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The role of digital technologies in achieving sustainable development in the agricultural sector in Algeria

1- Ali BELKACEMI (*) University Amar Telidji – Laghouat, Laboratory: Sociology of Cultural Communication. ali.belkacemi.sh@lagh-univ.dz ORCID: https://orcid.org/0009-0007-7704-4502

2- Djoudi BENGUIT University Amar Telidji – Laghouat, Laboratory: Sociology of Cultural Communication. d.benguit@lagh-univ.dz ORCID: https://orcid.org/0009-0001-7132-3195

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Abstract

Algeria is currently experiencing a digital era marked by technological advancements and the integration of artificial intelligence. This transformation has impacted all aspects of life, including the agricultural sector, which has become dependent on digital technologies at all stages of production. Therefore, the state has been working to prepare the ground and infrastructure to accommodate this technological wave, reduce digital illiteracy among users of these technologies, confront all challenges, and establish a legal framework to protect websites and applications from hacking and piracy, thus avoiding any financial and ethical losses.

Keywords: Digital technologies, sustainable development, agricultural sector, agricultural development, digital agriculture.

دور التقنيات الرقمية في إحداث التنمية المستدامة في القطاع الفلاحي بالجزائر

ملخص

تعيش الجزائر اليوم حقبة رقمية تتسم بالتقدم التكنولوجي واستخدام تقنيات الذكاء الاصطناعي، وقد أحدث هذا التحول تأثيرًا على جميع جوانب الحياة، بما في ذلك القطاع الفلاحي، الذي أصبح يعتمد على التقنيات الرقمية في جميع مراحل الإنتاج، لذلك عملت الدولة على تجهيز الأرضية والبنى التحتية لاستقبال هذا المد التكنولوجي، وتقليص الأمية الرقمية لدى مستخدمي هذه التقنيات، ومجابهة كل التحديات، وتهيئة الأرضية القانونية لحماية المواقع والتطبيقات من الاختراقات وأعمال القرصنة تجنبًا لأي خسائر مادية ومعنوية.

الكلمات المفاتيح: تقنيات رقمية، تنمية مستدامة، قطاع فلاحي، تنمية زراعية، زراعة رقمية.

* **Corresponding author:** Ali BELKACEMI, ali.belkacemi.sh@lagh-univ.dz

1- Introduction:

In the past, humanity has always been at the mercy of nature and climate change. Agricultural production depended entirely on annual rainfall, temperature and humidity variations, and geographical limitations. For example, plants requiring high temperatures could not be grown in cold regions, and plants requiring low temperatures could not be grown in hot regions, Changing climatic conditions controlled the nature of agricultural production, Fruits and vegetables were seasonal, and meat was always of the same basic quality, with no variety.

But with technological advancements and the advent of the digital revolution and artificial intelligence, it's now possible to control this. Agricultural technology is constantly evolving, and there is now growing discussion about robots that pick fruits and vegetables, and multinational companies that are pumping millions of dollars into investing in developing agricultural technologies, This has become known as digital agriculture, which works to provide food varieties in general at all times of the year, regardless of climate change, while preserving the environment by reducing emissions of toxic gases that pollute the atmosphere resulting from traditional agricultural processes.

1-1- Problem: Statement of the Problem:

Digital technologies in the agricultural sector have become increasingly essential due to the growing population, the increase in large fermentation tanks producing dairy, smart tractors that drive themselves in sowing and harvesting operations, highly nutritious processed meat, modern water-saving irrigation systems, not to mention the provision of essential information to farmers, smart applications for pesticide and fertilization use, and other agricultural practices used to improve crop quality and quantity while reducing material costs.

Based on the above, the following research question can be raised:

- How do digital technologies contribute to sustainable development in the agricultural sector in Algeria?

To answer this main question, we have broken it down into a set of sub-questions as follows:

1- What is the concept of **digital agricultural technologies** and **sustainable development**, and the dimensions that combine them in the context of the agricultural sector?

2- What is the reality of adopting and applying modern digital agricultural technologies in the Algerian agricultural sector?

3- How do applications of artificial intelligence and integrated digital technologies contribute to improving agricultural and animal productivity and rationalizing resource consumption in Algeria?

4- What are the most prominent challenges and obstacles facing the process of digitizing the agricultural sector in Algeria, and the proposed strategic prospects to ensure the successful integration of these technologies?

1-2- Importance of the study:

The importance of this study is evident in the following points:

1- Digital technologies have the potential to revolutionize the agricultural sector by making it more efficient, productive, and sustainable.

2- The rapid growth of digital technologies in the agricultural sector provides new ways to exchange information and deliver it to farmers accurately and in a timely manner, accompanying them at all stages of production with proactive agricultural extension campaigns.

3- Striving to achieve self-sufficiency, especially in crops experiencing significant productivity shortages, and exploring ways to address this shortage and thus achieve food security in these commodities.

