ASPECTS REGARDING DIGITALIZATION OF ROMANIAN AGRICULTURE

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Abstract: *The adoption and integration of advanced technologies into agricultural practices—commonly referred to as "Agriculture 4.0"—represents a transformative shift toward smarter, more efficient, and sustainable farming systems. This new era of agriculture is characterized by the widespread implementation of digital innovations such as Internet of Things (IoT) sensors, drones, artificial intelligence (AI), big data analytics, GPS-guided machinery, and cloud-based farm management platforms. These tools have the potential to revolutionize the agricultural value chain, enabling real-time decision-making, optimizing input use, increasing yields, and reducing environmental impact. In the Romanian context, Agriculture 4.0 holds significant promise due to the country's rich agricultural heritage, extensive arable land, and ongoing integration within the European Union's digital and sustainability frameworks. However, the uptake of smart farming technologies remains uneven and limited. Key barriers include low levels of investment capacity among small and medium-sized farms, underdeveloped rural digital infrastructure, limited access to training and digital education for farmers, and fragmented policy implementation. These challenges have created a digital divide that risks excluding a large share of rural producers from the benefits of technological progress. This paper explores the current state of digital agriculture in Romania, analyzing both the structural challenges and emerging opportunities associated with its modernization. Special emphasis is placed on assessing the role of EU funding mechanisms, national digital strategies, and private sector innovation in driving this transformation. The paper argues that a coordinated, inclusive, and well-financed approach is necessary to accelerate Romania's transition to smart farming. Bridging the technological gap in rural areas is essential not only for increasing productivity and resilience in the agricultural sector, but also for aligning with broader EU goals related to sustainability, climate adaptation, and rural development.*

Key words*: transformation, technologies, agriculture, digitalization, farmers.*

INTRODUCTION

The integration of digital technologies into Romanian agriculture presents a multifaceted transformation, impacting productivity, sustainability, and market competitiveness [23, 24]. Agriculture is undergoing a significant shift, often referred to as the "fourth revolution," driven by the pervasive influence of digitalization across various sectors [10]. This transition is characterized by the adoption of advanced technologies like sensors, the Internet of Things, big data analytics, 3D printing, artificial intelligence, digital twins, augmented reality, and integrated systems, all of which are reshaping traditional agricultural practices [1]. Romanian farmers are increasingly recognizing the potential of Agriculture 4.0 to enhance productivity while simultaneously promoting sustainability and resilience in their operations [5]. The utilization of digital technologies in agriculture extends beyond mere automation, encompassing sophisticated solutions such as smart irrigation systems, predictive analytics for crop and pest management, robotic pest control, automated harvesting, and enhanced traceability throughout the entire food supply chain, from the farm to the consumer [16]. The convergence of these technologies promises to optimize resource utilization, minimize environmental impact, and enhance the overall efficiency of agricultural production in Romania [18].

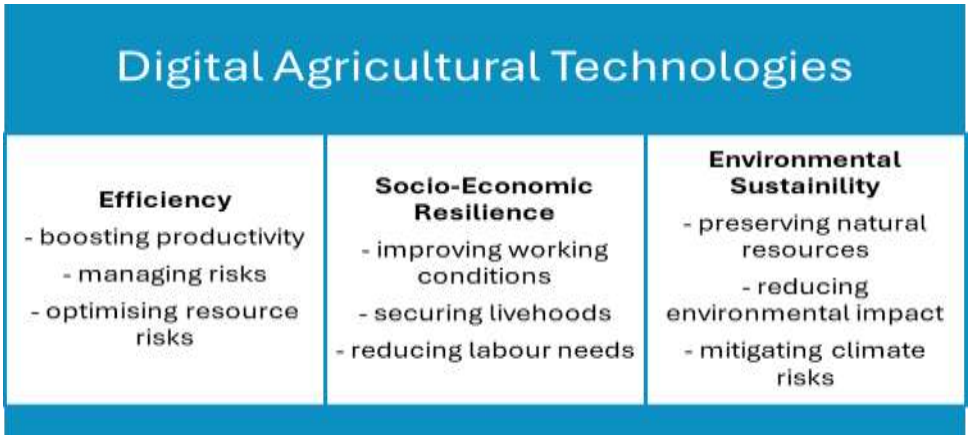

Figure 1. Benefits of digital agriculture
Source: Council of European Union, february 2025

