Scientific Papers. Series B, Horticulture. Vol. LXX, No. 1, 2026
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

THE IMPACT OF DIGITALIZATION IN THE SUSTAINABLE DEVELOPMENT OF VEGETABLE GROWING AND ATTRACTING YOUNG FARMERS. REVIEW

Iulian Andrei SZEIKELY[1], Valerica TUDOR[1], Adrian ASĂNICĂ[1], Irinel CRĂCIUN[1], Paul MUȘAT[2], Răzvan Ionuț TEODORESCU[1]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest,
59 Mărăşti Blvd, District 1, Bucharest, Romania
[2]AGROBRAVA SRL, Poiana, District Constanța, Romania

Corresponding author email: valericatudor@gmail.com

Abstract

The vegetable production sector is facing increasing pressures generated by climate change, market volatility, and the growing demand for fresh, safe, and sustainable products. This paper examines the role of digitalization in the transformation of modern vegetable production through the integration of technologies such as unmanned aerial vehicles (UAVs), Internet of Things (IoT) sensors, artificial intelligence (AI), digital farm management platforms, and Agricultural Knowledge and Innovation Systems (AKIS). The findings indicate that digitalization contributes to reduced resource use, improved production quality, and enhanced operational efficiency. The study also highlights the strategic role of young farmers in the adoption of digital technologies, as well as the importance of AKIS in facilitating knowledge transfer and accelerating innovation processes. Digitalization is therefore analyzed not only as a form of technological advancement, but also as a catalyst for ecological, economic, and social sustainability within the vegetable production sector.

Key words*: precision horticulture, young farmers, sustainable farming.*

INTRODUCTION

The digitalization of agriculture has experienced significant acceleration over the past decade, driven by technological advances in the fields of smart sensors, Internet of Things (IoT) systems, drones, data analytics platforms, and applications based on artificial intelligence (Canicattì & Vallone, 2024; Abobatta, 2024). These technologies enable the collection and processing of large volumes of data concerning environmental conditions, crop status, and resource utilization, thereby facilitating the development of agricultural systems based on predictive analytics and automated decision-making processes (Figure 1).

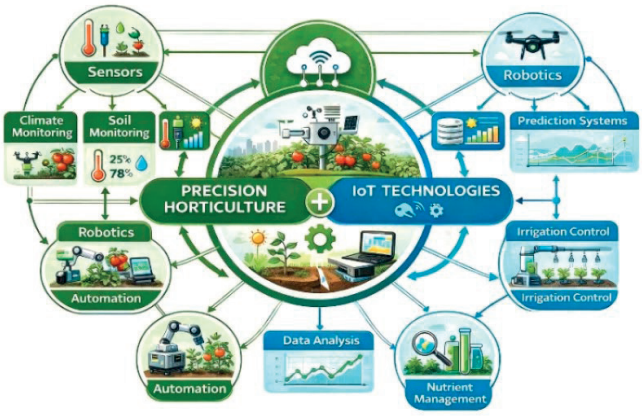

Figure 1. Innovative technological solutions in horticulture in 2025,
Source: Authors' own conception

Recent literature highlights that artificial intelligence and digital systems represent essential components of precision agriculture, contributing to crop monitoring, plant disease detection, the optimization of resource use, and improvements in agricultural productivity (Kumar et al., 2024; Padhiary et al., 2024; Aijaz et al., 2025).

In horticulture, and particularly in vegetable production, digital technologies are used to monitor crop development, optimize irrigation and fertilization practices, reduce post-harvest losses, and improve the traceability of agricultural products. The integration of data obtained from drones, sensors, and remote sensing systems enables farmers to observe spatial variability in environmental conditions and adopt management strategies tailored to the plot level, thereby enhancing the efficiency of horticultural production (Kumar & Bhatt, 2023; Getahun et al., 2024; Raj & Prahadeeswaran, 2025).

In this context, the concept of precision horticulture has become a central element of the digital transformation of the horticultural sector. Precision agriculture represents an approach based on the use of digital technologies for the continuous monitoring of crops and the variable-rate application of agricultural inputs, with the objective of optimizing production while reducing environmental impact. Recent studies emphasize that the integration of IoT sensors, drones, and artificial intelligence algorithms enables real-time crop monitoring and supports the adoption of management decisions grounded in data analysis (Nautiyal et al., 2025; Miller et al., 2025). However, the development of digital agriculture also has an important socio-economic dimension (Awais et al., 2025).