4- Understanding the nature of the problems facing Algerian farmers, particularly regarding how they deal with new agricultural technologies and the extent to which they benefit from them in increasing production and productivity of agricultural crops.

The importance of **sustainable development** in general, and sustainable development in the agricultural sector in particular, is particularly important for developing countries in maintaining their food security by reducing their dependence on foreign resources and lowering their import bills to maintain their political sovereignty.

1-3- Study Objectives:

The study seeks to achieve a number of objectives, including:

1- Establishing the conceptual and theoretical framework for the study variables.

2- Identifying the reality of digital agriculture in Algeria.

3- Understanding how digital technology contributes to agricultural marketing and e-commerce.

4-Identify the most important challenges and impacts of smart agriculture at the regional and international levels.

5-Highlighting the most important Obstacles to digitizing the agricultural sector in Algeria.

1-4- Literature Review:

1-4-1- Study (Al-Tawus Gharib and Hanan Drid, 2021), entitled: E-agriculture as a strategic direction for the agricultural sector in light of the digital transformation

The study aims to understand the importance of digital transformation and the role of information and communications technology in activating e-agriculture. The study adopted a descriptive approach by highlighting the importance of digital transformation.

The study arrived at several key conclusions, including:

1- E-agriculture requires the adoption of a comprehensive national strategy aimed at enhancing information and communications technology.

The study presented a number of proposals, most notably:

2- The necessity of activating and encouraging research and development in the field of information and communications technology and applying it to the agricultural sector.

1-4-2- Study (Bilal Bashta and Abdelkader Bourmana, 2020), entitled: The Reality of Developing the Agricultural Sector to Shift Towards Economic Diversification in Algeria

This study aims to shed light on Algeria's efforts in the agricultural sector as one of the most important sectors, which is important as a pillar of economic activity in Algeria. The study relied on the descriptive and analytical approach and reached a number of conclusions, the most prominent of which are:

1- The economic reality of the Algerian state imposes the necessity of diversifying sources of economic income in the agricultural sector, compared to its available capabilities. Algeria's capabilities in the agricultural sector are considered to be superior and have a competitive advantage, which makes the Algerian economy based on them.

The study presented a number of recommendations, including:

2- The necessity of adopting a clear, comprehensive, and forward-looking vision for agriculture and rural development in Algeria.

3- Supporting agricultural investment in Algeria by facilitating procedures for obtaining agricultural property and financing private projects for young university graduates by encouraging support for start-ups.

1-4-3- Study (Manish, Abhishek, Sunil, & Dileshwer, 2012), entitled: Uses of Information and Communication Technology in Agriculture

This study aimed to shed light on the issues underlying ICT and the obstacles preventing its optimal use for agricultural development.

The study reached a number of conclusions, including:

1- ICT is intended for communities, not just individuals. This requires a more holistic view of communities to identify optimal solutions, empower political leaders to implement them, and ensure appropriate content. This can only be achieved by making rural infrastructure an integral part of all national planning and infrastructure programs, striving to eradicate digital literacy, and the need for public-private partnerships to reduce the lack of funding and resources for investment in physical and human capital, The government bears the responsibility for adopting ICT in agriculture.

2- The study emphasized that e-agriculture is a major contributor to social and economic growth and development, ensuring rural sustainability, social issues, training, research, and political issues.

1-4-4- Study (Peter & Moses, July 2013): Current Status of E-Agriculture and Global Trends: A Survey Conducted in Trans Nzoia County, Kenya

This study aimed to ascertain farmers' awareness, usage, and perceptions of e-agriculture in Trans Nzoia County, Kenya. The study relied on quantitative survey techniques to collect data from farmers in the county on awareness, perception, and use of various e-agriculture technologies, such as smart farming and e-commerce.

The study reached a number of findings, including:

1- Most farmers in the county were familiar with e-agriculture practices.

2- Mobile phone costs should be reduced to enable the majority of farmers to access current information about agribusiness within the county.

Among the most important recommendations of the study:

1- The government should educate farmers on the best ways to use information and communications technology to conduct agribusiness.

2- The results of this study provide a practical framework for various stakeholders in the agricultural sector in the county to establish an e-agriculture platform to facilitate the marketing of agricultural products.

1-5- Study Methodology:

The linguistic definition of method is as stated in Lisan al-Arab: "Naḥj (path): 'A path clear and obvious' (tareeq naḥ)': 'Manhaj (method): 'He made the path clear' (manhaj), and minhaj (method) is like manhaj (method)." In the Qur'an, the Qur'an states: "To each among you We have prescribed a law and a method" (minhaj) (Quran, 5:48), Minhaj (method) is a clear path, and naḥj (method) means "He made clear and evident" (Ibn Manzur, n.d.).

Technically, it is a method by which a person arrives at a demonstrative truth or scientific knowledge (Hanafi, 2000: p. 17).

In analyzing this study, we relied on the descriptive approach, highlighting the role of digital technologies in influencing the nature of agricultural practice by farmers. This aims to advance the agricultural sector and achieve sustainable development, which in turn impacts the country's economic and political landscape.