Despite the promising potential, the adoption of digital technologies in Romanian agriculture faces several challenges, including the need for significant investments in infrastructure and digital literacy, particularly among smallholder farmers. One of the key barriers to the widespread adoption of digital technologies in Romanian agriculture is the limited access to reliable internet connectivity, particularly in rural areas. Farmers may be hesitant to share their data with external stakeholders due to concerns about data privacy, security, and potential misuse [6]. Addressing these challenges requires a multi-faceted approach involving government support, private sector investment, and collaborative efforts to bridge the digital divide and promote digital literacy among farmers. Furthermore, the absence of clear legal and regulatory frameworks governing the collection, processing, and sharing of agricultural data raises ethical considerations that need to be addressed to foster trust and ensure responsible data management practices [12]. The integration of ICT and data ecosystems is pivotal in supporting agricultural development, aligning with the concept of a 'Digital Earth' [15].

MATERIALS AND METHODS

The methodology employed in assessing the digitalization of Romanian agriculture integrates research techniques to provide a comprehensive understanding of the current landscape, challenges, and opportunities. Initial stages involve extensive literature reviews and document analysis focusing on identifying the drivers and barriers influencing the adoption of digital technologies [9]. The research integrates diverse materials including scientific publications, industry reports, and case studies to offer a well-rounded view of digital agriculture in Romania [21]. This study employs a qualitative research design aimed at examining the state of digitalization in Romanian agriculture, its opportunities, and the barriers hindering adoption. A combination of complementary methods was applied to ensure a comprehensive and reliable analysis. The analysis included official documents from the European Union, Romanian ministries, and relevant agricultural organizations, to contextualize how policy shapes the digital transition of the sector.

RESEARCH RESULTS

Smart farming and precision agriculture, driven by ICT-based interventions, are instrumental in improving the output and sustainability of traditional agricultural systems [3]. However, the successful implementation of these technologies necessitates careful consideration of factors such as data ownership, privacy, and security [19]. Governments can play a crucial role in supporting digitalization by developing appropriate policies and

programs, fostering innovation, and creating an enabling environment for technology adoption [13]. Investing in public goods that provide sufficient resources for successfully implementing digital technologies is crucial [25]. In addition, the development of open-source platforms and data standards can facilitate data sharing and interoperability, enabling farmers to access and utilize digital tools more effectively.

The transition towards digital agriculture necessitates a collaborative approach, involving farmers, researchers, policymakers, and technology providers, to co-design solutions that are tailored to the specific needs and contexts of Romanian agriculture [11]. This collaborative ecosystem should prioritize the development of user-friendly interfaces, intuitive data analytics tools, and accessible training programs to empower farmers to harness the full potential of digital technologies.

The transition to Agriculture 4.0 emphasizes data-driven decision-making, automation, and smart farming solutions, fundamentally reshaping production, logistics, and resource management in agriculture. By leveraging innovations such as IoT sensors, AI-driven analytics, robotics, and blockchain traceability, Agriculture 4.0 promises to enhance productivity while minimizing environmental impact.

Agriculture 4.0 represents a digital revolution in farming, replacing traditional methods with smart technologies. Core innovations include AI, IoT, automation, and blockchain, which improve efficiency and sustainability. However, challenges such as cost barriers, skill gaps, and unequal tech access require targeted policy interventions. The shift is crucial for future-proofing global food systems amid climate and population pressures.

Romanian agriculture has significant potential for digital transformation, but several barriers hinder the widespread adoption of smart farming technologies [2, 4, 7]. These limitations stem from economic, infrastructural, educational, and policy-related challenges, slowing down progress toward a more efficient and sustainable agricultural sector [8, 14, 17].