International organizations and academic studies underline that digital technologies can contribute to the modernization of the agricultural sector and increase the attractiveness of agriculture for younger generations by creating opportunities for the development of production models based on innovation and data-driven decision-making (Irawan et al., 2025). At the same time, there is a risk of the emergence of a "digital divide" between farmers who have access to digital infrastructure and technological skills and those who do not benefit from these resources (FAO, 2022; Mihai et al., 2025).

Maintaining the economic viability of farms, particularly small- and medium-sized enterprises, represents a major challenge in the context of current technological transformations. Although digital technologies and artificial intelligence–based applications can contribute to improving agricultural management efficiency, the level of adoption of these technologies remains limited in many regions. Recent studies indicate that the adoption of digital technologies is influenced by factors such as farm size, farmers' educational level, access to digital infrastructure, and investment capacity (Kramarz & Runowski, 2025). In this context, European agricultural policies are placing increasing emphasis on the development of digital competencies and the promotion of innovation in rural areas. Support programs targeting young farmers and initiatives for agricultural digitalization aim to facilitate access to technology, strengthen human capital, and accelerate the adoption of digital solutions in the agricultural sector (European Commission, 2023).

MATERIALS AND METHODS

The study analyzed the specialized literature (2015-2025) from the following sources:

- International scientific databases (ScienceDirect, Scopus, SpringerLink, MDPI, Web of Science);
- Reports and policy documents from organizations such as FAO, the European Commission, and the OECD.

Search strategy included the use of keywords such as "smart greenhouse", "precision horticulture", "IoT in agriculture", "sensor-based irrigation", "digital horticulture", and "vegetable production systems", as well as the use of Boolean operators (AND, OR) to combine them.

Articles published between 2015 and 2025, in English, were selected to reflect the most recent technological advances in the field.

Data analysis was carried out by compiling relevant information (authors, year, type of technology used, monitored parameters, and main results) into a tabular file created in Microsoft Excel. Subsequently, the data were compared and

synthesized to highlight the main research directions: digitalization of production processes (use of drones, sensors, and IoT in vegetable production); artificial intelligence in vegetable production; young farmers and the adoption of digital technologies; knowledge transfer and the role of AKIS in accelerating digitalization; and digitalization and sustainability in vegetable production.
The adopted methodology provides an overview of the current state of research on digitalization in horticulture and contributes to the identification of future research directions in digital vegetable production.

RESULTS AND DISCUSSIONS

The study's findings highlight a significant increase in academic and institutional interest in the digitalization of vegetable production and the role of young farmers in adopting digital technologies. Five major research directions were identified:
(1) Digitalization of production processes: the use of drones, sensors, and IoT in vegetable production;
(2) Artificial intelligence in vegetable production;
(3) Young farmers and adoption of digital technologies;
(4) Knowledge transfer and the role of AKIS in accelerating digitalization;
(5) Digitalization and sustainability in vegetable production.

1. Digitalization of production processes: drones, sensors, and IoT in vegetable production

1.1. Drones (UAVs) as a central tool for monitoring and intervention

Recent literature emphasizes that drones (UAVs – Unmanned Aerial Vehicles) have become an important instrument in precision agriculture, being used for crop monitoring, assessment of plant health, and the application of phytosanitary treatments (Yogalakshmi et al., 2025). The use of multispectral and hyperspectral sensors mounted on UAVs enables the rapid collection of plot-level data and the early detection of plant stress, disease, and pest outbreaks. These technologies contribute to the optimization of crop management and enhance farmers' decision-making processes (Guebsi et al., 2024). The integration of drones into agricultural management systems enables crop mapping and monitoring of spatial variability within agricultural fields, providing near real-time information on crop conditions and facilitating rapid interventions when phytosanitary issues arise. Recent literature considers drones an essential component of digital agricultural ecosystems, integrated with IoT sensors and data analytics platforms to support precision agriculture (Sharma et al., 2024). Moreover, images collected by drones can be analyzed using artificial intelligence algorithms. The use of convolutional neural networks (CNNs) for image analysis enables the automated detection of diseases and plant stress with high accuracy, contributing to the rapid diagnosis of phytosanitary problems (Ferentinos, 2018).