1-6- Study sample and study tools:

1-6-1- Study sample:

Because the study relied on the descriptive analytical approach to highlight the role of digital technologies and their impact on agricultural practice and sustainable development, it does not use a study sample in the procedural sense recognized in field research.

First: Type of study: Analysis of the reality of the phenomenon (digital technologies and sustainable development in the agricultural sector in Algeria) based on theoretical literature, previous studies, documented experiences and initiatives, such as the "Saqay" project, the Farm AI initiative, and the efforts of the Sawakri Group.

Second: What replaces the sample: is the theoretical and conceptual framework, and documented real-world studies and initiatives that have been analyzed and explained (such as examples of the use of artificial intelligence and drones).

1-6-2- Study tools:

Since the adopted approach is the descriptive analytical approach, the main study tool used is:

Content and document analysis.

First: Tool Description: This tool is based on the collection, review and analysis of the theoretical framework, concepts (such as digital agriculture, sustainable development), documented governmental or private efforts and initiatives (technical projects in the agricultural field in Algeria), as well as a critical analysis of previous relevant studies.

Second: Reason for use: This tool is best suited to meet the objectives of the study, especially:

1- Establishing the conceptual and theoretical framework.

2- Defining the reality of digital agriculture in Algeria.

3- Highlighting the role of artificial intelligence and its applications in the field.

2- Conceptual and theoretical framework of the study:

2-1-The Concept of Digital Agricultural Technologies:

This study uses the term "digital technologies", which refers to the design, development, and use of smart agriculture for a wide range of technologies, including, but not limited to, Global Positioning System (GPS) technology (Brini, 2023), the use of drones and autonomous vehicles, remote sensing devices, robotics, digital communication tools (Batat, n.d.: pp. 97–98), differential chains (Blockchains), and computer-aided decision-making in both open-field and controlled agriculture, such as greenhouses and hydroponic farms, and smartphone applications that facilitate regular remote irrigation, allowing for rational water consumption in times of drought and scarcity of rain, as well as diagnosing plant diseases and identifying effective treatments for them, avoiding the systematic and random use of pesticides.

Many agricultural institutes, organizations, and universities around the world, including in North Africa, are conducting studies under various names such as smart agriculture, digital agriculture, and precision agriculture. These refer to the use of advanced technology and artificial intelligence to improve agricultural processes and production, Smart agricultural systems collect and analyze data from a wide range of sources (Masoud, 2011: p. 310), such as weather conditions, soil moisture, and plant growth.

The goal of using smart agriculture is to provide farmers with data, insights, and recommendations at the right time.

Digital agriculture aims to enhance the efficiency and sustainability of agriculture by reducing environmental impacts and increasing quality (Waman & Rashid, 2017: p. 23).

2-2- The Concept of Sustainable Development:

The term sustainable development emerged and gained significant attention from the World Commission on Environment and Development in 1987, when the definition of sustainable development was formulated as: development that meets the needs of the present without compromising the ability of future generations to meet their needs.

Many countries around the world agreed, at the Earth Summit in 1992, to define sustainable development as: development that reconciles environmental, economic, and social development, creating a viable cycle between these three poles, It is economically effective, socially just, and environmentally feasible, It is development that respects natural resources and ecosystems, supports life on Earth, and ensures economic sustainability without neglecting the social goal of combating poverty, unemployment, and inequality, and the pursuit of justice (Satori, 2016: pp. 299–311).

Sustainable agricultural development is also defined as: a set of measures and policies that structure the agricultural sector in a way that leads to the optimal use of agricultural resources, achieving increased production and productivity, with the aim of raising the national income

and the standard of living for individuals across generations without harming the environment (Muhammad, 2003: p. 4).

2-3- Technology Acceptance Model (TAM):

This model focuses on the influencing factors that influence the implementation of new technology. It can be incorporated to understand the factors that influence the acceptance and use of digital technologies as a tool for achieving sustainable development in the agricultural sector, this model, commonly used in the social sciences, explores the acceptance and use of new e-services.

It is based on the belief that users' perceptions of the usefulness and ease of use of technology influence their attitudes and intentions to use it.

Among the studies conducted in the Arab world that addressed the process of diffusion and use of digital information technology based on the technology acceptance model are the studies of (Rose & Straub, 1998, Bouattour et El Louadi) (Gefen & Straub, 1997).

By adopting these theoretical frameworks, we can better understand and enhance the relationship between digital technologies and achieving sustainable development, and guide research and analysis strategies toward deeper understanding and practical applications.

3- The reality of sustainable digital agriculture in Algeria:

Smart agriculture in Algeria is witnessing remarkable development. We live in an era of modern technologies, artificial intelligence, and digital transformation in the Algerian agricultural sector.

We will review the latest digital technologies used in farm management using artificial intelligence and remote sensing applications for agricultural crops, and how to improve the productivity of these crops through information systems and digital agriculture technologies.