Economic Barriers

- high costs of technology adoption: many romanian farmers, especially smallholders and family farms, lack the financial resources to invest in precision agriculture tools (e.g., gps-guided tractors, iot sensors, drones). high upfront costs for automated machinery, farm management software, and data analytics make digital solutions inaccessible for most small and medium farms [20].
- limited access to financing: low eu fund absorption for rural development (e.g., delays in accessing CAP digitalization funds). Banks and investors perceive agriculture as high-risk, leading to limited credit options for tech upgrades.

Infrastructure & Connectivity Issues

- poor rural internet & mobile coverage: over 30% of rural areas in romania still lack high-speed internet (4g/5g), essential for real-time data transmission in smart farming. Weak connectivity limits the use of cloud-based farm management systems, remote sensors, and AI-driven analytics.
- lack of digital platforms & interoperability: many romanian farmers rely on manual record-keeping due to a lack of integrated digital platforms. Different technologies (e.g., tractor telemetry, soil sensors) often use incompatible software, reducing efficiency.

Low Digital Literacy & Resistance to Change

- aging farmer population & skills gap: the average Romanian farmer is over 55 years old, with limited exposure to digital tools. Many prefer traditional methods and distrust new technologies due to a lack of training.

- insufficient training & extension services: few private programs offer hands-on training in precision farming. Most agricultural schools do not teach digital farming techniques, leaving young farmers unprepared.

Policy & Regulatory Challenges

- slow implementation of EU digital farming policies: while the EU promotes smart agriculture (e.g., CAP 2023-2027), Romania lags in subsidy distribution and tech incentives. Bureaucratic delays in accessing EU funds for digitalization (e.g., PNDR – National Rural Development Program) [22].
- lack of standardized data & cybersecurity risks: no unified national agricultural data system, leading to fragmented information. Farmers fear data privacy breaches (e.g., unauthorized use of field data by agribusinesses).

Market & Supply Chain Limitations

- low demand for digital solutions: many Romanian farms are subsistence-based or semi-subsistence, reducing incentives for high-tech investments. Lack of digital marketplaces for agricultural products limits price transparency and e-commerce adoption.
- weak collaboration between stakeholders: tech providers, farmers, and policymakers often work in isolation, slowing innovation. Few public-private partnerships to promote digital farming pilot projects.

CONCLUSIONS

Offering targeted financial support can enable small farms to invest in modern agricultural technologies. This may include grants for equipment purchases, tax incentives for technology-related expenses, and low-interest loans for upgrades. These measures can lower financial barriers and boost productivity through wider technology adoption.

Access to high-speed internet is essential for embracing digital tools. Expanding broadband infrastructure and enhancing mobile connectivity in rural regions will allow farmers to utilize online platforms, access digital services, and engage in e-commerce. Public-private partnerships and government-led initiatives can play a crucial role in bridging the connectivity gap.

Equipping farmers with digital competencies is vital for effective technology use. EU-funded programs can offer hands-on training, workshops, and e-learning opportunities on topics such as precision agriculture, data analysis, and farm management software. These programs will help farmers harness the full potential of digital tools.

Streamlining the implementation of agricultural policies is critical to promoting digital integration. Ensuring that Common Agricultural Policy (CAP) funds are distributed swiftly and transparently will give farmers timely access to financial resources needed for technological investments.

Encouraging the development of agri-tech startups and promoting collaboration between the public and private sectors can fuel innovation. This can be supported through accelerators, incubators, and innovation hubs tailored to the agricultural sector. Collaborative platforms involving farmers, researchers, and tech companies can drive the creation of impactful digital solutions.

If these challenges are not addressed, Romania risks lagging behind other EU nations in terms of agricultural productivity, sustainability, and competitiveness. By implementing these strategies, Romania can strengthen its agricultural sector and secure a more sustainable and competitive future.

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