1.2. IoT sensors: monitoring soil, microclimate, and nutrition

Sensor-based systems are a fundamental element of precision horticulture, particularly in controlled environments such as greenhouses and tunnels. Multiparameter sensors can monitor real-time factors such as soil moisture, temperature, pH, light, and CO_2 concentration, providing essential data for optimizing plant growth conditions (Mansoor et al., 2025).
Integrating these sensors into IoT systems enables continuous data collection and transmission to digital farm management platforms. These systems facilitate the adoption of data-driven irrigation and fertilization strategies, contributing to reduced water consumption and improved efficiency in the use of agricultural inputs (Toselli et al., 2023; Jaiswal et al., 2025).
In modern horticulture, the concept of the "smart greenhouse" is becoming increasingly important. Systems based on sensor networks, digital platforms, and AI algorithms allow for the automatic control of temperature, ventilation, and irrigation, stabilizing production conditions and enhancing energy efficiency (Bicamumakuba et al., 2025; Kumar & Runowski, 2025).

1.3. System integration: from monitoring to automation

The digitalization of production processes in horticulture is evolving from simple monitoring systems toward integrated digital ecosystems,

where data from drones, IoT sensors, and AI-based analytics are used to automate agronomic decision-making. This approach is characteristic of Precision Agriculture 4.0, where data analysis and predictive models enable the automatic adjustment of irrigation, fertilization, or ventilation according to environmental conditions and crop status (Raj & Prahadeeswaran, 2025).

The integration of AI and IoT technologies contributes to the development of autonomous agricultural systems capable of analyzing large volumes of data and optimizing the use of agricultural resources (Awais et al., 2025). Recent studies indicate that these systems can improve crop productivity and foster the development of more efficient and sustainable agricultural systems (Zhang et al., 2024; Nautiyal et al., 2025)

2. Artificial intelligence in vegetable production

Artificial intelligence (AI) represents a central pillar in the digital transformation of modern agriculture. In vegetable production, AI applications are employed for automatic image analysis, early detection of plant diseases, yield estimation, irrigation optimization, and real-time decision support. The literature highlights a clear shift from mere data collection via drones and sensors toward advanced data interpretation using machine learning and deep learning algorithms, facilitating the development of predictive and automated agriculture (Kamilaris et al., 2017; Padhiary et al., 2024; Awais et al., 2025).

2.1. Aerial and ground image analysis using deep learning algorithms

Image analysis is one of the most important applications of AI in precision horticulture. Deep learning algorithms, particularly convolutional neural networks (CNNs), are used to automatically extract relevant features from multispectral, hyperspectral, or RGB images captured by drones, ground-based cameras, or mobile devices (Ferentinos, 2018; Awais et al., 2025).

Recent studies demonstrate the effectiveness of these methods for early disease detection. CNN systems can identify symptoms of foliar diseases and nutrient deficiencies with high accuracy, often outperforming traditional diagnostic methods (Ferentinos, 2018; Wakchaure et al., 2023). More recent research shows that deep learning models can rapidly process large volumes of agricultural images and detect multiple types of plant diseases or stresses in a very short time (Awais et al., 2025).

Integrating UAV-acquired aerial images with AI algorithms allows the early detection of water stress or nutrient deficiencies before symptoms become visually apparent. Subtle variations in leaf color or vegetation indices can provide valuable information for fertilization adjustments and crop management optimization (Canicattì & Vallone, 2024; Padhiary et al., 2024).

2.2. AI for irrigation, fertilization, and resource management

Beyond diagnostic applications, AI is increasingly used to optimize the use of agricultural resources. Predictive models based on machine learning can analyze climate data, soil moisture, and crop status to estimate optimal water and fertilizer requirements at different plant growth stages (Kamilaris et al., 2017; Mana et al., 2024). When integrated with IoT sensor networks, these models enable the automatic, real-time adjustment of irrigation and fertilization according to environmental conditions and crop needs (Gupta et al., 2025; Mansoor et al., 2025). In intensive horticulture, such systems contribute to resource-use efficiency and reduce input consumption (Jaiswal et al., 2025).