3-1- Technical Agriculture in Algeria:

With the increasing demand for food worldwide and the ongoing debate over rising consumer prices, Algeria has moved towards adopting smart agriculture, which relies on modern technologies supported by artificial intelligence systems.

This requires giving great importance to specialized scientific research and encouraging young people to join agricultural programs. This approach ensures the expansion of agricultural investments and the increase and improvement of production efficiency.

One promising experiment in precision agriculture is the work of Nasser Bouziani and Mourad Bouzit, two Algerian researchers in robotics and physics residing abroad. Their "Saqay" project involves autonomous, solar-powered robots used for automatic irrigation and deep root fertilization, requiring virtually no human intervention, this delivers sufficient water and fertilizer to each plant at the right time.

These machines are equipped with precise sensors that can detect soil moisture, tree health, and signs of diseased plants. They are also operated by an artificial intelligence-based monitoring and operation system that continuously provides the necessary information and displays to the farmer all the details of his soil and plants.

This innovative project, the researcher adds, has impressed NASA and several Chinese research centers, which have offered to contribute to its development, It is currently in the research and development phase. The researchers believe that adopting a system like "Saqay" instead of drip irrigation and surface fertilization would reduce premature tree mortality from 45% to 15%, In addition to being environmentally friendly, deep fertilization also saves water, as a single robot can irrigate and fertilize approximately 120 hectares, depending on tree density and the location of the water source, according to the explanations provided by the inventors.

Precision agriculture is not limited to irrigation, fertilization, and plant disease control; it extends to the development of complete agricultural systems that monitor all stages of the agricultural process, from plowing to harvest.

A promising project in this regard is the modern farms that the Sawakri Group is preparing to launch soon in Algeria, together with a Turkish partner, the company has been developing a comprehensive automation system equipped with artificial intelligence to control all steps of cherry tomato production for export, with the aim of controlling farm yields and product quality. The AI-based system intervenes in crop management, where agriculture requires a great deal of precision to ensure maximum productivity and minimize risks.

Another promising experience is that of Farm AI, an Algerian startup ranked second in the 2023 Tech 4 Good global competition in China, for developing a system to identify plant diseases using drones (Nour El-Din & Mounia, 2015).

Algeria is one of the leading countries in North Africa in adopting modern technologies in agriculture, despite climatic challenges and the growing need to improve agricultural productivity, these technologies include:

1- The use of artificial intelligence in crop management at all stages of production.

2- The application of remote sensing technologies for continuous crop monitoring.

3- The use of geographic information systems to improve agricultural planning.

4- The use of robots and drones in agricultural operations (Al-Zoubi, 2018).

These measures offer integrated solutions that combine these technologies to provide a comprehensive and effective vision for Algerian farmers.

3-2- The role of artificial intelligence applications in improving agricultural productivity in Algeria:

Despite its high rankings according to international bodies, the government continues to strive to increase food production. Now, however, it is through smart agriculture, which takes into account the rapid development of technology by deploying renewable energy in irrigation, using solar energy for pumping instead of oil-powered engines, and relying on the university as an important partner in promoting innovation and research, This explains the authorities' adoption of modern technology and a new concept of agriculture that enables complete control of environmental factors and the efficient use of resources. In addition, two national schools of agriculture have been established to help link agricultural projects with modern scientific research.

An agricultural food hub and a seed bank have been established, along with the creation of a gene bank. Furthermore, model farms have been transformed into nurseries for livestock and plants as a vehicle for research and development in the agricultural sector.

The most important measures taken to improve agricultural and livestock production in Algeria can be summarized as follows:

First: The improvement of Automated irrigation Systems

Artificial intelligence algorithms enable automatic crop management. When combined with Internet of Things (IoT) sensors that monitor soil moisture levels and weather conditions, the algorithms determine the amount of water allocated to crops in real time, The self-powered crop irrigation system is designed to conserve water while promoting sustainable agriculture and farming practices, Artificial intelligence in smart greenhouses improves plant growth by automatically adjusting temperature, humidity, and light levels based on real-time data.

Second: Detection of leaks and damage in irrigation systems

AI plays a pivotal role in detecting leaks in irrigation systems, By analyzing data, algorithms can identify patterns and anomalies that indicate potential leaks. Machine learning (ML) models can be trained to recognize specific signs of leaks, such as changes in water flow or pressure. Real-time monitoring and analysis enable early detection, preventing water waste and potential crop damage, AI also integrates weather data with crop water needs to identify areas that consume large amounts of water, By automating leak detection and sending alerts, AI technology improves water use efficiency, helping farmers conserve their resources.

Third: Crop and soil Monitoring

Poor soil nutrient selection can seriously impact crop health and growth. Identifying these nutrients and determining their impact on crop yields using AI enables farmers to easily make necessary adjustments. Despite the limitations of human observation, computer vision models can monitor soil conditions to gather the precise data needed to combat crop diseases, This plant data is then used to determine crop health, predict yields, and identify any specific problems. Plants power AI systems through sensors that detect their growing conditions, triggering automated adjustments to the environment.

