UP-SKILLING AND RE-SKILLING FOR DIGITAL AGRICULTURE IN ROMANIAN BIG CROPS FARMS: EXPLORATORY CONSIDERATIONS

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Abstract. *This paper aims to elevate the interest in the academic, professional, and policy-making circles to the need for a large-scale re-skilling and up-skilling effort for the management and the workforce in Romanian farms in light of the large-scale deployment of the Agriculture 4.0 technologies. The Romanian agricultural sector is a major contributor to the EU agricultural output and the aim of such an effort would be to secure and enhance its competitiveness by future-proofing the performance and sustainability of the Romanian farms in the context of yield growth imperative, sustainable exploitation of land and water resources and efficient and fast decision making enabled by digitalization. A review of the most influential papers and the bibliometric mapping (using VOSviewer) of Web of Science articles on digital agriculture was enriched with several expert interviews with executives involved in deploying digital technologies to Romanian farmers. The literature review illustrated that like in Industry 4.0, Agriculture 4.0 requires training and deployment of new skills. Expert interviews added extra perspectives from practitioners and highlighted that these new skills are needed at all farm work levels. The digitalization of agriculture is a structural change that will happen even if adoption rates seem still slow and it will affect all actors in the farm from owners/managers to operators giving a very important role to agricultural experts, engineers, and financial planners. It is the hope of this article to bring academic support to the conversation about the skills needed for Agriculture 4.0 and induce the operationalization of large-scale grassroots activities needed for the migration of today's agricultural practitioners to digital technologies.*

Keywords: *Agriculture 4.0, Change Management, Digital Agriculture/Digital Farming, Knowledge Management, Precision Agriculture Skills.*

Introduction

The Precision Agriculture concept emerged more than 30 years ago and given its scope (agricultural sciences, management, tools & machinery, information systems), it had many definitions circulating. In 2019 The International Society of Precision Agriculture (ISPA) following a very rigorous and broadly consultative process adopted the following definition of precision agriculture (ISPA, 2019):

„Precision Agriculture is a management strategy that gathers, processes and analyzes temporal, spatial and individual data and combines it with other information to support

management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production."

In a position paper of the European Agricultural Machinery Association (CEMA) (CEMA, 2017), digital agriculture/digital farming is defined as an evolution of precision agriculture (considered Agriculture 3.0) to what is known as Agriculture 4.0. In this new production system, the farms gather information through inter-connected devices (intelligent networks of sensors) producing data that is processed in real or near-real time with data management tools to generate knowledge that helps the management of resources and works making possible timely and accurate decision making. Furthermore, digital farming based on data collected via sensors and other on-farm sources (soil composition, humidity, etc.) as well as off-farm data (weather conditions and forecast, pest alerts, satellite maps, etc.) make precision agriculture work even better by using Variable Rate Technology (VRT) deployed based on variable rate maps. These maps could also be improved by improving the algorithms that generated the maps. The algorithm improvement would rely on machine learning (ML) and artificial intelligence (AI) tools using data from the farm and benchmarking pools.

Agriculture 4.0 is a term that is similar and was inspired by the term "Industry 4.0" (Kagermann et al., 2013), and its foundational pillars are according to Albiero and his colleagues (Albiero et al., 2020): the interconnectivity of devices that is made possible through Internet of Things (IOT), the cloud computing as both storage medium for information and repository of scalable computational power, as well as the Big Data and the power that machine learning (ML) and artificial intelligence (AI) are giving to data. Similarly to Industry 4.0, it will require new skills for all participants. According to Klerkx and Rose (2020), Agriculture 4.0 already comprises operational technologies such as robotics, nanotechnology, protein synthesis, cell agriculture, genetic editing technology, AI, blockchain, and ML whereas in the CEMA position paper (CEMA, 2017) robotics and advanced AI will be the hallmark of Agriculture 5.0.

In a United Nations' Food and Agriculture Organization (FAO) briefing paper its authors (Trendov et al., 2019) affirmed that digitalization will impact the entire agrifood chain allowing the optimized and anticipatory management of resources, adaptability to changes, even climate changes, permitting the monitoring and traceability of crops and leading to more food security, better profitability, and enhanced sustainability. They also identify two conditions required for a large-scale deployment of digital agriculture. The first category includes mandatory conditions such as: solid connectivity infrastructure (coverage at sufficient bandwidth also in the rural and arable areas), affordability of the services as well as digital literacy. In their argumentation, Trendov and his colleagues (Trendov et al., 2019) state that digitalization will significantly alter the nature of work in agriculture, the demand for labor, and the required skills set. Digital literacy will be a requirement in the competence profile for agricultural jobs. The second category of factors enabling digitalization deployment takes the digital skills requirement to the next level and considers digital entrepreneurship as a favoring factor driven especially by young farmers.