Similarly, the integration of robotic systems with AI algorithms supports the automation of production processes. Robotic platforms can perform tasks such as crop monitoring, application of phytosanitary treatments, or selective harvesting, increasing operational efficiency in horticulture (Hamrani et al., 2025). AI algorithms can also automatically regulate ventilation, shading, and fertilization systems in greenhouses, maintaining a stable microclimate and improving uniformity in production (Zhang et al., 2024).

2.3. AI in post-harvest processes: sorting, quality, and traceability

In the post-harvest phase, AI is used for automated classification of horticultural products based on size, color, and visual quality. Vision-based systems reduce sorting errors and improve batch standardization, enhancing the quality of

market-ready products (Ferentinos, 2018; Wakchaure et al., 2023; Matache et al., 2025). Moreover, AI technologies in supply chain management facilitate product traceability and quality monitoring throughout transport and distribution. Analysis of logistics data and the use of predictive algorithms can reduce post-harvest losses and optimize commercial flows in the horticultural sector (Gamage et al., 2024; Raj & Prahadeeswaran, 2025).

2.4. Integrated AI-IoT Systems: the foundation of autonomous agriculture

Current trends in horticulture focus on integrating AI with IoT technologies to develop autonomous production systems. Systems based on multiparameter sensors connected to digital platforms and AI algorithms allow automatic control of irrigation, ventilation, lighting, and fertilization in greenhouses and tunnels (Zhang et al., 2023; Bicamumakuba et al., 2025).

The integration of these technologies enables the analysis of historical data alongside real-time information to continuously adjust production parameters. AI-IoT systems thus form the foundation of the "smart agriculture" concept, in which production processes are continuously monitored and optimized based on data generated by the digital infrastructure (Abobatta, 2024).

3. Young farmers and the adoption of digital technologies

Young farmers play a crucial role in the digitalization of agriculture, being more open to innovation and generally possessing higher levels of digital literacy compared to older generations (Mihai et al., 2025; Arangurí et al., 2025). Higher education levels, easier access to information, and familiarity with digital environments facilitate the adoption of modern technologies, such as agricultural sensors, drones, crop monitoring systems, and digital farm management applications (Klerkx et al., 2019; Wolfert et al., 2017). By using these technologies, young farmers contribute to the development of precision agriculture and the optimization of production processes through data-driven decision-making.

At the same time, the literature identifies barriers that may limit the adoption of digital technologies, including high equipment costs, limited access to financing, and insufficient digital infrastructure in rural areas (Rotz et al., 2019). Additionally, the lack of advisory services and specialized training programs can slow down farm digitalization (Klerkx et al., 2019; FAO, 2019).

Nevertheless, the integration of digital technologies enhances resource-use efficiency, reduces production costs, and improves crop productivity, particularly in horticulture and vegetable production (Wolfert et al., 2017; Rotz et al., 2019). Digitalization also increases the attractiveness of agriculture for younger generations by reducing reliance on labor-intensive work and transforming agricultural activities into more innovative, technology-oriented processes (FAO, 2019).

Furthermore, the use of digital technologies and intelligent crop monitoring systems allows farmers to make more informed decisions and improve the economic performance of their farms (Markovits, 2023). Consequently, digitalization is considered a key factor in revitalizing the agricultural sector and attracting young people to farming, contributing to the development of more efficient and sustainable production models (Mihai et al., 2025).

4. Knowledge transfer and the role of AKIS in accelerating digitalization

Knowledge transfer is an essential factor in the adoption of digital technologies in agriculture. Agricultural Knowledge and Innovation Systems (AKIS) facilitate the flow of information between research, agricultural advisory services, farmers, and the private sector, supporting the rapid dissemination of innovations and the integration of digital technologies in farm management (European Commission, 2023; Knierim et al., 2022). Access to advisory services, training, and knowledge-sharing networks is considered critical for the adoption of technologies such as agricultural sensors, data platforms, IoT systems, and digital analytics tools used in precision agriculture (Klerkx & Rose, 2020; OECD, 2021). Under the 2023–2027 Common Agricultural Policy reform, AKIS are recognized as a strategic pillar for promoting innovation and digitalization in the agricultural sector. Their integration into European agricultural policies aims to strengthen collaboration among farmers, research

institutions, universities, agricultural advisors, and technology companies, improving knowledge transfer and accelerating the adoption of digital solutions in agriculture (European Commission, 2023).