In practice, AI application in agriculture have demonstrated the ability to precisely monitor the growth stages of wheat and the ripening of tomatoes (Chenafi, 2020: p. 49) with a speed and accuracy unmatched by humans.

Fourth: Detecting Diseases and Pests

In addition to detecting soil quality and crop growth, computer vision can detect the presence of pests or diseases. This is done using artificial intelligence in agricultural projects to scan images to detect mold, rot, insects, or other threats to crop health. In conjunction with warning systems, this helps farmers move quickly to eliminate pests or isolate crops to prevent the spread of diseases. Artificial intelligence technology has been used in agriculture to detect black rot in apples with over 90% accuracy, It can also identify insects such as flies, bees, moths, and others with equal accuracy, However, researchers first needed to collect images of these insects to obtain the necessary training dataset size to train the algorithm.

Fifth: Livestock Health Monitoring

Integrating AI into livestock management is not just a technological advancement; it's a necessity for a robust and productive future, AI-based solutions are poised to increase yields, enhance animal welfare, and improve efficiency, ensuring the future of this vital industry.

1- Aerial Management: One of the most prominent applications is drones equipped with computer vision technology. Their importance lies in their ability to cover vast, remote areas. Drones can immediately alert herd managers when an animal is missing, enhancing herd safety and security.

2- Health and Welfare Monitoring: AI models play a pivotal role in monitoring livestock health and identifying signs of illness or injury. These models are trained to detect abnormal movements, which are often the initial indicators of health problems in animals, This early detection enables herd managers to intervene quickly, mitigating the spread of disease and improving overall animal welfare.

3- Feeding Rates: AI models are also used to track feeding rates by determining when an animal bends down to eat. This technology enables herd managers to closely monitor each animal's health by assessing its feeding patterns, Low feeding rates may be an indicator of poor health, enabling early intervention (Chenafi, 2020: p. 53).

Sixth: Application of Smart Pesticides

Farmers are well aware that pesticide that pesticide management remains an area in need of substantial improvement. Unfortunately, both manual and automated spraying operations suffer from significant limitations, Manual pesticide spraying offers greater precision in targeting specific areas, although it can be slow and difficult. Automated pesticide spraying is faster and less expensive, but it often lacks precision, leading to environmental pollution.

AI-powered drones offer the best advantages of each approach while avoiding their drawbacks; Drones use computer vision to determine the amount of pesticide to spray in each area. Although this technology is still in its infancy, it is rapidly evolving and becoming more accurate.

Seventh: Yield Mapping and Predictive Analytics

Yield mapping uses machine learning algorithms to analyze massive datasets in real time. This helps farmers understand the patterns and characteristics of their crops, enabling them to better plan, By combining technologies such as 3D mapping, sensor data, and drones, farmers

can predict soil yields for specific crops. Data is collected across multiple drone flights, enabling more accurate analysis using algorithms. These methods allow for accurate predictions of future yields for specific crops, helping farmers know when and where to plant seeds and how to allocate resources to achieve the best return on investment.

Eighth: Automated Weeding and Harvesting

As with pest and disease detection using computer vision, it can also be used to detect weeds and invasive plant species. When combined with machine learning, computer vision analyzes the size, shape, and color of leaves to distinguish weeds from crops, These solutions can be used to program robots that perform Robotic Process Automation (RPA) tasks, such as automated weeding. In fact, these robots have already been used effectively, and with the increasing accessibility of these technologies, intelligent robots could perform both weeding and entire crop harvesting.

Ninth: Post-Harvestet Product Sorting

Artificial intelligence not only helps identify potential problems with crops as they grow, but also plays a role after the crop is harvested. Most sorting operations are typically performed manually, but AI enables more accurate crop sorting. Computer vision can detect pests and diseases in harvested crops. Furthermore, it can classify produce based on its shape, size, and color. This enables farmers to quickly separate produce into categories, for example, to sell to different customers at different prices, In comparison, traditional manual sorting methods can be labor-intensive. By analyzing big data, AI plays a pivotal role in developing smart agriculture in Algeria related to crops, soil, and climate. AI can provide valuable insights to farmers.

3-3- Contribution of digital technology to agricultural marketing and e-commerce:

E-commerce refers to conducting business over the Internet, i.e., exchanging and maintaining business information and conducting business transactions over international communications networks, E-commerce is the platform through which business transactions, namely the buying and selling of goods, are conducted over the Internet, The size of the e-market is determined by the number of Internet and smart device users (Joseph, 2005).