Importantly, next to the great news of digitalization being the panacea of future agriculture they also identify a potential danger in the uneven distribution of the benefits of digitalization, a phenomenon that could lead to creating a digital divide between the highly vs. scarcely digitalized farms and farmers generating potentially undesirable social tensions. Rose et al. (2021) reported that the Agriculture 4.0 narrative has been predominant in terms of productivity improvement and environmental protection, and this fact has generated significant positive as well as negative social effects, underlining that beyond strict performance considerations, there is a need to include people and social matters in the full assessment of the impact of digitalization.

Literature review

The literature review started with an extended keywords search in the Web of Science database for either one of the following terms “agriculture 4.0”, “digital agriculture”, “digital farming” “precision agriculture”, “precision farming”, “smart farming”, “smart agriculture” by using the logical connector “or” among them. The resulting corpus comprised 14 057 articles from the agricultural sciences and technology-related categories (figure 1 and figure 2) and was published mostly in the past 5 years (figure 3). This illustrates that the academic focus on agriculture 4.0 is rather recent and follows a similar pattern to the pattern of the digital transformation literature (Markovits, 2022) with a similarly significant increase in the past five years. It is important to note that in the case of the analyzed corpus of articles, we do notice a “long tail” that goes back almost another 20 years, a situation that could be explained by the earlier use of the “precision farming”/ “precision agriculture” concepts.

Figure 1: Top 10 categories for the articles containing either one of the key words “agriculture 4.0”, “digital agriculture”, “digital farming” “precision agriculture”, “precision farming”, “smart farming”, “smart agriculture”
Author’s visualization Web of Science September 20th, 2022

Out of the 14057 articles, 846 were review articles that were used for mapping with VOSviewer (figure 4a and figure 4b) to illustrate the focus of research and publishing years through a mapping of keywords co-occurrence of 5 and above. The obtained maps illustrate the centrality of precision agriculture and the recent development of the agriculture 4.0 cluster that comprises the Internet of things, big data, and cloud computing.

Figure 2: Top 25 categories for the articles containing either one of the keywords "agriculture 4.0", "digital agriculture", "digital farming" "precision agriculture", "precision farming", "smart farming", "smart agriculture"
Author's visualization Web of Science September 20th, 2022

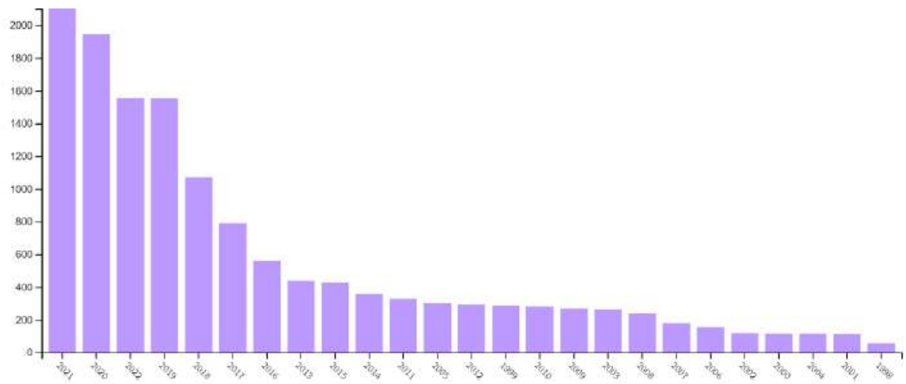

Figure 3: Number of articles with either one of the key words by publishing years
Author's visualization Web of Science September 20th, 2022

After restricting to the business categories, a corpus of 341 articles was obtained which was mapped for keywords co-occurrence (10+) and it revealed a rather strong interest for precision agriculture and its adoption (figures 5 and 6).

Klerkx and his co-authors (Klerkx et al, 2019) in their review of extant social science literature on digitalization in agriculture have identified five thematic clusters: 1) Adoption, uses, and adaptation of digital technologies on farms; 2) Effects of digitalization on farmer identity, farmer skills, and farm work; 3) Power, ownership, privacy, and ethics in digitalizing agricultural production systems and value chains; 4)

Digitalization and agricultural knowledge and innovation systems (AKIS); and 5) Economics and management of digitalized agricultural production systems and value chains.

