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The Ubiquity of Digital Technologies is Transforming Agriculture and Food Production

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Introduction

The ubiquity of digital technologies is transforming agriculture and food production. Specifically, in the agricultural sector, the diffusion of mobile technologies, remote sensing services and distributed computing are already improving producers' access to information, inputs and markets, increasing production and productivity, streamlining supply chains and reducing operating costs and environmental impact. But it's not just about farmers. Consumers, both at home and abroad, are becoming more knowledgeable about the products they buy. They demand high-quality, sustainably produced food and fiber and want to learn more about where products come from.

Romania is the last country in Europe in terms of digitization and innovation in agriculture. The main reasons are the fact that most farmers are over 64 years old, the low level of digital literacy, but also the resistance to change, namely technology.

The Farmer Loses, on Average, Three Times During the Production Cycle:

1. The first time when planning production, because without accurate data on the quality of the soil and the real needs of the crops, it cannot optimally calculate the necessary investments.
2. The second loss is in the production phase, mainly due to the wrong assessment of the timing of the application of specific ago technical measures (20% - 40% per year)
3. And the third loss of the farmer is at the price of the product. Only a product that meets the quality criteria, either in terms of visual characteristics or nutritional composition - and can prove it - manages to command a premium price.

According to statistical data provided by InaCom, in Romania, 75% of agriculture and food companies consider that they do not have digital expertise [1]. The main instrument for keeping records of land and agricultural works: 49,5% an agenda, 20% Excel-type programs, 13,5% say they don't think they need such tools, 17% use a computer program or a dedicated application for farm management.

Therefore, farmers need to develop a new set of skills in different fields of application. In order to address this macro-need, the Digital Farmer project, through European funding and an international multi-stakeholder cooperation between training institutions, research, universities, industrial consulting and territorial promotion companies, developed a project aimed at producing teaching materials and innovative work-based learning methodologies, platforms for awareness raising and exchange of good practices and a general qualification of European VET systems related to agriculture, the "Digital Education Action Plan" is based on the assumption that it has become indispensable for the European population to possess digital skills appropriate to our times.

Business Innovation Council, as a partner of a consortium made up of 7 states (Italy - coordinator, Spain, Greece, Turkey, Slovenia, Estonia) implemented the Digital Farmer project, financed by the Erasmus+ Program.

The project supported farmers in developing a new set of skills in different fields of application which have been identified as future trends in the agricultural sector: Decision Support Systems (DSS); Block Chain Technologies; Information and communication technologies (ICT); Nir's and Drones; Farmbox and E-Commerce software, marketing and advertising platforms. All the project results are available in all project partners' languages: English, Italian, Romanian, Estonian, Greek, Turkish, Slovenian, Spanish, also on the project website: www. digital-farmer. net.

The course will start in October, it's free and can be accessed by anyone interested.

As the global population continues to rise, the agricultural sector faces mounting pressure to increase productivity and meet the ambitious "Zero Hunger" goal. The Food and Agriculture Organization of the United Nations (FAO) forecasts that the world population will reach 8 billion by 2025 and is projected to climb to 9.6 billion by 2050 [2]. This significant growth translates to an urgent need for a 70% increase in global food production by mid-century (FAO, 2009). The challenge lies not only in enhancing productivity but also in ensuring the efficient use of water and other resources in an increasingly resource-constrained environment.

The agricultural sector currently grapples with low-income levels and a shortage of skilled labor, making it essential to explore

innovative ways to boost productivity while operating within limited resources. Fortunately, advancements in technology, particularly in agricultural technology (aggrotech), offer promising solutions to address these challenges. Research indicates that aggrotech has the potential to enhance productivity, meet rising food demands, and maintain competitiveness in the market.

