.	Descriptive statistics	**Partially validated** Result: the digitalisation of the farm is not a top priority according to the responses received.

Source: own editing (2023)

4.5. Cluster analysis (two-step cluster analyses)

One of the key objectives of the analysis was to create distinct clusters of ICT, precision agriculture technologies and agricultural drones, which could help formulate the right strategy/proposal(s) for a faster and more efficient development of digital agriculture. The variables included in the first cluster analysis are: drone application categories, farm size (how many hectares do you farm), minimum cultivated parcel size, age, income and education. In fact, through the first cluster analysis, based on the questionnaire survey, I created the profile of the farmer who has not used a drone and is not willing to use a drone. Thus, I can call the first cluster of the first cluster analysis as the group of farmers who do not use/refuse to use drones. While the second cluster depicts the profile of the group of farmers who use/are willing to use drones based on the questionnaire survey.

Through the following cluster analysis, I developed clusters of ICT tool use based on the questionnaire survey. As I have already described in the descriptive statistics, but also in the cross-tabulation analysis, it has been proven several times that the smartphone is one of the most used ICT devices. This is also confirmed by the cluster analysis, as in all three clusters the smartphone is listed as a used ICT device. In fact, it can be concluded that farmers belonging to the second cluster are the ones who use all ICT tools on the farm in a higher proportion, while those belonging to the third cluster use only two ICT tools. The most used ICT tools are laptop and smartphone.

The first and third cluster analysis outlined that farmers who know/apply precision agriculture technology and farmers who use/willing to use agricultural drones have similar characteristics: larger average farm size, younger age group (average age 37), higher level of education (high school), higher turnover (above 25 000 RON). At the same time, farmers who do not know/do not use precision farming technology and farmers who do want to use agricultural drones also have similar characteristics: smaller farm size, middle age, lower level of education (vocational school), lower turnover (below 25 000 RON).

5. CONCLUSIONS AND PROPOSALS

In the following section, I summarise the results of the research, the problems identified and some suggestions for solving them. In the first part, I summarise the results of validating the hypotheses, and then the main conclusions of the questionnaire survey on the knowledge and use of ICT, precision agriculture technology, outlining the profile and opinions of farmers.

The first part of the dissertation aimed at assessing the situation of farmers' use of ICT, digital and precision agriculture technologies. From this perspective the questionnaire survey shows that small farms (farms with less than 20 hectares) and fragmented farm structure predominate, which are not necessarily conducive to the process of agri-digitalisation. This has also been confirmed by the literature review. The first hypothesis is also partly relevant to this topic, which states that the digitalisation of agriculture in the Central Region and Szeklerland is influenced to varying degrees by the structure of the economy and the structure of farms. Medium (over 20 hectares) and large (over 100 hectares) farms are more familiar with ICT, digital tools, precision farming technologies and their use is more widespread, while smaller farms (under 20 hectares) are less familiar with them. The hypothesis was tested through cross-tabulation analysis, which proved that there was a significant relationship between farm size and the use of professional mobile apps in four cases: weather forecasting apps, temperature monitoring apps, crop condition assessment apps, and market information apps. In these cases, it can be stated that the aforementioned mobile applications are used less or not at all by smaller farms than by medium or large farms. In two cases, the relationship was not significant for the variables of monitoring farm size and irrigation by using mobile apps and monitoring nutrient supply by using mobile apps. There was a significant relationship between farm size and the use of agricultural drones, with smaller farms tending to be neither willing nor using agricultural drones, while medium and larger farms had higher rates of use and willingness to use drones. A similar trend was also outlined when examining farm size and the adoption of precision agriculture technologies, with large farms having a higher awareness and adoption rate of precision agriculture technologies, while medium farms are aware of precision agriculture technologies but do not use them, and smaller farms are less aware and less likely to use them. When examining the correlation between farm size and the use of ICT tools, it can be stated that the relationship was not significant in two cases: for the smartphone variable and the variable I do not use any ICT tools. Overall, the range of ICT tools and use on larger farms is more diverse than on smaller farms. The first hypothesis is partially validated, i.e. farm size has an impact and influences the use of ICT, digital, precision agriculture technologies on farms, but not always can a significant correlation be reported.

