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THE COMPETENCIES REQUIRED OF THE AGRONOMY ENGINEER IN THE CONTEXT OF THE NEW LABOR MARKET DEMANDS

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Abstract. *In recent decades, the labor market has undergone significant transformations, driven by processes such as globalization, accelerated technological advancement, and climate change. In this context, the agricultural sector, traditionally perceived as conservative, has become a dynamic field characterized by the rapid adoption of innovative technologies and sustainable production practices. The role of the agricultural engineer has expanded considerably, no longer being just a specialist in plant cultivation, but a complex professional with multidisciplinary skills. The modern agricultural engineer is involved in management processes, uses advanced digital technologies, and actively contributes to environmental protection, being able to manage integrated agricultural systems and respond to the demands of a constantly changing labor market. In this context, it becomes necessary to redefine the set of skills specific to this professional profile. The paper aims to identify and analyze the essential knowledge, skills, and abilities for the future agricultural engineer, in correlation with the new demands of the labor market. The methodological approach is qualitative in nature, based on the analysis of specialized literature, international reports and current trends in the field. The research results highlight the need to integrate digital, managerial and ecological skills into the professional training process. At the same time, key skills such as critical thinking, adaptability, teamwork and innovation orientation are identified, essential for effective integration into the labor market. The importance of using modern technologies, such as precision agriculture and digital solutions, in optimizing agricultural production is also emphasized. In conclusion, the paper highlights the need to modernize the agricultural education system and promote lifelong learning, in order to ensure the training of specialists capable of meeting the challenges of the future. The agricultural engineer of the future will have a strategic role in ensuring food security and promoting sustainable agriculture.*

Keywords*: globalization, technology, redefinition, change, continuous learning*

INTRODUCTION

Agriculture is one of the most important sectors of the world economy, playing an essential role in ensuring food security, economic development, maintaining social balance and protecting the environment. Through its economic, social and ecological functions, this sector directly contributes to the well-being of the population, the development of rural communities and the management of natural resources.

In recent decades, agriculture has been deeply influenced by globalization, digitalization, climate change and the transition to sustainable production models. These processes have led to important transformations both in the structure of agricultural activities and in the professional profile of specialists in the field. In this context, the agricultural engineer is no longer perceived exclusively as a specialist in plant cultivation technologies, plant protection, soil fertilization and mechanization of agricultural work, but as a multidisciplinary professional, capable of integrating technical, economic, digital, ecological and managerial knowledge.

● *Technological transformation of agriculture*

The rapid evolution of agricultural technologies has significantly changed the way production activities are organized and carried out. Traditional agriculture is complemented

and, in certain situations, progressively replaced by smart and precision agriculture, based on the use of global positioning systems, GIS applications, drones, smart sensors, automated equipment and computer programs for the management of agricultural holdings.

These technologies allow the collection, processing and interpretation of large volumes of data relating to soil characteristics, crop condition, climatic conditions, water consumption, fertilizer requirements and production trends. By using them, agricultural processes can be optimized, production costs reduced and resource use improved. Consequently, the agronomist must be able not only to operate various digital tools, but also to interpret the information obtained and use it to substantiate technical and economic decisions.

The digitalization of holdings has also generated the emergence of new professional opportunities. Agricultural engineers can work in fields such as precision agriculture, agricultural consultancy, farm management, research and innovation, agri-food industry, organic farming, environmental protection and rural development. However, the diversification of fields of activity requires complex and flexible professional training, supported by continuous learning and permanent adaptation to technological and economic developments.

● *Sustainability and green skills*

In parallel with technological transformation, climate change, soil degradation, biodiversity loss and pressure on water resources have highlighted the need to develop sustainable agriculture. The increase in agri-food production must be achieved while reducing the impact of agricultural activities on the environment and conserving natural resources for future generations.

European and international policies promote ecological agricultural practices, efficient use of resources, reducing emissions, reducing losses and adapting production systems to climate change. In this context, the agricultural engineer must have skills regarding sustainable soil and water management, responsible use of fertilizers and plant protection products, protecting biodiversity, applying the principles of the circular economy and implementing technologies with low environmental impact.

