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THE SKILLS OF THE FUTURE IN CONTEMPORARY AGRICULTURE

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Abstract. *The paper entitled "Future skills of the future in contemporary agriculture" addresses a major topical issue, located at the intersection of technological innovation, environmental sustainability and socio-economic transformations in the agricultural sector. In a global context marked by accelerated digitalization, climate change and increasingly stringent requirements for sustainable food production, modern agriculture is being redefined, requiring a new generation of professional skills. The main aim of the study is to identify and analyze the key skills that will shape the profile of the agricultural specialist of the future, able to manage resources efficiently, use advanced digital technologies and integrate the principles of the circular economy in practice. The analysis is based on an interdisciplinary approach, bringing together economic, technical and social perspectives, to outline a complex picture of the transformations in agriculture. Emerging trends such as precision agriculture, the use of artificial intelligence and IoT sensors, agricultural data management, as well as the transition to sustainable ecological practices are investigated. The study also highlights the need for continuous training and retraining, especially among young farmers and rural workers, who need to develop digital, entrepreneurial and collaborative skills. The research results underline the importance of adapting educational curricula and strengthening partnerships between academia, the private sector and public authorities. Promoting a culture of lifelong learning is essential to support the transition towards a smart, resilient and competitive agriculture at European and global level.*

Keywords*: skills, opportunities, trends, modern agriculture*

INTRODUCTION

Agriculture is one of the oldest and most essential fields of activity of humanity. However, in recent decades, agriculture has undergone profound transformations, driven by digitalization, globalization, climate change and the pressure for sustainability. (VASILE, M., 2024) If until recently the emphasis was mainly on productivity, today the focus is increasingly shifting to *efficiency*, *environmental protection* and *technological innovation*.

The contemporary agricultural sector is undergoing a profound transformation, driven by complex global factors: food security for a growing world population, climate change disrupting traditional agricultural cycles, and pressure for a more efficient use of natural resources (soil, water, energy). This "fourth agricultural revolution" or Agriculture 4.0 is centered on digitization, automation, and data analysis (Big Data), radically changing the skill requirements for all actors in the agricultural value chain (farmer, agronomist, technician, researcher). (WORLD BANK, 2024)

According to the European Commission (2020), the transition towards a fair, healthy and environmentally friendly food system, as defined by the Farm to Fork Strategy, cannot be achieved without a workforce with a renewed set of knowledge and skills. (COMISIA EUROPEANĂ, 2020) Digitalization promises to optimize input consumption and increase efficiency, but in return requires an increased capacity to understand and operate complex systems.

The accelerated transformations in agriculture, generated by digitalization, climate change and global market demands, are leading to a profound redefinition of the professional skills required by specialists in this sector. Contemporary agriculture is no longer just a

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production activity, but a complex field, interconnected with data science, biotechnology, the circular economy and sustainability policies. (FOOD AND AGRICULTURE ORGANIZATION, INTERNATIONAL TELECOMMUNICATION UNION, 2023)

In the 21st century, agriculture is undergoing a transition towards a new paradigm – smart and sustainable agriculture – based on the integration of digital technologies and the principles of sustainable development. (FOOD AND AGRICULTURE ORGANIZATION, 2022) The balance between economic performance, environmental protection and social equity is becoming the central criterion for agricultural success. In this context, the professional skills of agricultural workers are fundamentally changing, requiring a rapid adaptation of education and training systems. (POPESCU, I., DUMITRESCU, A., 2023)

The transition to smart agriculture involves the adoption of advanced digital technologies, such as the Internet of Things (IoT), artificial intelligence (AI), big data analytics, agricultural robots, drones and satellite monitoring systems. (FOOD AND AGRICULTURE ORGANIZATION, INTERNATIONAL TELECOMMUNICATION UNION, 2023) These tools generate large volumes of data and require an approach based on analysis, anticipation and informed decision-making. Consequently, the new agricultural worker must be able to manage complex technologies, interpret digital information and integrate interdisciplinary knowledge to optimize production processes.