The second hypothesis was confirmed: young people are motivated to engage in agricultural activities through the use of ICT and digital tools. The majority of the farmers who filled in the questionnaire, more precisely 90% of them, think that ICT, digital tools and software make farming more attractive for young people and only 10% do not.

Farmers can be classified into different groups based on their use of ICT and digital tools, and these groups have different attitudes towards agri-digitalisation. Farmers' attitudes are influenced by some external and internal factors such as demographic characteristics: education and age. Hypotheses 3 and 4 partly investigated this aspect. Hypothesis 3: The proportion of knowledge and use of ICT, digital tools and precision technologies varies according to participants' level of education. ANOVA analysis revealed that there is a significant relationship between level of education and computer/internet user knowledge, with a mean score of 3.79 for those with primary education, 4.65 for those with secondary education and 5.66 for those with tertiary education, while the mean score for the total sample was 4.46 for computer/internet user knowledge.

Cross-tabulation analysis of the relationship between level of education and ICT tools shows that the relationship between these variables was not significant for all ICT tools. Farmers with primary education do not use laptops but rather smartphones, while farmers with secondary and tertiary education use laptops, smartphones and farmers with tertiary education also use tablets in their agricultural work. When examining the relationship between the use of professional mobile apps by farmers and the variables of farmers' level of education, the relationship was significant in only one case using cross-tabulation analysis, namely, in case of mobile apps used for temperature monitoring. The majority of farmers with primary education, do not use and do not plan to use professional mobile apps, while farmers with secondary education, use these regularly, and the majority of farmers with tertiary education, use such apps occasionally. Results indicate that there is a significant relationship between farmers' level of education and their knowledge and use of precision farming technologies, whereby level of education influences the knowledge and use of precision farming technologies. The majority of farmers with tertiary and secondary education know and have heard of the concept of precision agriculture and it can be stated that they use it at a higher rate than farmers with primary education, the majority of which do not know about it and do not use it. Farmers with primary education have not used and are not willing to use agricultural drones, while farmers with tertiary education have used and are willing to use agricultural drones. Hypothesis 3 was partially validated, because as it was shown by the cross-tabulation analyses above, it is not always possible to state that there is a significant correlation between the variables under study, especially between level of education and the use of different ICT tools.

Hypothesis 4: Experience in agriculture (number of years) has a positive effect on the knowledge and use of ICT, digital and precision technologies, i.e. the more experience in agriculture, the higher the proportion of knowledge and use of ICT, digital tools and precision technologies. The results suggest that the younger age group is more likely to use mobile apps, ICT tools, precision farming technologies, agricultural drones, hence age or experience in agriculture does not have a positive effect on the use of professional mobile apps, ICT tools, precision technologies. In fact, the opposite of the fourth hypothesis was found based on the cross-tabulation analysis, according to which the older age group is less familiar with and hardly ever uses ICT, digital, precision farming tools, while the younger and, in some cases, the middle age group is more familiar with and uses ICT, digital, precision farming tools.

Hypothesis 5: For higher income farms, ICT, digital tools, precision technologies are known and used, so higher income has a positive impact on the digitalisation process of agriculture. The cross-tabulation analysis clearly shows that income has an impact on the use of agricultural drones and higher income has a positive impact. The use of ICT tools by farmers belonging to higher income group is more varied and richer than those belonging to the lower income group. Income has an effect on the use of agricultural drones, and higher income has a positive effect.

Hypothesis 6: Digitalisation contributes significantly to all three dimensions of sustainability. Based on the responses, it can be concluded that agri-digitalisation contributes significantly only to environmental sustainability, and I therefore reject hypothesis 6, which states that digitalisation contributes significantly to all three dimensions of sustainability.

Hypothesis 7: Strengthening digitalisation of farming in the future is essential for business competitiveness. Farmers who are planning to apply for an EU grant in the next 2-3 years will make the digitalisation of the farm a priority. Based on the responses, the top priority for farmers in terms of future improvements is the purchase of machinery/tools and the digitalisation of the farm is only the second priority. Accordingly, I can only partially validate hypothesis 7, as the digitalisation of the farm is not a top priority based on the responses received.