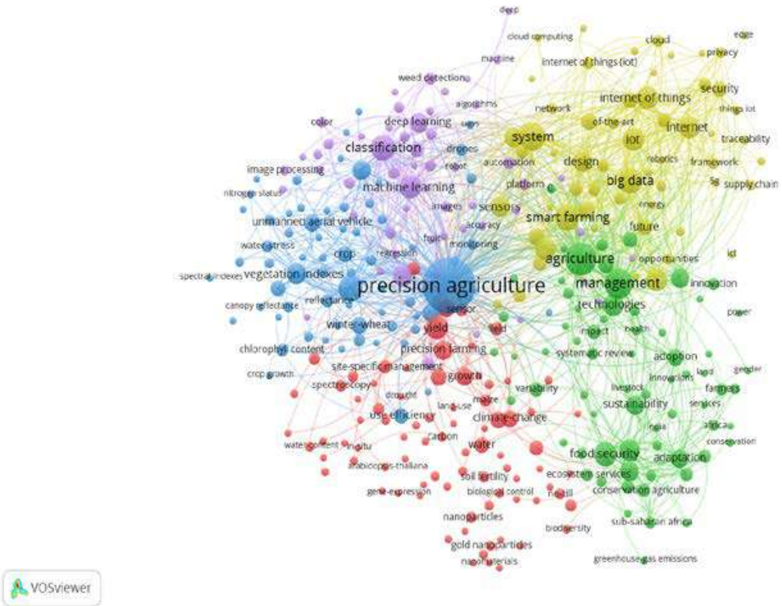

Figure 4a : Mapping of the "agriculture 4.0"
Author's visualization, Web of Science September 20th 2022

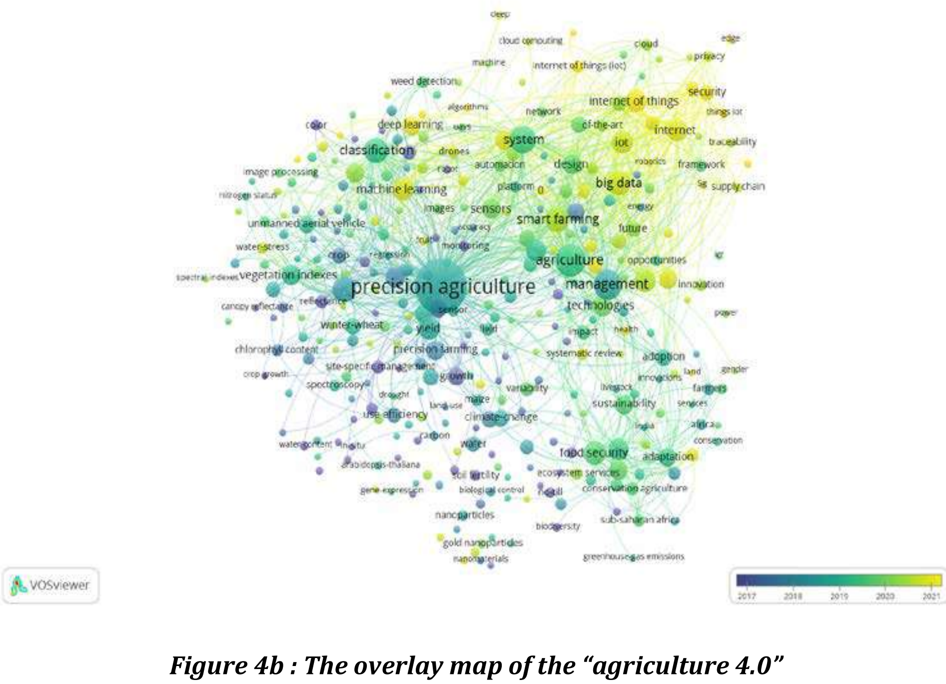

Figure 4b : The overlay map of the "agriculture 4.0"
Author's visualization, Web of Science September 20th 2022