At the same time, the pressures associated with climate change and the limitation of natural resources determine an orientation towards sustainable agriculture, based on ecological principles, crop rotation, reducing the carbon footprint and preserving biodiversity. This double transition – digital and green – is profoundly transforming the economic model and the skills required in agriculture. (FOOD AND AGRICULTURE ORGANIZATION, 2021)

Among the defining directions that are reconfiguring contemporary agriculture are:

● *Digitalization and data-driven agriculture* – the adoption of IoT sensors, drones, satellite imaging, telemetry, and big data/AI analytics platforms is transforming agricultural decisions from intuition-based to data-driven processes. This allows for optimization of resource consumption (water, fertilizers, pesticides), real-time monitoring of crop health, and automation of repetitive tasks. (WORLD BANK, 2021)

● *Sustainability and green transition* – European policies, such as the European Green Deal, the Farm to Fork Strategy and international commitments on reducing carbon emissions, promote regenerative agriculture and reducing food waste. (COMISIA EUROPEANĂ, 2020) The criteria for agricultural success are being redefined, including not only yield, but also ecological performance.

● *Standardization, interoperability and data infrastructures* – effective use of digital tools at scale requires common standards, interoperable platforms and robust data governance. International organizations, such as ITU and FAO, such as Digital Agriculture: A Standards Snapshot (2023), are developing snapshots of standards and good practices for the protection of farmers' data and the quality of information used in agriculture. (FOOD AND AGRICULTURE ORGANIZATION, INTERNATIONAL TELECOMMUNICATION UNION, 2023)

● *Automation and robotization* – the implementation of harvesting robots, automated milking systems, autonomous machines and intelligent control platforms reduces the need for repetitive manual labor, but increases the need for qualified technical personnel to supervise and maintain these systems. (ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, 2022)

● *Geopolitical pressures and food security* – global instabilities and national agricultural resilience strategies require the development of shorter, local and adaptable supply

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chains, capable of ensuring food security in crisis contexts. (FOOD AND AGRICULTURE ORGANIZATION, 2023)

● *Skills deficit and the need for continuous training* - European studies highlight a significant gap between the skills required by the market and the current curricula in the agricultural field, requiring an urgent modernization of vocational training programs, in partnership with the economic environment and research institutions. (EUROPEAN CENTRE FOR THE DEVELOPMENT OF VOCATIONAL TRAINING, 2022)

In this context of accelerated transformation, traditional skills are no longer enough. Identifying, developing and updating the skills of the future are becoming essential conditions for ensuring the sustainability and competitiveness of modern farms. The traditional skills of farmers are becoming insufficient in the context of digitalization. (TUDORACHE, F., POP, C., 2024) The new professional profile requires:

- advanced digital skills (use of IoT platforms, AI, GIS, etc.);
- ecological skills and sustainable resource management;
- analytical skills and data-driven decision-making;
- interdisciplinary knowledge (technology, economics, environment, biotechnology).

Adapting vocational training programs and creating partnerships between academia, research centers, and the private sector are becoming essential for training agricultural specialists of the 21st century. (EUROPEAN TRAINING FOUNDATION, 2023)

Although agriculture is one of the oldest fields of humanity, in recent decades it has experienced major transformations driven by globalization, digitalization, and the pressure to protect natural resources. (EUROPEAN COMMISSION, 2021) If in the past the focus was almost exclusively on increasing productivity, today the priorities are focused on efficiency, environmental protection and technological innovation.

The farmer of the future will no longer be just an operator of agricultural machinery, but a manager of the agricultural ecosystem, an advanced user of digital technologies and a promoter of sustainable innovation – a professional capable of combining agricultural tradition with data science, technology and environmental responsibility. In order to achieve this goal, an integrated approach to vocational training policies, technological standardization and international cooperation is needed.

MATERIAL AND METHODS

The main objective of this paper is to identify and classify the set of critical competencies (knowledge, skills and attitudes) that will define professional success in agriculture of the future. It starts from the hypothesis that the profile of the contemporary farmer and agronomist must evolve from a labor-intensive operator to a digital and biological ecosystem manager, capable of making informed, data-driven decisions. (POPESCU, I., MARINESCU, A., 2021) The paper will structure these skills into distinct categories: technical-digital, agronomic-sustainable and transversal (soft skills), providing a clear perspective on the necessary professional training directions. In the global context of the development of the bioeconomy, it becomes imperative to train specialists to fully utilize agricultural waste and by-products, transforming the linear production model into a circular one. (POLI, J. G., 2021)

The paper is based on a bibliographic and documentary analysis methodology, having as main sources: international and European public policy documents, reports and studies published by relevant international organizations, which address the themes of digitalization, innovation and sustainability in agriculture, as well as scientific articles and synthesis papers on digital and

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ecological skills in green economy sectors. (BIELSA, S., GAGO, A., 2023; SMITH, J., LEE, K., 2022; COMISIA EUROPEANĂ, 2020; EIT FOOD, 2024; COMISIA EUROPEANĂ, 2025)

The analysis method used was thematic content analysis, applied to the set of identified documents, with the selection of the main categories of emerging skills: technical and biotechnological, digital, ecological and sustainability, as well as socio-economic and management. The process included the following stages: identification and selection of sources, coding of information and identification of categories of emerging skills.