Based on the empirical research, it can be stated that the majority of farmers use smartphones and laptops as ICT devices on the farm, with smartphone and internet use being the most common ICT devices used on a daily basis. Among professional mobile applications, farmers mostly use professional mobile applications for weather forecasting and market information, and for computer programs, Excel is used, alongside spray diary. However, the majority of farmers who do not use any computer software do not want to use them in the future, due to lack of knowledge, poor digital literacy or lack of knowledge of current software. Farmers who do use ICT tools and software on the farm believe that their use makes daily work and administration easier and helps them reduce costs. The majority of farmers know/have heard about the concept of precision agriculture and the concept of agricultural drones, but their actual use is lower, especially in case of smaller farms. The three strongest barriers to digitalisation of agriculture by farmers are lack of expertise, lack of confidence and being financially burdensome. At the same time, farmers' responses suggest that the possibility of accessing expert advice, more detailed information, training and skilled labour would greatly help the digitalisation of agriculture. As for the future, most of the farmers would like to expand and develop the farm and would also like to apply for an EU grant in the next 2-3 years to purchase machinery and equipment.

The digitalisation of smaller farms (up to 2-20 hectares) is equally important in the process of the digitalisation of agriculture, since in Romania (in the Central Region, and in Szeklerland as well), as it was shown in the literature review and also based on the questionnaire survey, smaller farms are dominant. In order to achieve this, it is essential to develop an agricultural strategy that focuses on the digitalisation process of smaller farms, in which the state must also play a role. At the same time, the primary research also revealed that the majority of farmers know and have heard of precision farming technologies, but have only superficial knowledge and fragmented information. In this respect, one solution is to seek advice from experts and to participate in professional training. In the latter case, educational institutions, including higher education institutions, have a key role to play in providing training opportunities for farmers to learn how to use digital, ICT tools and precision farming technologies.

The cluster analysis also confirmed that the differences between clusters, more specifically between farmers who know/apply precision technologies, agricultural drones and farmers who do not, are bridged by financial support, education, vocational training and, in the case of farm size, cooperative membership. The study of ICT tools and their use by cluster analysis confirmed the need to expand the range of ICT tools available to farmers, so that they are not limited to the smartphone. The same can be said for computer software and the use of professional mobile applications, the range and use of these should be expanded and more varied. Education, training and professional advice also have a key role to play in this process.

6. THE MAIN FINDINGS, NEW OR NOVEL RESULTS OF THE THESIS

1. The results of the empirical research do not confirm that digitalisation contributes significantly to all three dimensions of sustainability, as the responses suggest that agri-digitisation contributes significantly only to environmental sustainability. Based on the responses and performing cross-tabulation analyses, the following have been found:
2. The cluster analysis also allowed me to group farmers in the sample according to three criteria. Among these, farmers were clustered into distinct groups according to whether or not they were/are willing to use a drone, whether or not they were/are familiar with precision agriculture technology, and whether or not they were/are using ICT tools. For all three clusters, the smartphone is listed as the ICT tool used. Farmers belonging to the second cluster are those who use all kinds of ICT tools on the farm in higher proportions, while those belonging to the third cluster use only two ICT tools. The most used ICT devices were laptop and smartphone.
3. My research was the first to assess and evaluate the situation of digitalisation of agriculture among farmers in the Central Region and in Szeklerland.

SUMMARY

The central topic of my PhD thesis is the digitalisation of agriculture, which is a priority topic in the European Union, as agricultural digitalisation also includes solutions that help to ensure safe and adequate food supply for the world, the conscious and optimal use of scarce input resources, and the reduction of environmental pollution. The digitalisation of agriculture is not happening in a uniform way across Europe, depending on many factors and actors, with Member States, farmers' organisations and farmers playing an important role. In my doctoral thesis, I studied the digitalisation of agriculture in the Central Region of Romania, with a special focus on Szeklerland, where I defined two important objectives: a situation analysis in the Central Region and Szeklerland, focusing on farmers' opinions on the current situation of agriculture, with special attention to the use of ICT, digital tools and solutions, and their vision of the future, where the use of new digital technologies and tools was also studied.