Digital marketing involves understanding the market and identifying consumer needs and desires through market research, marketing information management, and data on buyers and the market. This data is provided to farmers to understand the national and international market needs for agricultural crops, so that their crop cultivation is not random and routine, but rather planned and systematic. This marketing process extends to designing a marketing strategy based on customer needs and product development and design, To achieve consumer confidence in agricultural products, websites must contain all data related to the organization marketing agricultural crops, among the advantages of global e-marketing include the fact that it is not affected by geographical boundaries, as customers can shop from anywhere through the establishment's dedicated website using a computer, In addition, there is an element of excitement in promoting the products offered by establishments, and the absence of paper documents among those involved in e-marketing, which reduces the effort and time required for buying and selling (Al-Adili, 2015).

3-4- Smart Agriculture and Modern Technologies:

The Future of Sustainable Agriculture in Algeria:

Precision agriculture and modern technologies represent the future of the agricultural sector in Algeria, These technologies include: The use of robots in all stages of agricultural production to save time and effort and reduce high financial costs; the implementation of smart irrigation systems to rationalize water consumption, especially in areas with hot and dry climates; the use of drones to monitor agricultural crops; and the application of vertical farming techniques in urban areas, These technologies are being integrated into the search for solutions to provide a comprehensive approach to smart agriculture.

3-4-1- Geographic Information Systems for Agricultural Planning and Management:

Geographic Information Systems play a vital role in the development of smart agriculture in Algeria, These systems help in:

1- Identifying the best geographical locations for growing specific crops based on soil and climate characteristics.

2- Improving the management of natural resources to ensure the rational and efficient use of these resources.

3- Strategic planning to expand the use of unused agricultural areas and reclaim barren lands (Manish et al., 2012).

4- Analyzing the impact of climate change on seasonal agriculture and taking the necessary measures to protect agricultural crops.

5- Remote monitoring of plant health using smart technologies, This technology enables monitoring of plant health through:

a- Early detection of diseases and environmental pests that can reduce crop yield and quality.

b- Identifying areas of water stress in crops so that farmers can grow crops according to the specificity of the area.

c- Evaluating the effectiveness of fertilizers and pesticides and the extent to which they achieve their desired objectives.

d- Preparing periodic reports on the status of agricultural crops to intervene in a timely manner to protect them from all threats.

e- Agricultural data analysis is essential for achieving sustainable agriculture in Algeria, through:

1- Collecting and analyzing data from multiple, reliable sources.

2- Providing practical and achievable insights for farmers.

3- Supporting decision-making based on data and statistics from known sources.

4- Improving the efficient use of various natural, human, and technical resources.

This strategy helps achieve a balance between increased productivity and the conservation of natural resources.

3-4-2- Sustainable Agriculture and Modern Technologies for Achieving Sustainable Agricultural Development in Algeria:

The value of the agricultural market in Algeria was estimated at $4.64 billion in 2023 and is expected to reach $5.82 billion by 2028, representing an annual growth rate of 4.65 percent, according to the American website "Mordor Intelligence" (The website name "Murder Intelligence" was corrected). The website explained that the agricultural sector has recorded steady growth despite fluctuations in demand, noting that Algeria is technically capable of producing 30 million tons of grain annually and exporting 21 million tons of it to neighboring countries.

FAO data revealed that the value of vegetable production in Algeria in 2023 reached $23 billion, placing second in the Arab world after Egypt, ($27 billion), and ahead of Saudi Arabia, ($17 billion). According to the Ministry of Agriculture and Rural Development, the agricultural sector contributes 14.7 percent of the gross domestic product and employs more than a quarter of the active labor force, equivalent to 2.7 million workers, The ministry highlighted that the value of Algerian agricultural production in 2022 was estimated at $35 billion, with local production covering 75 percent of national food needs.

4- Indicators of Modern Technology integration in Algeria's Agricultural sector: Achievements and International Experiences

4-1- Current applications of modern technologies (digitization) in Agriculture:

Algeria is working to modernize its agricultural sector by integrating modern technologies. These efforts are evident in the following areas:

1- Precision and smart agriculture: using positioning systems (GPS), drones to monitor crops, smart irrigation systems, and soil sensors to improve nutrient and water management (Belhat, 2022).
2- Digital and administrative transformation: Digitization of the National Agricultural Register, which has been completed at the level of all states (according to recent reports). This aims to provide accurate and transparent databases (Louar et al., 2025: p. 115).
3- Decision support and monitoring: Using Geographic Information Systems (GIS) to plan land use, big data to analyze agricultural trends, and satellite images to monitor crop health (specialized platforms such as Farmonaut) (Sayari & Jebli, 2023: pp. 27–48).
4- Value chains and marketing: developing digital platforms for marketing agricultural products (Qanfoud, 2023).
5- Animal production: Start using electronic chips to track the herd in the livestock breeding division to increase productivity and reduce losses.
6- Infrastructure: Connecting increasing numbers of agricultural investors to the electricity grid, with more than 66,000 investors connected to support intensive production. (The phrase "female agricultural investors" was changed to "agricultural investors" for better context, assuming the original text meant investors generally.)
4-2- Recent statistics and indicators (2022-2025): Recent indicators show the increasing role of the agricultural sector as part of the national economy, which increases the need to modernize it with technologies.