Stage of identification of categories of emerging skills – based on the content analysis, four major categories of skills were identified: technical skills (use of modern equipment, automation, robotization); digital skills (IoT, artificial intelligence, big data, geospatial analysis); ecological skills (sustainable resource management, carbon footprint reduction, regenerative agriculture); socio-economic skills (management, entrepreneurship, networking and social innovation).

The aim of the analysis was to identify and structure the future skills needed by farmers and agricultural specialists in the perspective of the time horizon 2035, in correlation with the global trends of digitalization and sustainability. The results of this analysis provide a conceptual basis for formulating recommendations on updating vocational training programs and adapting agricultural curricula to the new requirements of the green and digital economy.

RESULTS AND DISCUSSIONS

The bibliographic and documentary analysis carried out highlighted the fact that digitalization and the green transition represent two essential pillars of the transformation of contemporary agriculture. By correlating the sources analyzed, a new architecture of professional skills required in the agricultural sector is outlined, centered on the integration of technology, sustainability and data-driven management. (FOOD AND AGRICULTURE ORGANIZATION, INTERNATIONAL TELECOMMUNICATION UNION, 2023; ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, 2022; EUROPEAN COMMISSION, 2021)

The analysis of literature and trends indicates that a successful agricultural professional in the contemporary context must possess a complex portfolio of skills, classified into four major areas, the interaction of which defines the new professional profile.

1. *Technical and biotechnological skills*

The results show a significant increase in demand for technical skills related to the operation and maintenance of smart agricultural equipment: IoT sensors, drones, harvesting robots, automated irrigation systems and autonomous machines. (WORLD BANK, 2021; LEE, W. S., AL-KHAIFI, H., AL-AMRANI, A., 2019)

On modern farms, the use of these technologies is recalibrating professional roles, from manual operators to digital technicians. The ability to integrate and calibrate intelligent systems is becoming a standard requirement for agricultural workers in the next decade. (FOOD AND AGRICULTURE ORGANIZATION, 2022)

At the same time, skills in data analysis and interpretation of information collected from the field (big data analytics, GIS, remote sensing) are essential for making quick and efficient decisions regarding irrigation, fertilization and disease and pest control. These skills are transforming agriculture into an activity increasingly closer to data science. (DAHMER, M. A., RUSU, M., 2020)

The progress of biotechnology – from the use of beneficial microorganisms to ethical genetic improvement – requires the formation of skills related to biosecurity, certification and applied innovation in agriculture.

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Biotechnological advances offer new solutions to increase yields and reduce dependence on chemicals. In this context, the following become important:

• knowledge about beneficial microorganisms and biofertilizers;

• the use of safe and ethical genetic technologies;

• understanding the certification processes of organic and biotechnological products.

These skills will allow farmers to apply science directly in practice, generating added value and higher quality products.

2. *Digital skills*

Precision farming, the use of IoT sensors, satellite data analysis and the automation of agricultural processes require advanced skills in managing digital platforms. The farmer of the future must be able to interpret real-time data, use drones and integrate the information obtained into productive decisions.

The research results indicate that the digitalization of agriculture generates an urgent need for extensive digital literacy at the level of all actors in the agricultural value chain. Farmers, consultants and agricultural specialists must acquire skills in:

• the use of digital agricultural management platforms;

• the interpretation of data from satellites and sensors;

• data protection and governance (cybersecurity, interoperability, standardization).

International initiatives such as Digital Agriculture: A Standards Snapshot highlight the importance of developing common data standards and building skills in the field of interoperability of systems. (FOOD AND AGRICULTURE ORGANIZATION, INTERNATIONAL TELECOMMUNICATION UNION, 2023)

The digitalization of agriculture is one of the dominant directions of the transformation of the sector. Precision farming systems allow for precise control of the amount of water, fertilizers or pesticides, optimizing resources and reducing costs.

The farmer of the future must have:

• knowledge of using sensors and drones to monitor crops;

• skills in interpreting data from computer and satellite systems;

• skills in managing digital sales platforms, logistics and economic analysis;

• the ability to integrate artificial intelligence into production decision-making.