Agricultural advisors play a central role within these systems, acting as intermediaries between research and practice. They support farmers in interpreting technical information, using digital tools, and integrating precision agriculture technologies into production processes (Ingram & Maye, 2020; Knierim et al., 2022). Studies show that farmers who have access to advisory and specialized technical support adopt digital technologies more rapidly and utilize agricultural data more effectively.

Farmers' digital skills are also a key determinant in the adoption of modern technologies. Professional training programs, technology demonstrations, and participatory innovation initiatives contribute to skill development and enhance decision-making in farm management (Klerkx & Rose, 2020; OECD, 2021). Simultaneously, digital platforms and agricultural innovation networks facilitate experience exchange among farmers and access to technical information, accelerating technology diffusion and the development of locally adapted solutions (European Commission, 2023; Kountios et al., 2024).

Strengthening AKIS, expanding advisory services, and developing digital training programs are therefore essential for accelerating agricultural digitalization and supporting farm modernization in the transition toward more innovative and sustainable agricultural systems (Del Puente et al., 2026).

5. Digitalization and sustainability in vegetable production

Digitalization is increasingly associated with sustainability goals, providing tools to optimize resource use and enhance the economic and social performance of farms. Digital technologies - including agricultural sensors, IoT systems, drones, data analytics platforms, and AI applications - enable real-time crop monitoring and support farmers' decision-making. The literature highlights that integrating these technologies contributes to the development of more efficient and resilient agricultural systems, optimizing resource use and reducing environmental impact (Wolfert et al., 2017; Klerkx et al., 2019).

In vegetable production, characterized by high input intensity and the need for continuous crop monitoring, digital technologies significantly improve ecological sustainability. Precision agriculture, based on soil sensors, aerial imagery, and crop monitoring systems, enables variable-rate application of water, fertilizers, and pesticides, reducing resource consumption and environmental impact (Gupta et al., 2025). Sensor-based smart irrigation systems and digital control platforms contribute to more efficient water use, while drones and remote sensing technologies facilitate early disease and pest detection and targeted phytosanitary interventions (Hamrani et al., 2025). In controlled environments, digital climate-control systems allow for automatic adjustment of temperature, humidity, and ventilation, stabilizing production conditions and reducing energy consumption (Zhang et al., 2024).

Beyond ecological benefits, digitalization strengthens the economic sustainability of vegetable farms. Real-time crop monitoring and data analysis allow for optimized input use and reduced operational costs, while predictive models and data analytics support yield estimation and production planning (Kamilaris et al., 2017; Ferentinos, 2018). These technologies help reduce losses, improve production efficiency, and enhance the economic resilience of farms-particularly important for the vegetable sector.

Digitalization also impacts the social dimension of sustainability. Automating labor-intensive agricultural processes transforms farmers' activities into more monitoring-, analysis-, and data-management-oriented work (Rotz et al., 2019). At the same time, digital technologies generate new skills and professional roles in agriculture and can increase the sector's attractiveness to younger generations, contributing to professionalization and farm modernization (Klerkx et al., 2019).

Therefore, digitalization is a key factor in consolidating sustainability in vegetable production by integrating ecological, economic,

and social dimensions of agricultural development.

CONCLUSIONS

The literature analysis confirms that digitalization is a key factor in the modernization of vegetable production. Technologies such as drones, IoT sensors, and artificial intelligence algorithms enable real-time data collection and interpretation, facilitating predictive, automated, and efficiency-oriented agriculture.

From an ecological perspective, digitalization reduces the use of water, fertilizers, and pesticides, contributing to the protection of natural resources and enhancing the resilience of horticultural systems.

From an economic standpoint, smart technologies optimize costs, reduce losses, and improve production planning.

The social dimension is supported through the active involvement of young farmers, who adopt digital solutions more rapidly and contribute to the transformation of agricultural business models. Nevertheless, the success of the digital transition depends on the strengthening of AKIS, access to professional training, and the development of rural digital infrastructure.

Digitalization in vegetable production is not merely a technological innovation but a strategic process of structural transformation, integrating ecological sustainability, economic competitiveness, and generational renewal in the agricultural sector.

REFERENCES

Abobatta W.F., 2024.Precision farming applications in horticulture, Horticult Int J., 2024; 8(3): 91–93.