Green skills thus become essential components of the professional profile of the agricultural engineer. He must be able to identify environmental risks, assess the effects of agricultural activities and propose solutions that ensure a balance between productivity, economic efficiency and ecosystem protection.

● *The relationship between education and the labor market*

The importance of analyzing the skills required for an agricultural engineer is also determined by the strategic role of agriculture in sustainable development. Population growth, the need to ensure food security and the pressures exerted on natural resources require the training of specialists capable of designing and managing high-performance, resilient and sustainable agricultural systems.

Currently, the agricultural labor market is facing a series of difficulties, including the shortage of specialists, labor migration and the lack of sufficient correlation between university training and employer requirements. In some situations, graduates of agronomic study programs encounter difficulties in using modern technologies and adapting to the dynamics of agricultural activities. These aspects highlight the need to update university curricula and strengthen practical training.

Higher agricultural education institutions are called upon to adapt their educational programs to the transformations of the sector and to the requirements of the economy based on knowledge and innovation. Modernizing training involves introducing disciplines focused on smart agriculture, digitalization, data analysis, sustainability, management and

entrepreneurship. At the same time, it is necessary to expand practical activities, organize internships in agricultural holdings and develop partnerships between universities and the economic environment.

This paper aims to highlight the main skills needed by the agricultural engineer in the context of the new demands of the labor market, by analyzing the relationship between university training, employer demands and current trends in agriculture. The paper aims to contribute to a better understanding of the professional profile of the contemporary agricultural engineer and to highlight the need for interdisciplinary training. The permanent adaptation of the educational process to economic, technological and ecological transformations is a fundamental condition for the integration of graduates into the labor market and for the development of a competitive, innovative and sustainable agriculture.

MATERIAL AND METHODS

The research was based on the use of documentary analysis and the comparative method, in order to identify the evolution of professional skills required in the agronomic field. The analyzed material was made up of specialized scientific works, studies and reports on labor market dynamics, European documents and strategies regarding green and digital skills, as well as publications on the development of smart and sustainable agriculture.

The methodological approach included the analysis of specialized literature regarding the transformations of the agricultural sector and the labor market, followed by the identification and classification of skills considered essential for the training of the future agronomist engineer. In this regard, three main categories were considered: technical skills specific to the agricultural field, digital skills associated with precision agriculture and transversal skills necessary for effective integration and adaptation in the labor market.

The research analyzed current trends in the use of modern technologies in agriculture, with an emphasis on geographic information systems (GIS), agricultural drones, smart sensors, automation of production processes and software applications for farm management. At the same time, the analysis followed the requirements formulated by employers regarding the practical training of graduates, their ability to adapt to technological and economic changes, as well as the level of entrepreneurial skills.

The identified data and information were selected, grouped and analyzed according to their relevance to the research objectives. The interpretation of the results was carried out through a descriptive and comparative approach, which allowed highlighting the main changes in the professional profile of the agronomist engineer. Based on the results obtained, the relationship between the evolution of the agricultural sector, the new requirements of the labor market and the need to modernize the educational process in higher agronomic education was analyzed.

RESULTS AND DISCUSSIONS

The analysis highlights the fact that the agricultural labor market is undergoing an accelerated process of transformation, driven by technological progress, digitalization, climate change and the focus on sustainable development. In this context, the skills required of the agricultural engineer have become much more complex and interdisciplinary compared to the traditional requirements of the profession. The research results show that employers no longer exclusively pursue technical training specific to agriculture, but appreciate the ability of specialists to integrate modern technologies, make data-based decisions and adapt agricultural activities to new economic and environmental challenges.

The digitalization of agriculture is one of the main forces driving the change in professional skills. Smart agriculture uses global positioning systems, GIS technologies, sensors, drones, robots, IT platforms, artificial intelligence and data analysis tools. These technologies allow for the monitoring of crops, the differentiated application of inputs and the substantiation of decisions based on information collected in real time (WOLFERT, S. *et al*., 2017). Consequently, the agricultural engineer must be able to use digital technologies, but also to interpret the data generated by them.