Digitization involves not only technical skills, but also a change in mentality, in which agriculture becomes a data-driven field (data-driven agriculture).

3. *Ecological and sustainability skills*

Adapting to climate change and transitioning to green agriculture require solid knowledge of agroecology, conservation of natural resources and waste management. Regenerative practices (no-till farming, crop rotation, agroforestry) are becoming core competencies. Another emerging category of competencies is ecological, associated with the transition to low-carbon agriculture and oriented towards the circular economy. European policies and the United Nations 2030 Agenda define a clear framework for the adoption of regenerative practices: crop rotation, reduction of chemical inputs, conservation of biodiversity and valorization of organic waste. (EUROPEAN COMMISSION, 2020)

In the context of the European Green Deal, farmers need to understand the impact of their activities on the environment and adopt sustainable practices.

These skills include:

• knowledge of agroecology and regenerative agriculture;

• the ability to implement climate change adaptation measures;
• natural resource management skills (water, soil, biodiversity);
• understanding of the product life cycle and the circular economy.

Thus, the farmer of the future must be not only a user of technology, but also a responsible manager of the agricultural ecosystem, able to assess the ecological impact of production decisions and adopt conservation measures.

4. *Socio-economic and management skills*

In the context of smart agriculture, socio-economic skills become as important as technical ones. These include:

• resource management and multidisciplinary team skills;
• the ability to collaborate in digital networks and innovation partnerships;
• entrepreneurial thinking, oriented towards short supply chains and local markets;
• intercultural communication and negotiation skills in global markets. (ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, 2022)

The analysis highlights that the success of implementing digital agriculture depends not only on the availability of technologies, but also on qualified human capital, capable of adopting and integrating them effectively.

The modern agricultural economy requires management skills, sustainable marketing, communication and collaboration in innovation networks. Young farmers must become ”rural ecosystem managers”, able to access European funds and lead multidisciplinary teams. (ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, 2023; EUROPEAN NETWORK FOR RURAL DEVELOPMENT, 2022) Overall, the results indicate that the agriculture of the future will require a hybrid professional profile, at the intersection of science, technology and sustainability.

The results confirm the conclusions from the specialized literature on the need for a systemic reform of vocational training in agriculture. (EUROPEAN CENTRE FOR THE DEVELOPMENT OF VOCATIONAL TRAINING, 2022; EUROPEAN TRAINING FOUNDATION, 2023) Current curricula are, in many cases, focused on traditional skills, while the labor market requires digital, analytical and sustainable skills. In this regard, agricultural education institutions need to update their curricula, include digital training modules and develop partnerships with the private sector for applied internships.

A need for inter-institutional cooperation between universities, research institutes, agricultural organizations and the private sector was also observed, for the development of integrated continuous training programs (up-skilling and re-skilling). (EUROPEAN COMMISSION, 2024) Without these initiatives, the skills gap risks widening, affecting the competitiveness of European farmers in global markets.

Contemporary agriculture is also a complex economic activity, and the modern farmer must have management, leadership and communication skills. These skills include:

• the ability to develop business plans and marketing strategies;
• the use of financial instruments and European funding programmes;
• teamwork and networking skills within agricultural cooperatives or clusters;
• intercultural communication and negotiation skills in an international context.

Therefore, the farmer of the future becomes a sustainability entrepreneur, able to innovate and collaborate in a complex ecosystem.

The results suggest that by 2035, the farmer will become an operator of intelligent systems, a data analyst and a promoter of sustainable innovation. Thus, the agriculture of the

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future will combine technological expertise with ecological thinking and digital leadership skills. (ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, 2023)

CONCLUSIONS

The skills of the future in agriculture are based on the integration of technological, ecological and entrepreneurial knowledge. Investment in modern agricultural education and lifelong learning will be the main factor of competitiveness of the European agri-food sector. Training flexible, digitalised and innovation-oriented specialists is the essential condition for a sustainable and resilient agriculture. (UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION, 2023)

The future of contemporary agriculture is inextricably linked to the ability of professionals to adopt and master new digital technologies, integrating them with a deep understanding of the principles of sustainability. Future skills are not just a plus, but a necessary condition to ensure the competitiveness, resilience and contribution of the agricultural sector to global environmental and food security objectives.

