Digital Agriculture as a Strategic Option for Achieving Food Security in Algeria: an Analytical Approach between Potential and Challenges

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Abstract:
This research aims to analyze the role of digital agriculture in enhancing food security in Algeria, in light of the increasing challenges associated with the scarcity of natural resources, climate change, and geopolitical fluctuations affecting global food markets. The study adopted a descriptive analytical approach based on a literature review and an analysis of reports from international organizations such as the Food and Agriculture Organization (FAO) and the World Bank. The results showed that Algeria still relies heavily on importing grains, oils, and sugar, making its food security fragile and vulnerable to external fluctuations. Accordingly, the research concluded that achieving food security in Algeria through digitalization requires strong political will, sustainable investments, and the modernization of digital infrastructure and legal frameworks, in addition to strengthening agricultural scientific research.
Keywords: ; Food security; Digital agriculture; Digitalization; Sustainable development.
Jel Classification Codes: Q18, O33, Q16, Q25.

1. INTRODUCTION

Global food systems are undergoing profound transformations amidst growing challenges related to demographic growth, climate change, geopolitical unrest, and rising commodity prices. These challenges have directly affected countries' ability to ensure adequate and secure food supplies, making food security a top priority on national and international agendas. In this context, digitalization has emerged as one of the most effective solutions for developing productive sectors, particularly agriculture, by integrating modern technologies such as artificial intelligence, big data, the Internet of Things, and drones into agricultural value chains.

Research Problem

Despite its natural and human potential, Algeria remains heavily dependent on imported grains, oils, and sugar to meet its consumer needs. This situation exposes it to fluctuations in global markets and external crises, threatening its economic and social stability. Hence, the main problem is: To what extent can digital agriculture effectively contribute to enhancing food security in Algeria?

Research Objectives

• To analyze the concept of food security and it's theoretical and applied dimensions.
• To study the reality of food security in Algeria and identify existing challenges.
• Highlighting the role of digital agriculture as a mechanism for enhancing productivity and reducing waste.
• Reviewing international and Arab experiences to benefit from them in the Algerian context.
• Proposing practical recommendations for decision-makers to enhance food security through digitalization.

Importance of the Research

The importance of this research is highlighted by its relevance and practical dimensions. On the one hand, it addresses the strategic issue of food security, which is one of the pillars of social and political stability. On the other hand, it contributes to enriching the literature on digital agriculture as an innovative development option in Algeria and the Arab world, while providing a practical framework that can help shape future agricultural policies.

Methodology

The research relied on a descriptive analytical approach, based on:
• A review of the literature and previous studies related to food security and digital agriculture.
• An analysis of reports by international institutions such as the Food and Agriculture Organization (FAO), the World Bank, and the Organization for Economic Co-operation and Development (OECD).
• A study of international and Arab cases to highlight best practices.
• Integrating recent data and statistics to support the analysis with quantitative data.

2. The Theoretical Framework of Food Security

The concept of food security represents one of the most important and pivotal concepts in contemporary economic, social, and political studies. Historically, this concept has evolved from a focus on food availability to a focus on quality, food safety, environmental sustainability, and equity in distribution.

2.1 Definitions of Food Security

The Food and Agriculture Organization (FAO) defines food security as "the situation in which all people, at all times, have access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life." (FAO, Declaration of the World Summit on Food Security, 2009, p. 1) This definition highlights four interrelated dimensions:

• Availability: Relates to the quantity of food produced domestically or imported.
• Accessibility: Refers to individuals' ability to obtain food economically and geographically.
• Utilization: Reflects how food is used to achieve proper nutrition.
• Stability: Refers to the continued availability and accessibility of food over time.

2.2 Schools of Thought on Food Security

• The Self-Sufficiency School: This school believes that a country must achieve sufficient domestic production to avoid external dependence. This approach became prominent in developing countries during the 1970s.
• The Open Trade School: This school emphasizes the importance of international trade as a mechanism for compensating for food deficits, arguing that importing food may be less expensive than producing it locally.
• The Modern Food Systems Approach: This approach combines the two previous dimensions while incorporating new elements such as environmental sustainability, climate change, and food safety. (FAO, The State of Food Security and Nutrition in the World, 2018, p. 23)

2.3 Indicators for Measuring Food Security

International organizations have adopted several indicators, the most prominent of which are: (EIU, 2022, p. 5)

• The Self-Sufficiency Ratio (SSR).
• The Prevalence of Undernourishment (PUM).
• The Economist Intelligence Unit's Global Food Security Index (GFSI).