Aijaz, N., Lan, H., Raza, T., Yaqub, M., Iqbal, R., & Pathan, M. S. (2025). Artificial intelligence in agriculture: Advancing crop productivity and sustainability. Journal of Agriculture and Food Research, 20, 101762, https://doi.org/10.1016/j.jafr.2025.101762

Arangurí M., Mera H., Noblecilla W., Lucini C., 2025. Digital literacy and technology adoption in agriculture: A systematic review of factors and Strategies, AgriEngineering 2025, 7(9), 296; https://doi.org/10.3390/agriengineering7090296

Awais M., Wang X., Hussain S., Aziz F., Mahmood M.Q., 2025. Advancing Precision Agriculture Through Digital Twins and Smart Farming Technologies: A Review, AgriEngineering, 2025, 7(5), 137; https://doi.org/10.3390/agriengineering7050137

Bicamumakuba E., Reza M.N., Jin H., Samsuzzaman, Lee, K.-H., Chung S.-O., 2025. Multi-sensor monitoring, intelligent control, and data processing for Smart Greenhouse Environment Management, Sensors, 2025, 25, 6134, https://doi.org/10.3390/s25196134

Canicattì M., Vallone M., 2024. Drones in vegetable crops: A systematic literature review, Smart Agricultural Technology, Vol. 7 (2024) 100396, https://doi.org/10.1016/j.atech.2024.100396

Del Puente, F., Del Giudice, T., Alessandro S., Concetta M., 2026. Rethinking agricultural districts as innovation systems: The role of AKIS and collaborative governance. Agricultural and Food Economics, 2026) 14:12, https://doi.org/10.1186/s40100-025-00439-6

Ferentinos, K.P., 2018. Deep learning models for plant disease detection and diagnosis. Computers and Electronics in Agriculture, 145 (2018), 311–318, https://doi.org/10.1016/j.compag.2018.01.009

Gamage, A., Gangahagedara, R., Subasinghe, S., Gamage, J., Guruge, G., Senaratne, S., Randika, T., Rathnayake C., Hameed Z., Madhujith T., Merah O., 2024. Advancing sustainability: The impact of emerging technologies in agriculture. Current Plant Biology, Vol. 40 (2024) 100420, https://doi.org/10.1016/j.cpb.2024.100420

Getahun, S., Kefale, H., & Gelaye, Y., 2024. Application of Precision Agriculture Technologies for Sustainable Crop Production and Environmental Sustainability: A Systematic Review. The Scientific World Journal, 2024, 2126734, https://doi.org/10.1155/2024/2126734

Guebsi R., Mami S., Chokmani C., 2024. Drones in Precision Agriculture: A Comprehensive Review of Applications, Technologies, and Challenges. Drones, 2024, 8(11), 686; https://doi.org/10.3390/drones8110686

Gupta S., Chowdhury S., Govindaraj R., Amesho K., Shangdiar S., Kadhila T., Iikela S., 2025. Smart agriculture using IoT for automated irrigation, water and energy efficiency. Smart Agricultural Technology, Volume 12, December 2025, 101081, https://doi.org/10.1016/j.atech.2025.101081

Hamrani, A., Allouhi, A., Bouarab F.Z., Jayachandran K., 2025. AI and Robotics in Agriculture: A Systematic and Quantitative Review of Research Trends (2015-2025). Crops 2025, 5, 75, https://doi.org/10.3390/crops5050075

Irawan N.C., Irham, I., Mulyo J.-H., Suryantini A., 2023.Unleashing the Power of Digital Farming: Local Young Farmers' Perspectives on Sustainable Value Creation. Agraris Journal of Agribusiness and Rural Development Research, 9(2):316-333, DOI:10.18196/agraris.v9i2.239

Jaiswal N., Kumar T.V., Shukla C., 2025. Smart drip irrigation systems using IoT: A review of architectures, machine learning models, and emerging trends. Discover Agriculture, Vol. 3, 253, https://doi.org/10.1007/s44279-025-00430-1

Kamilaris, A., Kartakoullis, A., Prenafeta-Boldú, F., 2017. A review on the practice of big data analysis in agriculture. Computers and Electronics in Agriculture,