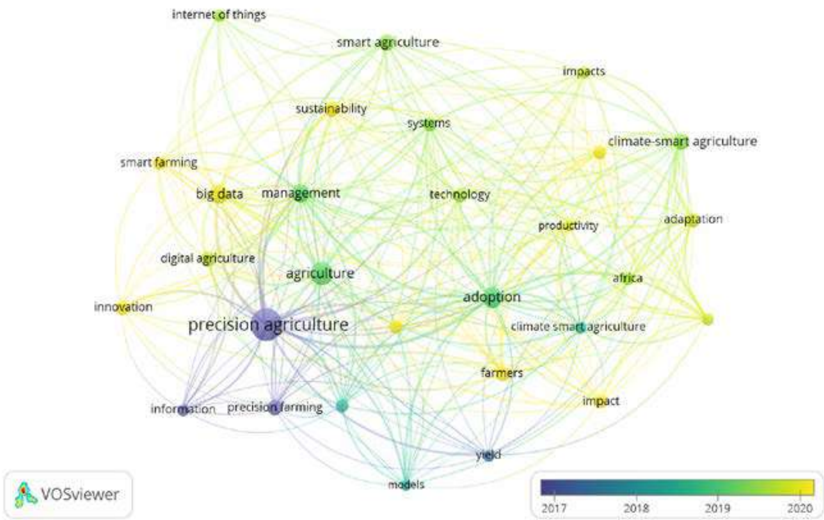

Figure 5: The overlay mapping of articles in the business categories keywords co-occurrence (10) in the corpus of the 341 articles clustered by years of publication. Author's visualization Web Of Science September 25th , 2022

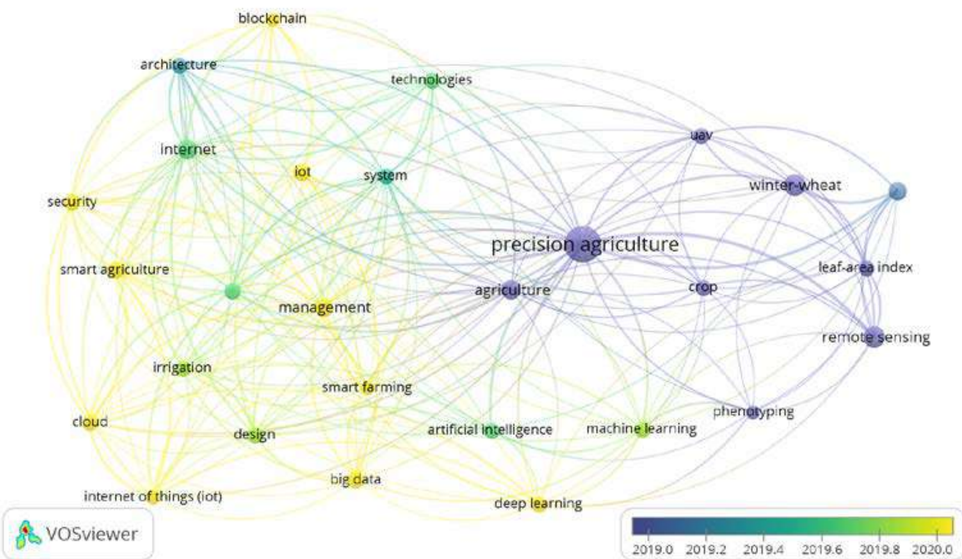

Figure 6: The overlay mapping of keywords co-occurrence (5) in the most influential review articles (a corpus of 68 articles) clustered by years of publication.
Author's visualization Web Of Science September 25th , 2022

The leap from Agriculture 3.0 to Agriculture 4.0 was made possible by the introduction of the smart machine that connected (CEMA, 2017). The use of the Internet of Things (IoT) and data analytics (DA) step changed the operational efficiency and productivity in the agriculture sector (Elijah et al, 2018). This also made a paradigm shift possible from using wireless sensor networks (WSN) as a major enabler of smart agriculture to using IoT and DA. The IoT integrates several existing technologies, such as WSN, radio frequency identification, cloud computing, middleware systems, and end-user applications. In one of the most influential papers about the role of Big Data in smart farming, the authors (Wolfert et al, 2017) state that its usage impacts the entire value chain in the agrifood supply chain not only in agriculture. In smart farming, it provides real-time operational decisions and enables predictive insights into farming operations (Kamilaris, 2017). On a more strategic level, it could help redesign business processes and even business models.