In the literature review section of the thesis, I summarized the situation of agriculture in Romania, in the Central Region and Szeklerland, and then the development of agriculture, the main milestones, which included precision agriculture, the concept of agricultural drone, ICT tools, software, and mobile applications in agriculture. Secondary data analyses also included an insight into the process of agricultural digitalisation in different European Member States, according to which it can be stated that developed countries are putting more emphasis on agricultural digitalisation. The use of digital technologies in agriculture is steadily increasing, so there is a growing trend in the European region, which is also supported by the CAP 2021-2027 objectives, i.e. to introduce digital solutions and technologies in agriculture that reduce environmental pollution and bureaucracy, promote generational renewal and make farmers' work easier. Lack of knowledge, expertise, digital literacy, insecurity, adequate financial background, farm structure/holding structure are all factors that hinder the adoption and use of digital technologies. The last part of the literature review section was the topic of digitalization and its conditions within the Romanian and Szekler agriculture, through which I explored the current perspective and position of the literature on the digitalization of agriculture. On the one hand, in Romania, the digitalisation of agriculture is being slowly implemented, small farms dominate in terms of farm structure and the fragmentation of agricultural land is typical for the country. On the other hand, the lack of digital competences is also a hindering factor. Romania has a high agricultural potential, which can only be exploited in a conscious and sustainable manner if farmers also recognise the importance, usefulness and relevance of digitalisation of agriculture and demand the use of innovative technologies. In the latter case, the most important

question is whether farmers have recognised the importance of digitalisation and its application possibilities in agriculture, whether they are willing to use modern digital solutions and tools, and what opportunities are there for smaller farms to acquire and use digital solutions. The answers to the above questions were relevant to the empirical research conducted.

Based on the empirical research, it can be stated that the majority of farmers use some form of ICT in their agricultural work, with the most commonly used ICT tools being smartphones and laptops. In the case of mobile applications, the best known and most commonly used applications are weather forecasting applications and in the case of computer programs, Excel. The range of ICT tools and usage on larger farms is more diverse than on smaller farms. Farmers' responses suggest that there is a need for awareness raising, as in most cases they are not familiar with the software and applications that they could use on the farm. When looking at the use of precision technology and agricultural drones, a similar trend was also outlined in the responses, i.e. in most cases farmers have heard of the concept of precision technology and drones, but do not use them or only few use them on the farm. Large farms are more aware of precision farming technologies and drones and have a higher proportion of usage, while medium farms are aware of precision farming technologies and drones but do not use them, and smaller farms are less aware and use them less. Smaller farms are more likely to not use agricultural drones, they do not even have willingness to use them, while medium and larger farms use them more and a higher proportion of them is willing to use agricultural drones.

Based on the cluster analyses, the profile of the farmer who knows/applies precision farming technology and who uses/is willing to use agricultural drones was outlined, according to which the profile is as follows: larger average size of the farm (70-148 hectares), average age 37, smallest cultivated parcel 0.86-1.22 hectares, level of education high school, income between 25 000-50 000 RON and above 300 000 RON. The profile of the farmer who does not know/use precision farming technology or who refuses to use agricultural drones is the following: smaller average size of the land: 19,22-19,61 hectares, average age 41-43, smallest cultivated parcel 0,52-0,57 hectares, level of education vocational school, income below 25 000 RON.

Overall, based on the empirical research findings, it can be stated that the majority of farmers would like to acquire new tools and machinery and are open to development, digitalisation and participation in vocational training, provided that such an environment is created that helps them and motivates them to complete and master the digitalisation process and overcome the inhibiting factors. The role of the state, educational institutions, farmers' organisation(s) and of the agricultural development agency is important and indispensable in the digitalisation process of agriculture, by developing an appropriate agricultural strategy, providing vocational training, disseminating knowledge, providing expert advice and financial support.

The results of the research can be useful on several levels: it can partly help agricultural policy makers to develop an appropriate agricultural strategy, which will contribute to the digitalisation of agriculture. The research has also identified problems and factors that hinder the implementation of the agri-digitalisation process from the perspective of the farming community, but at the same time it also contains a colourful range of solutions, also from the farmers' perspective. In fact, information and conclusions have been outlined that are useful not only for decision-makers in the sector, but also for the farming community, particularly in view of the problem of digitalisation of small farms. Moreover, the present study can provide valuable information not only for farmers and agribusiness decision-makers, but also for companies selling precision agriculture technology and ICT tools on the market, in such a way that it partly sheds light on whether farmers would like to use digital, ICT tools, precision technology, agricultural drones in the future, thus also partly touching the topic of market potential.

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