Volume 143, Pages 23-37, https://doi.org/10.1016/j.compag.2017.09.037
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: 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
Kountios, G., Kanakaris, S., Moulogianni, C., Bournaris, T., 2024. Strengthening AKIS for Sustainable Agricultural Features: Insights and Innovations from the European Union: A Literature Review. Sustainability 2024, 16(16), 7068; https://doi.org/10.3390/su16167068
Knierim, A., Kernecker, M., Erdle, K., Kraus, T., Borges, F., & Wurbs, A., 2022. Smart farming technology innovations - Insights and reflections from the German Smart-AKIS hub. Agricultural Systems, 190, 103099, DOI:10.1016/j.njas.2019.100314
Kramarz, P., Runowski, H., 2025. Possibilities of using digital technologies in agriculture in areas with high agrarian fragmentation. Precision Agriculture (2025) 26:48 https://doi.org/10.1007/s11119-025-10244-2
Kumar, C.D., Adiraju, R.V., Pasupuleti, S., Nandan, D., 2020. A review of smart greenhouse farming by using sensor network technology. In Proceedings of International Conference on Recent Trends in Machine Learning, IoT, Smart Cities and Applications: ICMISC 2020, 849-856, DOI:10.1007/978-981-15-7234-0_79
Kumar, N., Bhatt, D., 2023. S3A2: Smart Sustainable System for Agricultural Applications with IoT Emerging Artificial Intelligence. In: Kumar, M., Nayyar, A., Singh, A.K., Guo, Y. (eds) Convergence of AI, Federated Learning, and Blockchain for Sustainable Development. Advances in Science, Technology & Innovation. Springer, Cham. Print ISBN978-3-031-80948-4, Online ISBN978-3-031-80949-1, https://doi.org/10.1007/978-3-031-80949-1_1
Kumar, S., Wani, A.W. Kaushik R., Kaur H., Djajadi D., Khamidah A., Alasbali N., Alreshidi M.A., AlamM.W., Yadav K.K., Wani A.K., 2024. Navigating the landscape of precision horticulture: Sustainable agriculture in the digital age, Scientia Horticulturae 338 (2024) 113688, https://doi.org/10.1016/j.scienta.2024.113688
Ingram J. and Maye D., 2020. What Are the Implications of Digitalisation for Agricultural Knowledge? Front. Sustain. Food Syst. 4:66, doi: 10.3389/fsufs.2020.00066
Mana A.A., Allouhi A., Hamrani A., Rehman S., Jamaoui I, 2024. Sustainable AI-based production agriculture: Exploring AI applications and implications in agricultural practices, Smart Agricultural Technology, Volume 7, March 2024, 100416, https://doi.org/10.1016/j.atech.2024.100416
Mansoor S, Iqbal S, Popescu S.M., Kim S.L., Chung Y.S. and Baek J-H, 2025. Integration of smart sensors and IOT in precision agriculture: trends, challenges and future prospects, Front. Plant Sci. 16:1587869., https://doi.org/10.3389/fpls.2025.1587869
Markovits P.S., 2023. Digital Transformation of Agriculture in Romania: A Change Management Perspective, Ovidius University Annals Economic Sciences Series, Vol. XXIII(2):282-291, DOI:10.61801/OUAESS.2023.2.35
Matache M.G., Găgeanu, I., Brăcăcescu, C., Cristea O.D., Cristea R.D., 2025. Robotic harvesting methods for vegetables of the Solanaceae family in greenhouses and solariums using specialized grippers – a review. Acta Hortic. 1433, 323-330, DOI: 10.17660/ActaHortic.2025.1433.41
Mihai M., Mihai V., Pocol C.B., Ursa A., Dumitras E., 2025. Young Romanian Farmers' Perspective and Behavior Toward Fertilizer Use in View of the European Union's Farm to Fork Sustainable Strategy, Sustainability 2025, 17(22), 9952; https://doi.org/10.3390/su17229952
Miller, T., Mikiciuk, G., Durlik, I., Mikiciuk, M., Łobodzińska, A., Śnieg, M., 2025). The IoT and AI in Agriculture: The Time Is Now - A Systematic Review of Smart Sensing Technologies. Sensors, 25(12), 3583, https://doi.org/10.3390/s25123583.
NautiyalM., Joshi, S., Hussain, I., Rawat, H., Joshi, A., Saini, A., Kapoor, R., Verma, H., Nautiyal, A., Chikara, A., Ahmad, W., Kumar, S., 2025. Revolutionizing agriculture: A comprehensive review on artificial intelligence, machine learning and IoT applications in smart farming. Food Chemistry: X, Volume 29, July 2025, 102748, https://doi.org/10.1016/j.fochx.2025.102748
Padhiary, M., Saha, D., Kumar, R., Sethi, L. N., & Kumar, A., 2024. Enhancing precision agriculture: A comprehensive review of machine learning and artificial intelligence applications in agriculture. Smart Agricultural Technology, https://doi.org/10.1016/j.atech.2024.100483
Raj, M., Prahadeeswaran, M., 2025. Revolutionizing agriculture: a review of smart farming technologies for a sustainable future, Discover Applied Sciences (2025) 7:937, https://doi.org/10.1007/s42452-025-07561-6
Rotz, S., Gravely, E., Mosby, I., Duncan, E., Finnis, E., Horgan, M., LeBlanc, J., Martin, R., Neufeld, H.T., Pant, L., Shalla, V., Fraser, E., 2019. Automated pastures and the digital divide: How agricultural technologies are shaping labour and rural communities, Journal of Rural Studies, https://doi.org/10.1016/j.jrurstud.2019.01.023
Sharma, K., Shivandu, S.K., 2024. Integrating artificial intelligence and Internet of Things (IoT) for enhanced crop monitoring and management in precision agriculture, Sensors International, Vol. 5, 2024, 100292, https://doi.org/10.1016/j.sintl.2024.100292
Toselli, M., Baldi, E., Ferro, F., 2023. Smart farming tool for monitoring nutrients in soil and plants for precise fertilization. Horticulturae. 2023;9(9):1011.
Wakchaure, M., Patle, B.K., Mahindrakar, A.K., 2023. Application of AI Techniques and Robotics in Agriculture: A Review, Artificial Intelligence in the Life