An important aspect identified in the study is the increasing role of digital skills in agronomic activity. Precision agriculture involves the use of IT systems for monitoring crops, optimizing water and fertilizer consumption, evaluating agroclimatic parameters and efficiently managing agricultural production. In this context, the agricultural engineer must have skills in the use of specialized software applications, interpreting satellite images and using smart equipment.

Digital agriculture involves not only the introduction of modern equipment, but also the transformation of work processes, relationships between agricultural sector actors and decision-making methods. The analysis of the specialized literature shows that digitalization changes the roles of farmers, agronomists, consultants and service providers, generating the need for interdisciplinary skills and an increased capacity for continuous learning (KLERKX, L. *et al*., 2019). The profile of the future agricultural engineer must therefore include the ability to work with large volumes of data, to evaluate available technologies and to select the right solutions for each agricultural holding.

The results show that precision agriculture is becoming one of the most important development directions of the agricultural sector. The use of digital technologies contributes to increasing productivity and the efficient use of natural resources. In this context, skills in data interpretation, the use of IT platforms and the monitoring of agroclimatic parameters are considered essential for the professional competitiveness of the agricultural engineer. At the same time, the use of artificial intelligence and automatic monitoring systems creates the need to develop new skills, adapted to smart agriculture.

At the same time, digital technologies must be analyzed from the perspective of their usefulness for people, production and environmental protection. The implementation of Agriculture 4.0 can contribute to increased productivity and more efficient use of resources, but the results depend on the accessibility of technologies, the level of user skills and their responsible integration into agricultural activity (ROSE, D. C. *et al*., 2021). For this reason, the agricultural engineer must understand both the benefits and the economic, social and ethical limits of automation. An important competence is represented by the management of agricultural data.

Smart agriculture generates information on soil characteristics, humidity, weather conditions, vegetation status, water consumption, fertilizer application and production evolution. The agricultural engineer must collect, organize, analyze and interpret this data, transforming it into technical recommendations and management decisions. At the same time, he must be aware of issues related to the ownership, security, confidentiality and responsible use of agricultural data (BRONSON, K., 2019).

General digital competences can also be analyzed by reference to the European DigComp 2.2 framework, which includes information and data literacy, communication and collaboration, digital content creation, safety and problem solving (VUORIKARI, R. *et al.*, 2022). Applied to the agronomic field, these skills involve the use of databases, the operation of farm management programs, the interpretation of digital maps, communication through specialized

platforms and the identification of technological solutions for production problems.

The results also indicate a significant increase in the importance of skills related to environmental protection and sustainable development. Climate change and the degradation of natural resources determine the need to apply responsible agricultural practices, based on soil conservation, pollution reduction and efficient use of resources. Consequently, the agricultural engineer must know the principles of ecological agriculture, climate adaptation strategies and modern methods of sustainable management.

In addition to digitalization, the transition to a green economy significantly influences labor market requirements. Sustainable development involves adapting professional activities to the objectives of reducing emissions, protecting biodiversity, rational use of water, conserving soil and reducing food losses. The International Labor Organization emphasizes that the green transition changes both existing occupations and the skills needed to exercise them (INTERNATIONAL LABOUR ORGANIZATION, 2019).

In the agronomic field, green skills include assessing the effects of agricultural activities on the environment, applying soil conservation practices, efficient water and nutrient management, responsible use of plant protection products and valorization of agricultural by-products. The European GreenComp framework highlights the importance of understanding the values of sustainability, the complexity of systems, anticipating the future and actively engaging in achieving the necessary changes (BIANCHI, G. et al., 2022). Consequently, the agricultural engineer must view the agricultural holding as a component of a broader economic, social and ecological system.

Climate change increases the importance of skills in risk assessment and management. Rising temperatures, changing rainfall patterns, drought, floods and the emergence of new diseases or pests affect the stability of agricultural production. In this context, the agricultural engineer must know conservative farming methods, the selection of adapted crops and varieties, efficient irrigation systems and solutions to prevent land degradation. According to IPCC (2022), the adaptation of agricultural systems requires the integration of technological knowledge with risk planning and sustainable resource management (Intergovernmental Panel on Climate Change, 2022).