Table (1): indicates the increasing role of the agricultural sector as part of the national economy and the role of digital technologies in sustainable development.

Indicator	Value and time signal	Source / significance of information
Value of agricultural production	About $37 billion in 2024.	(2024 Estimate) - This represents significant growth compared to $35 billion in 2022, underscoring the dynamism in the sector.
Sector contribution to GDP	It exceeded 15% in 2024.	(2024 estimates) - The sector is thus the second largest contributor to GDP after the hydrocarbons sector.
Benefit from agricultural support	More than 4,000 files have been placed on the digital platform to benefit from support and incentives (recent data).	It indicates the actual beginning of digitizing services and simplifying procedures for farmers.
Achieving self-sufficiency	Achieving durum wheat production that covers about 80% of national needs (2024 forecasts), with full sufficiency expected in 2025.	It refers to the role of intensification and modern agriculture in raising the yield of strategic crops.
Providing water resources (irrigation)	Drilling 1,600 wells during the current agricultural season (with financial support of up to 60%).	There is a trend towards supporting farmers to adopt irrigation solutions, which are an essential part of smart agriculture to rationalize water.
General Census of Agriculture	The year 2024 witnessed the launch of the third general agricultural census, with the aim of establishing	(Official Statement - May 2024) - Confirms the state's commitment to providing

	an updated agricultural statistical system using advanced monitoring technology.	accurate data as a basis for digitization and intelligent planning.

Source: Prepared by researchers using a report from the Ministry of Agriculture and Rural Development (2024), Report on Evaluating the Performance of the Agricultural Sector and Economic Forecasts (2024), Al-Jamhouria, Algerian People's Democratic Republic, Algeria. pp. 8-15.

The reality of integrating modern technologies into the agricultural sector in Algeria is undergoing a significant strategic transformation phase led by the state, This is primarily focused on administrative digitalization (such as the agricultural registry) and expanding the use of smart agriculture to boost productivity in strategic crops. Recent figures indicate a substantial increase in production value and its contribution to GDP. However, the greatest challenge remains the practical and widespread application of these technologies at the peasant level, this requires sustained investment in infrastructure, training, and the enactment of a transparent and supportive legal and regulatory framework for agricultural innovation.

4-3- Pioneering International Experiences in Integrating Digital Technologies into the Agricultural Sector and Achieving Sustainable Development:

First: The Dutch Experience: A Pioneer in High-Tech Agriculture NL

The Netherlands, despite its small size, is the world's second-largest exporter of agricultural products and is the leading global model for implementing high-tech agriculture, Key technologies and statistics include:

1- Smart Greenhouses: Offer complete climate control, irrigation, and LED lighting to increase year-round production. This reduces the need for fertilizers and pesticides, cutting water use for some crops by up to 90% compared to traditional methods.

2- Vertical Farming: Involves using multiple layers of cultivation within cities, which reduces land consumption and brings production closer to the consumer. This increases productivity per unit area by 10 to 20 times compared to open fields.

3- Robotics and Precision Mechanization: Utilizes robots for tasks like harvesting vegetables and fruits and monitoring individual plants, This improves quality and reduces crop and labor waste, The Netherlands is one of the highest users of robots in dairy production and animal feeding, which helps reduce the carbon footprint of farms (Britts, 2018).

Second: United States of America: Large-Scale Precision Agriculture US

The American experience focuses on implementing advanced technologies, particularly precision agriculture, on large farms to enhance both operational and environmental efficiency. The most significant integrated technologies and statistics are:

1- Variable Rate Technology (VRT) / Precision Farming: Uses GPS to map fields and apply variable amounts of seeds, fertilizers, and pesticides only where needed. This can reduce fertilizer use by 10% to 15% and mitigate the environmental pollution from nutrient runoff.

2- Drones and Satellites: Provide accurate aerial monitoring of fields to detect pests, diseases, and nutrient deficiencies in the early stages, The precision agriculture market is growing significantly, with these technologies used across millions of hectares of major agricultural land.

3- Autonomous Mechanization: Employs self-driving, GPS-guided tractors and equipment to operate with high accuracy, this reduces human error, improves the efficiency of field operations, and lowers fuel consumption per unit of production. (FAO/MDPI, 2021: pp. 3223–3245)

Successful international experiences demonstrate that integrating modern technologies into the agricultural sector is not merely an option for increasing production, but a necessity for achieving sustainable development across three main dimensions:

1- Environmental Efficiency: Rationalizing water consumption (Netherlands) and reducing the use of chemicals (United States and Netherlands).

2- Economic Efficiency: Increasing productivity per unit area (Netherlands) and reducing operational costs (United States).
3- Social Efficiency: Supporting food security, stabilizing supply chains, and addressing challenges like labor shortages and an aging workforce. (Gamal & Harishi, 2023: pp. 101–125)

For Algeria, these experiences can serve as a reference model for adopting advanced drip irrigation to combat drought and developing high-tech agriculture in the interior and desert regions, with a focus on digitalization aimed at supporting farmers' decision-making.