Sciences 3 (2023) 100057, https://doi.org/10.1016/j.ailsci.2023.100057
Wolfert S., Ge L., Verdouw C., Bogaardt M.-J., 2017. Big Data in Smart Farming –A Review, Agricultural Systems 153 (2017) 69–80, https://doi.org/10.1016/j.agsy.2017.01.023
Yogalakshmi V., Jagadeeswaran R., Muthumanickam D., Thirukumaran K., Kavitha M., 2025. Application of Agricultural Drones in Vegetable Cultivation: A Comprehensive Review, PLANT SCIENCE TODAY ISSN 2348-1900 (online) Vol 12(2): 1-13, https://doi.org/10.14719/pst.8156
Zhang H., He L., Di Gioia F., 2023. Implementing Internet of Things (IoT) Sensor-based precision irrigation with LoRaWAN Technology for Enhancing Yield, Quality, and resource use efficiency of Soilless Basil. Acta Hortic. 1377, 647-654, DOI: 10.17660/ActaHortic.2023.1377.79
Zhang X., Feng G., Sun, X. R., 2024. Advanced Technologies of soil moisture monitoring in Precision Agriculture. J. Agric. Food Res., 101473. doi: 10.1016/j.jafr.2024.101473
European Commission, 2021. AKIS and Advisory Services in the CAP Strategic Plans 2023–2027.
European Commission, 2023. AKIS in the CAP Strategic Plans: Progress Report on the Implementation of Agricultural Knowledge and Innovation Systems. Publications Office of the European Union, Luxembourg
FAO. 2019. Digital Technologies in Agriculture and rural areas – Status Report. Rome: Food and Agriculture Organization of the United Nations.
FAO, 2020. Status of Digital Agriculture in 18 Countries of Europe and Central Asia
FAO, 2022. The State of Food and Agriculture 2022. Leveraging Automation in Agriculture for transforming agrifood systems. Rome, FAO
FAO, 2024. AgriTech Observatory (Europa & Asia Centrală)
OECD, 2021. Digital Opportunities for better agricultural policies. OECD Publishing
https://eu-cap-network.ec.europa.eu/support/innovation-knowledge-exchange-eip-agri/akis_en
https://scar-europe.org/images/AKIS/ Documents/ AKIS_5th-Mandate-Report_August2023.pdf