The study also highlights the growing importance of ecological skills and knowledge on sustainable agriculture. The increasing impact of climate change on agricultural production determines the need to implement agricultural technologies and practices that reduce the degradation of natural resources and polluting emissions. Agricultural engineers must know modern methods of soil conservation, efficient water use, reducing the consumption of pesticides and chemical fertilizers, as well as strategies for adapting to extreme climatic phenomena.

The results indicate that employers attach great importance to skills related to organic farming and sustainable farm management. The demand for agri-food products obtained through sustainable methods is constantly growing, and European agricultural policies support the development of organic practices and the reduction of environmental impact. In this context, green skills are becoming an essential component of the professional profile of the agricultural engineer.

The automation of agriculture also determines the modification of professional tasks. Autonomous machines, robotic systems and artificial intelligence can take over some of the repetitive activities, but their efficiency depends on the ability of specialists to configure, monitor and integrate them into production processes. FAO (2022) shows that automation can support productivity, work quality and the efficient use of resources, but requires investment in

professional training and avoiding the exacerbation of technological inequalities (Food and Agriculture Organization of the United Nations, 2022).

Digital transformation must be understood as a systemic process, in which technology interacts with organizations, institutions, policies and professional behaviors. RIJSWIJK, K. *et al*. (2021) highlights the need to develop collaboration and coordination capacities between farmers, consultants, researchers, technology companies and public institutions. The agricultural engineer must therefore be able to work in interdisciplinary teams and facilitate the transfer of knowledge between research and agricultural practice.

Another important category is represented by managerial and entrepreneurial skills. The agricultural engineer must be able to plan production activities, manage resources, calculate costs, analyze the return on investments and identify sources of financing. The introduction of modern technologies involves making complex economic decisions, as the benefits must be evaluated in relation to the price of equipment, the size of the farm, the level of staff training and the risks of the investment. BACCO, M. *et al*. (2019) emphasizes that the implementation of smart agriculture involves the integration of technology with the organization of the activity, infrastructure and information management.

Also, entrepreneurial and managerial skills have become increasingly important for agricultural engineers. Managing a modern agricultural holding involves planning economic activities, managing financial resources, developing development strategies and accessing European funds. The results of the study show that specialists who have economic and managerial skills have greater chances of integration and professional development in the labor market.

The entrepreneurial spirit allows the agricultural engineer to identify business opportunities, develop innovative products and services and respond to changes in demand. Entrepreneurial skills include initiative, creativity, planning, mobilizing resources and transforming ideas into activities that generate economic, social or ecological value (BACIGALUPO, M. et al., 2016). These skills are relevant both for managing a holding and for developing consulting services, rural projects or agri-food enterprises.

Alongside technical and digital skills, employers are increasingly placing importance on transversal skills. Analytical thinking, problem-solving, flexibility, creativity, collaboration and continuous learning are required in a labour market characterised by rapid technological change (World Economic Forum, 2025). The agricultural engineer must be able to analyse a problem from multiple perspectives and formulate solutions that take into account the productive, economic and ecological implications.

Another important result of the research is the emphasis on transversal skills. Employers believe that professional success does not depend exclusively on the level of technical knowledge, but also on the specialist's ability to communicate effectively, coordinate teams and manage complex situations. Problem-solving skills, critical thinking and adaptability are considered indispensable in the context of an agriculture in constant change. Entrepreneurial and economic skills are becoming important in the context of developing competitive agricultural holdings and accessing European funds.

Communication is an essential skill, as the agronomist collaborates with farmers, farm workers, researchers, authorities, suppliers, processors and consumers. He or she must present technical information in accessible language and formulate clear recommendations. The development of knowledge and innovation systems in agriculture emphasizes the importance of information exchange, cooperation between research and practice and agricultural advisory services (European Commission, 2024).