5- Challenges of Sustainable Agriculture in Algeria and the Regional/International Impact of Digital Technologies:

5-1- Obstacles to the Digitalization of Agricultural Production:

First: Legislative framework: Implementing new agricultural innovations and creating the digital database infrastructure requires a legal framework for regulation and protection. Some technologies also require a state license for their use (Beksultanova et al., 2023).
Second: Costs of Digital Technology Implemention: The high cost of developing the necessary infrastructure for effective digital technology adoption significantly impacts middle- and low-income agricultural producers, especially in rural areas (Wang et al., 2024).
Third: Digital Technology Infrastructure: Adequate infrastructure is essential for implementing digital technologies in agricultural projects (Alt et al., 2021). This includes the costs of installing solar energy poles, internet cables, and automated systems like milking machines.
Fourth: Digital Illiteracy: Most farmers lack experience in using the internet and smart technologies for crop management during production stages and do not fully benefit from them in the marketing process. (Ahmed, 2022)
Fifth: Digital Data Security: The risk of hacking digital data can cause significant losses for organizations due to weak digital programs, networks, and applications, This is a major concern during production and e-marketing processes (Daoud, 2009: pp. 53–54).

5-2- Environmental and Climate Challenges for Sustainable Agriculture and Digital Technologies climate:

Sustainable agriculture and modern technologies play a crucial role in addressing environmental and climate challenges by contributing to:
1- Rationalizing water use, particularly through the adoption of pivot irrigation techniques.
2- Reducing the use of chemical pesticides and fertilizers to mitigate their risks to human health and the environment.
3- Enhancing biodiversity on farms (Alt et al., 2021: pp. 12–20).
4- Supporting organic farming practices.

From the above, we conclude that technology can play a key role in achieving a balance between productivity and sustainability.
Despite significant progress, the agricultural sector in Algeria faces several challenges:
1- The need to train farmers in new technologies to reduce digital illiteracy rates.
2- Improving digital infrastructure in rural areas.
3- Addressing the effects of climate change on agriculture.
4- Increasing investment in agricultural research and development (R&D).

5-3- The Regional and International Impact of Agricultural Digital Technologies:

This impact includes:
1- Enhancing food security in the North African region.
2- Increasing the competitiveness of Algerian agricultural products in global markets.
3- Sharing expertise and technologies with neighboring countries.
4- Contributing to global efforts to combat climate change (Onyeha, 2020).

Conclusion:

Through previous studies on the role of digital technologies in achieving sustainable development in Algeria's agricultural sector, and an analysis of their results, we have identified the following:

1- Digital technologies, specifically GPS and Geographic Information Systems (GIS), enable the efficient identification of green spaces and areas of agricultural pest infestation, while these technologies are in use, the agricultural and industrial community still needs further education on their application.

2- Agricultural production efficiency increases by reducing costs and adopting technology-based farm management for irrigation and fertilization, as well as determining harvest seasons in record time, This achieves technical efficiency and increases long-term profits.

3- Obstacles to implementing digital technologies in agricultural facilities, such as the lack of adequate infrastructure and digital illiteracy, are evident, this leads to the inefficient use of economic resources, such as irrigation water and financial capital.

4- There is a lack of government support in developing clear, long-term strategies for integrating digital technology into agricultural production and e-marketing, Furthermore, the community, particularly in rural areas, lacks sufficient knowledge to embrace these technologies for sustainable development.

5- Sensors and weather devices simplify the monitoring of agricultural areas for humidity and temperature, thereby reducing the risks of spoilage in stored crops.

6- The e-market has expanded and is easily accessible via mobile devices, E-contracts, often secured by technologies like Blockchain, are easily conducted, reducing human intervention in product promotion and marketing.

7- Governments need to enact legal legislation to regulate the use of technology in agricultural production and e-marketing, ensuring cybersecurity for online users, secure online payments, and digital data security.

8- There is a need for the infrastructure necessary to effectively implement legal legislation that protects digital data security and holds violators accountable.

Proposals and Recommendations:

In light of the conclusions, the following set of recommendations can be drawn to achieve and enhance sustainable development and e-marketing through digital technologies in agricultural production:

1- Develop a long-term strategy to integrate digital technologies into agricultural production and e-marketing, which are crucial pillars for achieving sustainable development and economic growth.

2- Implement specific legal legislation for the application and use of digital technologies to help protect digital data and safeguard consumers and marketers, especially in financial transactions.

3- Develop human capital, particularly among agricultural workers, through training on the application of digital technologies in the agricultural sector and in e-marketing.

4- Develop the infrastructure for implementing digital technologies in agricultural production. This includes establishing sites for solar energy generation, digitizing production processes, marketing agricultural crops, and protecting the agricultural facilities' databases.

5- Further develop human capital working in agricultural production to provide a suitable technical environment, especially in rural areas reliant on crop and livestock production projects.

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