The analysis confirms that digitalization and the green transition represent converging processes that are profoundly transforming contemporary agriculture. They determine not only technological changes, but also structural reconfigurations of the professional skills needed in the agricultural sector. (ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, FOOD AND AGRICULTURE ORGANIZATION, 2022)

The results highlight four major emerging, interdependent and complementary skills areas, the set of key skills of the future in agriculture:

- Technical and technological skills, focused on the operation of digital equipment, automation and management of intelligent systems;
- Digital skills, essential for the use of IoT platforms, data analysis and information protection;
- Ecological skills, aimed at applying the principles of sustainability, circular economy and regenerative agriculture;
- Entrepreneurial and socio-economic skills, oriented towards management, innovation, cooperation and entrepreneurship.

The key skill set of the future in agriculture would be:

A. Digital skills
• Digital literacy and the use of agricultural applications;
• Analysis of data from sensors and satellite systems;
• Operation of drones, robots and automated equipment;
• Understanding the principles of artificial intelligence applied to agriculture;
• Data management and information security on farms.

B. Ecological and sustainability skills
• Understanding the principles of agroecology and regenerative agriculture;
• Application of water and soil conservation techniques;
• Implementation of the circular economy and management of agricultural waste;
• Adaptation to climate change through green technologies;
• Monitoring the carbon footprint and biodiversity.

C. Biotechnological skills
• Knowledge of beneficial microorganisms and biofertilizers;
• Understanding ethical genetic improvement processes;
• Management of biosecurity and organic certifications;

• Application of biotechnological innovations in plant and animal production.

D. Entrepreneurial and social skills

• Strategic planning and financial management;

• Digital marketing and promotion of agricultural products;

• Accessing European funds and project management;

• Communication and leadership in multidisciplinary teams;

• Creating networks and partnerships for rural innovation.

These categories define the profile of the agricultural specialist of the 21st century, characterized by interdisciplinarity, adaptability and orientation towards innovation and ecological responsibility.

The study also reveals a significant gap between the current skills of the workforce and those required by digital and sustainable agriculture. (EUROPEAN CENTRE FOR THE DEVELOPMENT OF VOCATIONAL TRAINING, 2022; EUROPEAN TRAINING FOUNDATION, 2023) This gap requires curricular reforms and integrated continuing professional training policies, capable of anticipating future labor market needs.

Based on the results obtained, the following directions of action can be formulated:

- *Reforming vocational education and training programs*

o Introducing interdisciplinary modules on artificial intelligence, big data analysis, IoT and agricultural sustainability in university and postgraduate curricula.

o Developing digital interactive learning platforms (e-learning, simulations, virtual laboratories) for the training of practical skills.

- *Promoting lifelong learning*

o Implementing flexible up-skilling and re-skilling programs for farmers, technicians and specialists in rural areas.

o Creating regional digital competence centers in agriculture, connected to universities and innovation hubs.

- *Strengthening partnerships between education, research and industry*

o Involving private actors, farmers' associations and research centers in defining professional skills and training standards.

o Promoting dual learning programs and internships in digital farms.

- *Creating a coherent public policy framework*

o Integrating digital and green skills into national agriculture and rural development strategies.

o Linking educational objectives with European policies (European Green Deal, Agenda 2030, Farm to Fork Strategy).

- *Ensuring digital inclusion in rural areas* (EUROPEAN NETWORK FOR RURAL DEVELOPMENT, 2023)

o Reducing the digital divide through investments in infrastructure (connectivity, equipment, basic IT training).

o Stimulating the participation of young people and women in digital vocational training programs in agriculture.

European agriculture, by 2035, will be characterised by an integrated digital ecosystem, based on data, standardisation and artificial intelligence. In this context, skilled human capital will become the main factor of competitiveness and sustainability.

The farmer of the future will be:

• an operator of intelligent systems and user of complex data;

• a manager of natural resources, able to reduce the ecological impact of production;

• a social innovator, involved in local networks and short supply chains;

• an ambassador of sustainability, combining agricultural tradition with science and technology.

These conclusions support the need to implement an integrated vision for the training of future skills, in which education, research and agricultural policies act convergently for a smart, fair and resilient agriculture.

The agriculture of the future will be characterised by a high degree of complexity and interconnectivity. Professional skills will no longer be strictly technical, but transversal, combining science, technology, ecology, management and social responsibility.

The success of the transition to Agriculture 4.0 depends on the ability of Romania and the European Union to strategically invest in the human capital of the agricultural sector, transforming today's farmers into data managers, sustainability innovators and pillars of food security.

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