Social and ethical skills also become relevant in relation to the unequal effects of digitalization. High costs, limited access to infrastructure and differences in training can create gaps between farms. ROSE, D. C., CHILVERS, J. (2018) supports the need for responsible innovation, which includes user participation and the assessment of the social consequences of technologies. The agricultural engineer must be able to contribute to the adoption of accessible, transparent and local-appropriate solutions.

Practical training remains a fundamental requirement. The graduate must be able to apply knowledge in real conditions, identify crop problems, interpret soil analyses, establish technological solutions and evaluate the results of interventions. LIOUTAS, E. D. *et al*. (2019) show that digital transformation does not eliminate the role of professional experience, but requires the combination of agronomic knowledge with new technological and analytical capabilities.

From the perspective of university education, the formation of the necessary skills cannot be achieved exclusively through theoretical teaching. Practical activities, interdisciplinary projects, internships on agricultural holdings, case studies and direct use of precision technologies are needed. KLERKX, L., ROSE, D. (2020) highlight the fact that emerging technologies are transforming agricultural systems and requiring changes in research, consultancy and education. Universities must periodically adapt study programs and develop partnerships with employers.

The analysis also highlights the existence of gaps between the skills developed within university programs and the real requirements of employers. In many cases, theoretical training is not sufficiently correlated with practical activities and the use of modern technologies on agricultural holdings. Employers value practical experience and the ability of graduates to use digital equipment and applications from the time of university studies.

Lifelong learning is essential because equipment, applications and legislative requirements are constantly changing. The agricultural engineer must assess his/her training needs, use scientific and professional sources and participate in advanced training courses. Organisation for Economic Co-operation and Development (2022) shows that the digital transition determines the increase in demand for technological skills, but also for cognitive and social skills that allow adaptation to new forms of work organization.

The discussions resulting from the research also highlight the important role of continuous learning in the professional development of the agricultural engineer. The rapid evolution of agricultural technologies and the emergence of new production methods require the constant updating of knowledge and the development of skills throughout professional life. Participation in specialization courses, continuous training programs and research activities becomes essential for maintaining professional competitiveness.

Another important aspect identified is related to the internationalization of the agricultural sector and the integration of Romanian agriculture into the European and global market. In this context, language skills and the capacity for international collaboration become important advantages for agricultural engineers. Participation in European projects, exchange of experience and access to international information and technologies contribute to professional development and increase the competitiveness of the agricultural sector.

The discussions resulting from the analysis of the specialized literature emphasize the need to adapt university programs to the current requirements of the labor market. The results support the need to modernize the educational process in agronomic education. Universities must introduce disciplines oriented towards digitalization, smart agriculture, agricultural management and sustainability, as well as develop partnerships with farms and agricultural

companies to increase the level of practical training. The integration of internships, applied projects and interdisciplinary training can contribute to reducing the differences between graduates' skills and labor market requirements.

In conclusion, the current professional profile of the agricultural engineer is built by integrating several categories of skills: technical, digital, ecological, managerial, entrepreneurial, social and ethical. University training must ensure both a solid agronomic foundation and the ability to adapt to emerging technologies and the requirements of sustainable development. Correlating educational programs with the evolution of the agricultural sector and with the demands of employers is an essential condition for the integration of graduates into the labor market.

Overall, the results of the study demonstrate that the professional profile of the agricultural engineer is in a continuous process of transformation, being influenced by digitalization, sustainability and the requirements of the modern economy. The agricultural engineer of the future must combine classic technical skills with digital, managerial and social ones, in order to effectively respond to the challenges of contemporary agriculture and to contribute to the development of a competitive and sustainable agricultural sector.

CONCLUSIONS

Technological, economic and ecological transformations in recent decades have profoundly changed the professional profile of the agronomist engineer. His training can no longer be limited to traditional knowledge of plant cultivation, plant protection, soil fertilization and mechanization of agricultural work. The new demands of the labor market require the training of specialists capable of integrating agronomic skills with digital, ecological, managerial, entrepreneurial and social skills.