In recent years, the concepts of smart farming, precision agriculture, and intelligent agriculture have gained widespread recognition. While these terms are often used interchangeably, they all refer to the application of advanced technologies in agriculture to optimize resource utilization and minimize environmental impacts. Smart agriculture is no longer an exclusive strategy for seasoned farmers; it has become a necessary approach for anyone seeking to maximize efficiency and sustainability in farming practices.

With urban migration and an aging population leading to a decline in agricultural labor, there is an urgent need for innovative solutions. Additionally, the intensifying effects of climate change are making growing conditions increasingly unpredictable, while the depletion of natural resources and biodiversity adds to the urgency of the situation. Smart agriculture tools can help mitigate these challenges by reducing environmental constraints and lowering production costs, allowing farmers to operate more sustainably.

These tools encompass a wide range of technologies, including mapping, robotics, geomatics, automation, and data analytics. By integrating these technologies into their practices, farmers can optimize their activities in a sustainable manner. The adoption of smart agriculture represents a transformative shift in the sector, bridging traditional farming methods with modern technological advancements to create an efficient, sustainable, and ecologically-friendly agricultural landscape.

At the core of smart farming is the utilization of information and communication technologies (ICT), which facilitate the automation and intelligence of agricultural production. This technological revolution is not only enhancing agricultural output but is also fostering an era of sustainable farming practices that are essential for meeting the demands of a growing population. Embracing smart agriculture is crucial for ensuring food security and promoting environmental sustainability in the years to come.

The Role of Digital Transformation in Shaping the Future of Agriculture

As agriculture evolves, the integration of wireless communication technologies has become pivotal in enhancing farming practices. Each generation of wireless communication is ushering in a new era of smarter agriculture, allowing farmers to leverage the latest communication tools to propel their operations forward. Smart farming seamlessly integrates information and communication technologies into agricultural machinery, equipment, and sensors. Innovations such as the Internet of Things (IoT) and cloud computing are advancing this integration, incorporating more robots and artificial intelligence (AI) into farming processes. Farmers can now utilize smartphones and tablets to access real-time data on various aspects of their daily operations, significantly improving decision- making.

Agriculture 4.0, considered an evolution of precision farming, represents the application of innovative technologies in the agri-food sector. This new paradigm relies on automated data collection, integration, and analysis directly sourced from the fields via sensors and other technologies. These digital tools support farmers in their daily tasks and strategic planning, fostering collaboration across the entire supply chain. This interconnectedness creates a virtuous cycle that adds value to individual farms and their partners.

The introduction of digital technologies—including IoT, AI, big data analytics, autonomous tractors, and drones—has empowered farms to enhance their economic, environmental, and social sustainability while increasing profitability. In agriculture, AI aims to enable machines to perform complex tasks typically requiring human intelligence. This capability allows machines to take over not only repetitive mechanical tasks but also more nuanced operations that demand human expertise.

However, the AI used in agricultural contexts differs from human intelligence, creating new opportunities for developers to explore various applications across industries—from industrial production to cybersecurity and energy management. To effectively harness AI, it is essential to understand its foundational elements, including reasoning, planning, and problem-solving. Programming languages such as Python, R, Lisp, Java, and Prolog are commonly utilized in developing AI applications.

As a data-centric technology, AI requires substantial computational resources, making it an ideal candidate for edge computing. This technological advancement enhances AI capabilities, addressing challenges associated with AI application use cases. In recent years, the technological boom has led to the development of innovative digital agricultural tools and machines that enable farmers to optimize their land management. Farmers can now monitor soil moisture and nutrient levels, accurately predict weather impacts, manage irrigation more precisely, control greenhouse environments, and automate manual tasks. Research by ONDO Smart Agriculture Solution indicates that digital agriculture can reduce water usage by up to 85%, decrease energy consumption by 50%, boost crop yields by 40%, and lower human error rates by 60% [3]. Consequently, much of the agricultural process is now managed by software, with farmers responding to data-driven insights.