2.4 Theoretical Challenges

Among the most prominent challenges facing theoretical studies of food security are: (UN, 2019, p. 7)

• Climate change: which affects agricultural productivity, especially in environmentally fragile areas.
• Demographic growth: The world's population is expected to reach 9.7 billion by 2050, increasing pressure on food resources.
• Limited natural resources: especially arable water in regions such as North Africa.

2.5 Digital Agriculture as a Part of Modern Theory

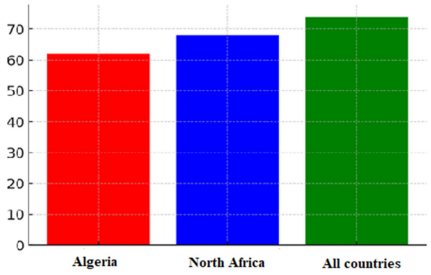
Digitalization has become a complementary element to the theoretical debate on food security, viewed as a tool for improving resource management, increasing production efficiency, and providing accurate data to decision-makers. (WB, Digital Agriculture Roadmap Playbook, 2023, p. 12)

3. Food Security in Algeria (Context and Challenges)

3.1 Overview of the Food Situation

Algeria is one of the largest countries in North Africa in terms of area and natural resources. However, its agricultural sector has not yet achieved self-sufficiency in basic commodities, especially grains. FAO data indicates that Algeria relies heavily on imports to cover more than 70% of its soft wheat needs, making it vulnerable to external fluctuations (FAO, GIEWS Country Brief: Algeria, 2024, p. 2).

Fig.1. Food security indicator (2023)



Source: (FAO, GIEWS Country Brief: Algeria, 2024, p. 2)

The figure illustrating food security indicators for 2023 shows that the level of food security in Algeria is relatively lower compared to the average for North African countries and the average for all countries. The indicator is estimated at approximately 60% in Algeria, compared to about 65% in North Africa and over 70% globally.

These results indicate that Algeria still faces challenges in achieving complete food security, despite the relative improvement in agricultural production and supportive policies for the sector. This disparity is due to factors such as fluctuating production caused by recurrent droughts, declining water resources, and high import costs.

To improve the situation, it is advisable to enhance agricultural sustainability, diversify food sources, and develop supply chains to ensure a reduction in the gap with the regional and global averages.

3.2 Agricultural Production

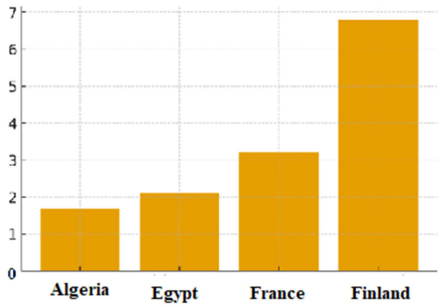
Despite efforts to expand cultivated areas and support farmers, agricultural production remains affected by natural and structural factors, including:

• Water scarcity: Water resources available per capita do not exceed 300 cubic meters per year, which is far below the water poverty line (1,000 cubic meters) (WB, Water Scarcity in the Middle East and North Africa, 2022, p. 14).

• Rainfall variability: This leads to fluctuations in grain production from one season to the next.

• Traditional techniques: Such as reliance on flood irrigation and traditional farming methods, which limit productivity.

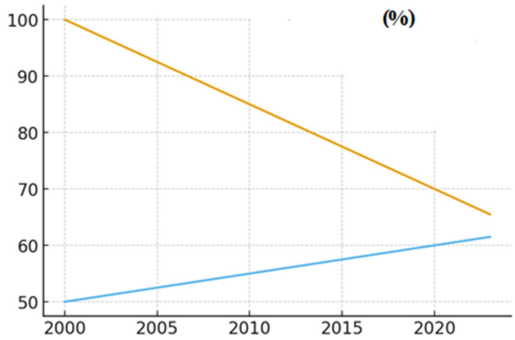
Fig.2. Wheat productivity



Source: (FAO, GIEWS Country Brief: Algeria, 2024, p. 2)

This figure compares wheat productivity (in tons per hectare) among four countries: Algeria, Egypt, France, and Finland. Algeria records the lowest productivity (approximately 1.7 tons/hectare), followed by Egypt with about 2 tons/hectare. France's productivity reaches approximately 3.2 tons/hectare, while Finland tops the list with a productivity of nearly 7 tons/hectare. The differences between the countries highlight the impact of climatic factors, seed quality, and the level of agricultural mechanization in determining wheat yield. Algeria shows relatively low performance, which necessitates continued efforts in technological improvement and agricultural research to achieve food self-sufficiency.