One of the main results of the research is the highlighting of the increasingly important role of digital skills. Modern agriculture uses information technologies to monitor and control production processes, such as GPS systems, GIS applications, agricultural drones, smart sensors and programs for farm management. These tools allow the collection and analysis of significant volumes of data on soil moisture and fertility, crop condition, water consumption, fertilizer needs and production trends. In these conditions, the agricultural engineer must be able to use digital technologies, interpret the data obtained and transform them into efficient technical and economic decisions. The development of these skills contributes to optimizing production, reducing costs and increasing the competitiveness of agricultural holdings.

The research also highlights the importance of skills related to sustainability and environmental protection. Contemporary agriculture must simultaneously respond to the need to ensure agri-food production and the objectives of conserving natural resources, reducing environmental impact and adapting to climate change. Therefore, the agricultural engineer must know the principles of organic and conservative agriculture, sustainable soil and water management methods, responsible use of inputs, biodiversity protection and climate risk prevention and management strategies. Green skills thus become indispensable for building a productive, resilient and responsible agricultural system.

The results of the study also emphasize the contribution of transversal skills to the professional integration and career development of graduates. Effective communication, teamwork, adaptability, critical thinking, creativity and problem-solving skills are increasingly valued by employers. The agronomic engineer carries out activities in collaboration with farmers, researchers, consultants, suppliers, representatives of public institutions and

professional organizations. For this reason, the ability to communicate technical information in a clear form and to cooperate in interdisciplinary teams is an important condition for the efficiency of his work.

In a sector characterized by rapid change and the use of complex technologies, adaptability and continuous learning become essential. The agricultural engineer must constantly update his knowledge and be open to the use of new methods, equipment and applications. University training is the basis of professional training, but it must be continued by participating in advanced training programs, specialization courses, research activities and exchanges of good practices.

Another important conclusion concerns the role of entrepreneurial and managerial skills. The modern agricultural engineer must be able to effectively manage material, financial and human resources, plan production activities, analyze costs and profitability and develop development strategies. He must also identify financing and investment opportunities, assess economic risks and contribute to the valorization of agricultural products. The development of competitive and sustainable farms requires the existence of specialists capable of combining technical training with management, initiative and economic planning.

The analysis carried out indicates the need for a more effective correlation between the educational process and the real requirements of the labor market. The differences between the skills acquired in university programs and those required by employers can make it difficult for graduates to integrate into the labor market. Reducing this gap requires the periodic updating of study programs and the introduction or expansion of disciplines related to precision agriculture, digitalization, GIS systems, data analysis, sustainability, climate change, entrepreneurship and agricultural management.

Practical training must occupy an important place in the training of future agricultural engineers. Laboratory and field activities, the use of modern equipment, case studies, interdisciplinary projects and internships carried out on agricultural holdings can contribute to the transformation of theoretical knowledge into applicable skills. At the same time, the development of partnerships between universities, agricultural holdings, companies, public institutions and professional organizations can facilitate the transfer of knowledge, the adaptation of educational programs and the integration of graduates into the labor market.

Overall, the agricultural engineer of the future must be an interdisciplinary professional, capable of using modern technologies, interpreting agricultural data, efficiently managing resources and applying sustainable practices. He must combine specialized technical training with critical thinking, flexibility, collaboration capacity and entrepreneurial initiative.

Modernizing agricultural education is therefore an essential condition for training specialists adapted to new economic, technological and ecological realities. Correlating study programs with labor market requirements, strengthening practical training and promoting digital and green skills can contribute to increasing the competitiveness of graduates and the agricultural sector. Investments in agricultural education and in the continuous development of professional skills are fundamental elements for building a high-performance, innovative, resilient and sustainable agriculture.

BIBLIOGRAPHY

BACCO, M., BARSOCCHI, P., FERRO, E., GOTTA, A., RUGGERI, M. (2019) - The digitisation of agriculture: A survey of research activities on smart farming, Array, 3–4, 100009. https://doi.org/10.1016/j.array.2019.100009.

BACIGALUPO, M., KAMPYLIS, P., PUNIE, Y., VAN DEN BRANDE, G. (2016) - EntreComp: The entrepreneurship competence framework, Publications Office of the European Union, https://doi.org/10.2791/593884.