Unlike traditional farming, where farmers made numerous decisions based on their expertise, the rise of digital agriculture has shifted decision-making to data and software. Many actions are now

automated, requiring farmers to monitor technology rather than perform all tasks manually. As a result, knowledge of traditional farming practices is becoming less critical, while proficiency in software and computing is increasingly important. This transition not only enhances profitability but also ensures the long-term viability of farms. Although digital farming is still in its infancy, its potential is already becoming evident.

In Estonia, for instance, nearly all farms utilize some form of smart digital agricultural technology daily. Enhanced digitalization, remote sensing, and information and communication tech-

nologies (ICT) can improve the efficiency, quality, and timeliness of inspections and audits. Today's technologies allow for precise measurements and automation of procedures, reducing the need for outdated Common Agricultural Policy (CAP) regulations. Streamlining these regulations through digital solutions can significantly reduce bureaucratic burdens for both farmers and administrative bodies, ultimately benefiting the economy.

Technological advancements have already introduced robotic harvesting tools that ensure timely crop collection, and as this trend continues, the demand for manual labor in agriculture may decline sharply. Drones are currently employed to monitor extensive tracts of land, and it is anticipated that they will soon operate autonomously, providing farmers with digital reports via email detailing inspections, findings, and actions taken. This evolution could transform farmers from active participants in their operations to more passive observers, although many believe this transition is still years away.

The combination of technology and digital transformation enables farmers to increase efficiency and productivity while adapting to dynamic market demands. However, a critical challenge remains: how to implement digital technologies effectively and manage the data generated on farms. Ironically, despite the growing availability of data, farmers often lack the resources—both in terms of management and labour—to process this information, largely due to economic and market pressures.

To address this, farmers could benefit from tailored guidance and consulting services, as well as Decision Support Systems (DSS) that can alleviate the burden of data processing. It is vital that the agricultural sector participates actively in ongoing discussions about digitalization at both the EU and global levels. The launch of the EU's digital single market strategy includes numerous initiatives that could prove advantageous for agriculture, such as the Digital Skills and Jobs Coalition Initiative.

Addressing these issues with farmers' interests at the forefront is essential, rather than solely from the perspective of the ICT sector or technology companies. The digitalization of agriculture promises to enhance competitiveness, boost farmers' incomes, and attract younger generations to this vital field. With environmental challenges looming, such as water scarcity affecting over 40% of the global rural population, soil erosion from improper management, and greenhouse gas emissions from agricultural practices, the need for sustainable solutions is urgent.

As the global middle class expands alongside population growth, so does the demand for meat relative to grains, legumes, and wheat. Future agricultural operations will increasingly rely on sophisticated technologies—ranging from sensors and devices to advanced machinery and IT systems. Agriculture
4.0 will leverage these advancements to become more profitable, efficient, safe, and environmentally friendly. Rather than applying water, fertilizers, and pesticides uniformly across fields, farmers will adopt more precise approaches, minimizing or eliminating inputs entirely. This will enable cultivation in arid regions while harnessing abundant resources such as sunlight and seawater for food production, paving the way for a sustainable agricultural future.

The agricultural landscape is rapidly evolving, driven by technological advancements and a growing focus on sustainability. Several key trends are emerging that promise to reshape how farming is conducted in the future.

Aerial Imagery and Crop Management
One of the most significant trends is the increased reliance on aerial imagery for crop management. Drones and satellite technology are becoming indispensable tools for farmers, allowing them to observe and assess variations in crop health from above. This aerial perspective enhances decision- making by providing real-time insights into crop conditions, enabling farmers to respond swiftly to any issues.

Enhanced Yield Forecasting
The ability to accurately forecast yields before harvest is another critical development. By utilizing various agricultural methods and technologies, farmers can predict their output more reliably. This foresight not only aids in effective marketing and selling of produce but also helps minimize food waste, ultimately boosting revenue.

Data Integration for Informed Decisions
Data management software is at the forefront of agricultural innovation, allowing growers to harness vast amounts of information for informed decision-making. With real-time data integration, farmers can make timely adjustments to their practices, optimizing operations for better outcomes.