Machine learning developed and its use gained traction through the accumulation of agricultural big data leveraging high-performance computing power (most often cloud resident software). With the application of machine learning on-farm (sensor data e.g. humidity) and off-farm data (weather, satellite imagery), farm management systems evolved to be real-time and near-real-time advisory programs that provide more substantiated recommendations for farmers' decision-making and action (Liakos et all, 2018). Data becoming the key element of contemporary agriculture, it is important to be efficiently managed and preferably coming from objective sources (e.g., sensor data). This way its full value could be benefitted from increased efficiency by avoiding the misuse of resources and the pollution of the environment. Data-driven agriculture, with the help of robotic solutions incorporating artificial intelligent techniques, sets the grounds for the sustainable agriculture of the future already heralded as Agriculture 5.0 (Saiz-Rubio & Rovira-Más, 2020)

Bucci and her colleagues in their review of the precision agriculture literature (Bucci et al, 2018) identify the following factors affecting the adoption of precision farming: the size of farms, farmer's experience with technology and their awareness of the precision agricultural practices as well as (the high) cost of the initial investment. Further introspection into the factors affecting the adoption of precision farming techniques reveals other internal factors such as farmers' age and education and farmers' perception of the advantages of the new technology (the potential to get better profit per ha). External factors that were found to play an important role include: the cost of labor and cost of land, the regulatory and market (clients) pressure for sustainability as well as the availability of consultants. In fact, it is the analysis of the complete cost of adoption (investment cost, comfort/discomfort with technology, and efficiency gains) vs the complete cost of non-adoption (loss of competitiveness vs adopters, regulatory pressure) that will tilt the balance. is key to adoption or non-adoption.

Farmers' age and education is mentioned more in the context of knowledge and comfort with technologies; however, it would be important to note that if we consider the fact that precision agriculture is made possible by a digitally enabled decision support system, it becomes also an appropriate angle to analyze the adoption phenomenon through the lens of decision-making processes and differences between young and old farmers.

Methodology

Key words search aiming to identify a corpus of articles in the Web of Science database that would simultaneously fulfill the co-occurrence of any of the digital agriculture aliases and key word “change management” have yielded no results. The same results were obtained when pairing digital agriculture and its aliases with “skilling”. However, a handful of articles have been identified when pairing digital agriculture with key word “training” (Medvedev & Molodyakov,2019, Sousa & Rocha, 2019).The main skills identified (Spöttl & Windelband,2021, Rotatori et al, 2021) were generically linked to the frequent 4.0 technologies : artificial intelligence, robotization, Internet of things, augmented reality to be learned preferably through tablets, and smartphone applications (Knihova & Hronova,2019).

Therefore a number of 5 expert interviews were done, as semi structured qualitative exploratory interviews. The purpose of these interviews was to explore the kind of new skills needed to be developed by the farmers, based on the experience of practitioners involved in the deployment of digital agriculture tools.

Results and discussion

In one of the first expert interviews (Dimcea, 2022) when probing for the persuasion techniques employed in the enrollment of farmers to utilize the digital platform for farm and farm works management, the use of demonstration sessions and testimonials were mentioned as very effective tools. This reconfirmed some of the barriers identified in the precision agriculture literature (Bucci et al, 2018) as well as the decision making (Bratianu et al., 2021), complexity of the problems (Bratianu & Vasilache, 2009), and knowledge management (Bratianu, 2022; Bratianu & Bejinaru, 2019) literature. A very important new angle to understand the adoption process of precise agriculture was also expressed by Bucci (Bucci et al, 2018) when underlining the fact that by adopting precision farming techniques in fact farmers move from an experiential decision-making to a data-driven decision-making. This move generates uncertainty and discomfort for those who do not feel confident with use of technologies generating and interpreting the data (e.g. weather forecast, satellite images, pest alerts, NDVI maps) or when the investment does not seem to generate efficiency gains big enough to pay out fast. In this context, the use of demos and testimonials (with other farmers already enrolled) as uncertainty reductions tools became natural.

Further interviews with practitioners (Dobre,2022; Radoi,2022) validated the approach found in the work of Saiz-Rubio & Rovira-Más (2020). The resulted activities map (figure 7) served as base to identify the required new skills. In the case of crop nutrition products, the first activity is soil analysis done through collection of soil samples for analysis using a randomization map to make sure that the result could be extrapolated to the entire analyzed plot. The farm manager or owner is therefore required to have a basic understanding of the sampling algorithm as well as a good understanding of the soil configurations. In all cases the next phase implies the availability of agronomical advice either through a consultant or an assisting AI enabled digital companion (chat bot, AI enabled benchmarking).