BIANCHI, G., PISIOTIS, U., CABRERA GIRALDEZ, M. (2022) - GreenComp: The European sustainability competence framework, Publications Office of the European Union, https://doi.org/10.2760/13286.

BRONSON, K. (2019) - Looking through a responsible innovation lens at uneven engagements with digital farming, NJAS: Wageningen Journal of Life Sciences, 90–91, 100294, https://doi.org/10.1016/j.njas.2019.03.001.

EASTWOOD, C., KLERKX, L., AYRE, M., & DELA RUE, B. (2019) - Managing socio-ethical challenges in the development of smart farming: From a fragmented to a comprehensive approach for responsible research and innovation, Journal of Agricultural and Environmental Ethics, 32, 741–768, https://doi.org/10.1007/s10806-017-9704-5.

KLERKX, L., JAKKU, E., LABARTHE, P. (2019) - A review of social science on digital agriculture, smart farming and Agriculture 4.0: New contributions and a future research agenda, NJAS: Wageningen Journal of Life Sciences, 90–91, 100315, https://doi.org/10.1016/j.njas.2019.100315.

KLERKX, L., ROSE, D. (2020) - Dealing with the game-changing technologies of Agriculture 4.0: How do we manage diversity and responsibility in food system transition pathways? Global Food Security, 24, 100347, https://doi.org/10.1016/j.gfs.2019.100347.

LIOUTAS, E. D., CHARATSARI, C., LA ROCCA, G., DE ROSA, M. (2019) - Key questions on the use of big data in farming: An activity theory approach, NJAS: Wageningen Journal of Life Sciences, 90–91, 100297, https://doi.org/10.1016/j.njas.2019.04.003.

RIJSWIJK, K., KLERKX, L., BACCO, M., BARTOLINI, F., BULTEN, E., DEBRUYNE, L., DESSEIN, J., SCOTTI, I., BRUNORI, G. (2021) - Digital transformation of agriculture and rural areas: A socio-cyber-physical system framework to support responsibilisation, Journal of Rural Studies, 85, 79–90, https://doi.org/10.1016/j.jrurstud.2021.05.003.

ROSE, D. C., CHILVERS, J. (2018) - Agriculture 4.0: Broadening responsible innovation in an era of smart farming, Frontiers in Sustainable Food Systems, 2, Article 87, https://doi.org/10.3389/fsufs.2018.00087.

ROSE, D. C., WHEELER, R., WINTER, M., LOBLEY, M., CHIVERS, C. A. (2021) - Agriculture 4.0: Making it work for people, production, and the planet, Land Use Policy, 100, 104933, https://doi.org/10.1016/j.landusepol.2020.104933.

VUORIKARI, R., KLUZER, S., PUNIE, Y. (2022) - DigComp 2.2: The digital competence framework for citizens—With new examples of knowledge, skills and attitudes, Publications Office of the European Union, https://doi.org/10.2760/115376.

WOLFERT, S., GE, L., VERDOUW, C., BOGAARDT, M.J. (2017) - Big data in smart farming, Agricultural Systems, 153, 69–80, https://doi.org/10.1016/j.agsy.2017.01.023.

*** European Commission (2024) - Digitalisation of agriculture and rural areas in the European Union, Directorate-General for Agriculture and Rural Development, Digitalisation of agriculture and rural areas.

*** Food and Agriculture Organization of the United Nations (2022) - The state of food and agriculture 2022: Leveraging automation in agriculture for transforming agrifood systems, FAO, https://doi.org/10.4060/cb9479en.

*** Intergovernmental Panel on Climate Change (2022) - Climate change 2022: Impacts, adaptation and vulnerability, Cambridge University Press.

*** International Labour Organization (2019) - Skills for a greener future: A global view based on 32 country studies, ILO.

*** Organisation for Economic Co-operation and Development (2022) - Skills for the digital transition: Assessing recent trends using big data, OECD Publishing.

*** World Economic Forum. (2025) - The future of jobs report 2025, World Economic Forum.