Fig.3. The relationship between water scarcity and agricultural production (2000-2023)



Source: (FAO, GIEWS Country Brief: Algeria, 2024, p. 2)

The figure shows an inverse relationship between water scarcity and agricultural production in Algeria during the period (2000–2023). The data reveals a gradual decrease in water resources from approximately 100% in 2000 to about 65% in 2023, while agricultural production increased slightly from around 50% to over 60% during the same period.

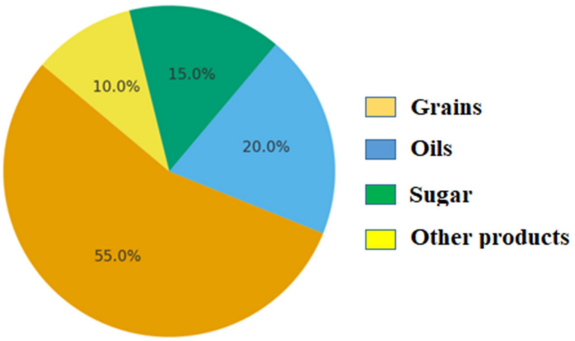
This trend indicates that the agricultural sector has managed to achieve relative growth despite the increasing severity of water scarcity. This can be attributed to the government's efforts in developing modern irrigation methods (such as drip and sprinkler irrigation), improving water resource management, and implementing policies to support farmers and expand cultivated areas.

However, the continued decline in water resources portends significant future challenges, necessitating enhanced innovation in water-saving technologies and diversification of agricultural production to align with limited water availability.

3.3 Consumption and Imports

Algeria relies on the global market to meet its needs for wheat, oils, and sugar. The food import bill reached approximately $10 billion in 2022, of which more than $3 billion was for grains alone (ONS, 2023, p. 6). This over-reliance on foreign sources places the national economy under significant pressure, especially in light of fluctuating global food prices.

Fig.4. The rate of reliance on food imports in Algeria 2023-2024

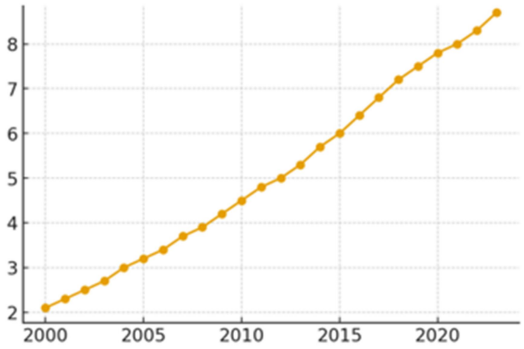


Source: (ONS, 2023, p. 6)

The figure shows that Algeria relies heavily on food imports, with cereals accounting for approximately 55% of total imports, followed by oils at 20%, and sugar at 15%, while other products represent about 10%.

This distribution reflects the fragility of the national food system, as the reliance on foreign sources is concentrated in essential commodities, particularly cereals and oils, due to weak domestic production, climate fluctuations, and high domestic demand.

Fig.5. The evolution of grain imports in Algeria (2000-2023) million tom



Source: (usda, fas.usda., 2025)

At the beginning of the millennium, Algeria was a major importer of grains, but in smaller quantities than in the following two decades; for example, in 2000, the government/GAIN report recorded that Algeria imported approximately 3.3 million tons of grains (usda, fas.usda., 2025).

Since the mid-2010s, Algeria's reliance on imports has increased, and during seasons of weak domestic production, annual wheat imports reached approximately 8–9 million tons (e.g., the 2016/17 season reached 8.4 million tons) (usda, fas.usda, 2025).

In the 2022/23 season, wheat imports were approximately 8.2 million tons, according to USDA/GAIN estimates (fas, 2025). Estimates for the 2023/24 season showed an increase in total grain import requirements to about 14 million tons (all grains—wheat, corn, barley, etc.) due to low domestic production resulting from drought. This is a comprehensive figure for import requirements (not only wheat) (fao, 2025). In terms of trade value: In 2023, the value of Algeria's grain imports amounted to approximately $3.1 billion (OEC/Comtrade data) (oec, 2025).