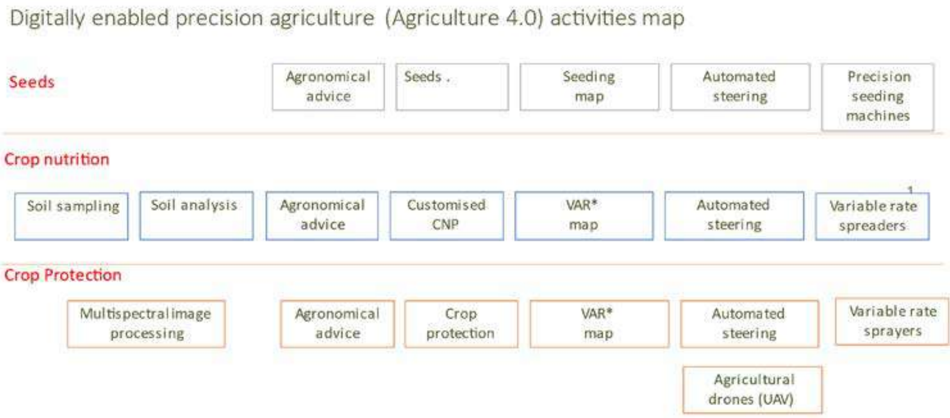

Figure 7: The precision agriculture activities map by type of input (seeds, crop nutrition, crop protection)
Author's visualization, expert interview (Dobre, 2022)

The next two phases are the determination of the appropriate product (seed, fertilizer treatment or protection product) and creating the digital variable rate seeding plan or application/treatment map. This might also be performed through the services of a consultant, or an AI-enabled digital companion/software in the farm management suite of tools. Again, the farm manager/owner in her/his capacity of decision maker must possess enough product and agricultural knowledge to create and/or understand what criteria should/could be used for a proper decision.

The final two stages are about executing the works and here besides the manager/owner of the farm and the agronomical expert a new actor joins in the process, the Agriculture 4.0 operator (tractor driver, agricultural implement operator (e.g. precision seeding machine/variable rate sprayers/weeding machine). The operator will be required to upload the variable rate maps, install the correct implements and execute the variable rate seeding/spraying. The complexity of this phase is augmented by the fact that operating UAVs (Unmanned Aerial Vehicles), commonly known as drones, could be required besides tractor-powered activities. This is a completely new skill set that requires also formal credentialing (permit to operate and pilot a drone). Most of the digital platforms available to date, focus on the agricultural mission of the farm, i.e., obtaining the maximum yield and managing the farm works (field access planning, fleet management, etc.). A platform that digitalizes the farm's relations with its suppliers (input distributors, financial services institutions, authorities (e.g. APIA) and beneficiaries (plot owners, traders) would have a competitive advantage (Tatar, 2022). This might also function as a multi-user application with specific access rights to parts of the platform.

The Romanian Farmers' Club for Performing Agriculture (CFRO, 2022) is a farmer lead think tank created in December 2018. Its mission is to promote sustainable agriculture development in Romania. As part of its core activities, it organizes training programs for young farmers (Young Leaders in Agriculture-TLA) and experienced ones (Antreprenor

4.0). The course curricula include dedicated sessions for digital agriculture and sustainable agriculture observing the EU standards. This is a grassroot effort (Ciolacu, 2022) financed by the Club from private donations. Enticed by the learnings from the courses several TLA alumni have already implemented digital technologies on their own farms. "Antreprenor 4.0" is a program for practicing farm managers with 5+ years of experience. It already has a successful first series of alumni and is a premiere in Romania.

Conclusions

Digital literacy and proficiency and the farmers' belief in the advantages of precision agriculture are key factors favoring the adoption of digital agriculture methods. However, having a business case in which benefits outweigh the investment and operating costs is essential. Therefore, a key factor for the success of the effort to deploy digital agriculture methods will be the digital and agricultural up-skilling and re-skilling of the owners, managers, and farm workforce (Medvedev& Molodyakov, 2019). This should be done by leveraging knowledge-building and sharing methods (Bratianu et al., 2011; Bratianu & Leon, 2015), also adapted to the generational situation (Ciolacu, 2022) and shift happening today in the Romanian farms (Pinzaru et al, 2016, Germain, 2020).

This is an exploratory study, its purpose being to start the conversation about reskilling and upskilling the farm personnel. Future work should concentrate on identifying and benchmarking the skill development needs of the Romanian farm actors (owner/manager, technical experts, operators) with farms in other countries. The focus of the exploratory work was on arable farms, future works could include livestock farms or other types of farms.

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