Technological Advancements in Livestock Production
In the livestock sector, advancements in genetics, digital technologies, and nutritional science are making a substantial impact. The integration of sensor and data technologies allows for the early identification of sick animals and targeted improvements in care, significantly enhancing productivity. Additionally, computer vision technology provides objective insights that can be distilled into actionable information.

Precision Agriculture and Management Zones
Precision agriculture is revolutionizing farming by utilizing management zones—areas within fields with similar characteristics. This approach allows for the targeted application of inputs, optimizing resource use and increasing profitability while minimizing environmental impact.

Post-Liberalization Trends
In the post-liberalization era, agriculture is witnessing increased productivity and diversification, alongside a burgeoning horticulture sector. Modern methods are being adopted, export volumes are rising, and the food processing industry is expanding, reflecting the sector's adaptation to changing market demands.

Decision Support Systems for Sustainability

The decisions made by farmers are critical to sustainability and occur within a complex web of interests and values. Agricultural Decision Support Systems (AgriDSS) are poised to play a vital role in fostering sustainable agricultural practices with minimal environmental impact. However, many existing DSS fail to address the real needs of farmers and do not adequately understand their decision-making processes. This gap results in

low acceptance rates among farmers, as these systems are often designed based on what scientists and developers consider necessary, rather than practical agricultural realities.

The future of AgriDSS looks promising as advancements in data collection and storage are driven by increasing technological connectivity and the proliferation of smart devices in the field. Enhanced data integration will improve the accuracy and reliability of these systems, making them more user-friendly. Companies are now offering mobile interfaces that can be accessed in real-time from smartphones and tablets, empowering farmers as the primary users of these transformative technologies.

The Role of Image Processing and Drones

The application of image processing techniques in agriculture enables rapid and remote analysis of various factors. This technology can be used to detect plant diseases, pests, and weeds, monitor crop growth, model irrigation methods, and assess soil properties, among other applications.

Unmanned Aerial Systems (UAS), particularly drones, have gained popularity in agriculture for their versatility and efficiency. Initially recognized for military applications, drones are now integral to meteorological studies and agricultural practices. Their ability to enhance productivity and food security makes them invaluable to farmers.

Drones offer several advantages, including the ability to capture high-resolution images of agricultural fields at a low cost. With tools like RGB, near-infrared (NIR), and thermal sensors, drones can monitor crops and livestock effectively. Their environmental sustainability, affordability compared to larger machinery, and ease of operation contribute to their rising popularity among farmers.

A Smart Future for Agriculture

In summary, smart agricultural methods and tools, including drones, are paving the way for financial success and improved resource management for farmers. The initial use of drones to capture aerial images provided significant value, and today's technology allows farmers to use drones regularly to identify issues such as irrigation leaks, leaf discoloration, and pest infestations. By highlighting problem areas, drones help farmers plan their actions more effectively, leading to better management of their resources and enhanced productivity. As these trends continue to unfold, the future of agriculture looks promising, characterized by sustainability and innovation.

The Future of Agriculture: Embracing Technology for Growth and Sustainability

As the agricultural industry continues to evolve, the integration of advanced technologies is reshaping how farmers operate. Drones are at the forefront of this transformation, with the ability not only to monitor crop health but also to plant seeds in remote areas. This capability significantly reduces equipment and labor costs, potentially generating an economic value estimated between $85 billion and $115 billion by improving yields and cutting expenses.

The Rise of Autonomous Vehicles

Autonomous vehicles are becoming a notable trend in agriculture, allowing various machines— ranging from drones to robots—to operate independently without human intervention. This technology addresses critical challenges, such as global population growth, labor shortages, and shifting consumer preferences. The agricultural equipment market reflects this shift, projected to grow from $168.3 billion in 2022 to $272.36 billion by 2029 [4]. Key factors driving this growth include increased mechanization and rising incomes among farmers, which support the adoption of autonomous tractors, agricultural robots, unmanned vehicles, drones, sensors, and software designed to lower food production costs. Despite the high initial costs associated with agricultural equipment, especially for low-income farmers, solutions like renting these vehicles can help mitigate financial barriers and facilitate access to these technologies.

Agriculture's Evolution and Environmental Impact

Agriculture has been pivotal in shaping human society since its inception approximately 12,000 years ago during the Neolithic Revolution. This transition to farming allowed humans to settle in one place, leading to the development of complex civilizations and explosive population growth. The industrialization of agriculture over the past two centuries has supported an increase from 1 billion to nearly 7.7 billion people. However, this growth has also imposed substantial strain on environmental resources. With an estimated 2 billion additional people expected by 2050, the agricultural sector faces the urgent challenge of enhancing productivity while ensuring sustainability. To meet these demands, it is essential to invest in digital technologies that can boost agricultural productivity. Engaging young people and small farmers in this process is crucial, as the agricultural sector, which employs millions directly and indirectly, has historically lagged in digitalization compared to other industries. While there is still time to catch up, a greater emphasis on investment, innovative ideas, and enhanced participation is necessary.

Opportunities in Digital Marketing and E-Commerce

In the rapidly evolving landscape of digital marketing, competition remains fierce. This underscores the importance of consulting with specialized professionals in digital marketing to navigate the complexities of the field. The growing e-commerce market for food products presents an opportunity to enhance the application of EU legislation regarding the food supply chain in online sales. This collaboration between food control authorities can address the unique challenges posed by the borderless online world. EU food legislation aims to empower consumers to purchase food online with confidence, ensuring a high level of safety. This initiative not only builds consumer trust in e- commerce but also fosters greater awareness and information sharing among stakeholders throughout the food supply chain.

The agricultural sector stands on the brink of a technological revolution that promises to enhance productivity, sustainability, and consumer trust. As farmers adopt innovative tools like drones and autonomous vehicles, they can streamline operations and meet the challenges of a growing global population. By investing in digital technologies and engaging the next generation of agricultural professionals, the industry can secure a prosperous future that balances productivity with environmental stewardship.

Conclusion

The Digital Farmer Project has been initiated to enhance vocational training and establish new methodologies and content for digital internships in the agricultural sector, particularly focusing on innovative technologies. A significant outcome of this initiative is the development of the "Digital Internship in Agriculture" manual. As technology continues to evolve rapidly, its influence spans various aspects of life, from everyday activities to advancements in space exploration. Innovations such as Information and Communication Technologies (ICT), big data, robotics, simulation, blockchain, artificial intelligence, machine learning, the Internet of Things, augmented and virtual reality, and cloud computing are transforming industries globally. These technological advancements are reshaping vocational education and promoting lifelong learning. Vocational education plays a crucial role in equipping individuals with the relevant knowledge, skills, and work habits for specific professions while also enhancing their overall capabilities. In today's dynamic environment, it is vital to develop flexible educational systems that foster critical thinking, support personal development, encourage teamwork, and promote entrepreneurship, all while updating existing frameworks. Within the scope of the Digital Farmer Project, the VET Trainer in Agriculture manual has been created. This resource provides a theoretical foundation, outlines EU policies and recommendations, emphasizes key pedagogical principles, and offers various capacity-building methodologies and tools aimed at improving teaching effectiveness in agriculture. The manual also includes self-learning materials, educational platforms, assessment tools, and references for further knowledge enhancement.

Ultimately, digitalization stands out as one of the most significant global trends affecting individuals, organizations, industries, and society at large. In agriculture, digitalization enhances productivity through precise mechanization, automation, and improved decision-making. The Digital Farmer Project is thus instrumental in strengthening vocational training and creating innovative methodologies and content for digital internships, paving the way for a more efficient and technologically advanced agricultural sector.

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