3.4 Agricultural Policies

Since the beginning of the third millennium, Algeria has pursued a set of policies to support agriculture, most notably:

• The Rural Renewal Program (2009–2014): which focused on supporting farmers and expanding investments in rural areas.

• The National Agricultural and Rural Development Plan (PNDAR): which sought to modernize the agricultural sector through financial and technical support. (MADR, 2015, p. 11)

• However, results remain below expectations due to weak institutional coordination, lack of follow-up, and the failure to direct support toward sustainable solutions.

3.5 Structural Challenges

Among the most prominent challenges hindering the achievement of food security in Algeria are: (MADR, 2015)

• Weak infrastructure: especially storage, transportation, and refrigeration.

• Fragmentation of agricultural ownership: Most farms are small, which hinders the adoption of modern technologies.

• Weak financing: Small farmers have difficulty accessing bank loans.

• Technological deficit: The limited use of digital technologies in production and marketing.

3.6 Towards digital transformation

In recent years, Algeria has begun taking its first steps toward integrating digitalization into agriculture through pilot initiatives, such as the use of smart irrigation systems and digital platforms to connect farmers to markets. These steps remain limited, but they reflect the real potential of employing digital agriculture as a strategic tool to reduce food dependency. (FAO, Digital Agriculture Profiles: North Africa, 2023, p. 18)

4. Mechanisms for Digital Agriculture's Contribution to Enhancing Food Security

4.1 Improving Agricultural Productivity

Headings, or heads, are organizational devices that guide the reader through your paper. There are two types: Digital agriculture enables the use of precision agriculture technologies, which rely on sensors, satellites, and drones to provide real-time data on soil and plant conditions. This data enables farmers to make informed decisions, such as determining the optimal amount of

fertilizer or water for each plot of land. Field studies have shown that precision agriculture can increase productivity by 15% to 25% compared to traditional methods. (FAO, E-agriculture in Action: Drones for Agriculture, 2020, p. 19)

4.2 Rationalizing the Use of Natural Resources

Water scarcity is one of Algeria's biggest challenges, and this is where smart irrigation systems based on sensors and the Internet of Things (IoT) come in. These systems allow for control of water distribution based on actual crop demand, reducing waste by up to 40% (WB, Water Management through Smart Irrigation Systems, 2021, p. 8). Digitization also helps track energy and fertilizer consumption, thus contributing to resource sustainability.

4.3 Reducing Post-Harvest Loss

Statistics indicate that between 20% and 30% of agricultural production in Algeria is lost during transportation and storage due to poor infrastructure. Digitization offers solutions such as blockchain tracking systems and smart cold chains, which help reduce this loss and improve the quality of agricultural products. (OECD, Food Loss and Waste in the MENA Region, 2022, p. 27)

4.4 Improving Market Access

Digital platforms play an important role in connecting producers to local and international markets. Farmers no longer have to rely solely on intermediaries; they can now display their products directly to consumers or traders through applications and online platforms. This mechanism increases farmers' profits and enhances transparency in pricing. (FAO, Digital Technologies in Agriculture and Rural Areas, 2019, p. 33)

4.5 Supporting Decision-Making and Public Policy

Digital agriculture allows governments and official bodies to access accurate databases on agricultural production, consumption, stocks, and price movements. This facilitates food policy formulation and enables rapid intervention in times of crisis such as drought or global price fluctuations. (WB, Digital Agriculture Roadmap Playbook, 2023, p. 15)

4.6 Enhancing Food System Resilience

By integrating digitalization, the food system becomes more resilient to shocks. For example, during the COVID-19 pandemic, digital platforms helped continue marketing agricultural products despite movement restrictions. Digital agriculture thus enhances resilience and resilience to crises. (FAO, The Impact of COVID-19 on Food Security, 2021, p. 44)

4.7 Promoting Social Inclusion

Digital agriculture can open new horizons for marginalized groups, such as small farmers and rural women, by enabling them to access agricultural information and services via smartphones. This contributes to reducing social gaps and achieving greater equity in resource use. (UNDP, Women in Digital Agriculture, 2022, p. 12)

5. Basic Digital Technologies and Their Detailed Impact

There are multiple digital technologies that form the backbone of modern agricultural transformation, with their impact varying depending on the agricultural context and technological

level of each country. The following is a review of the most important of these technologies and their role in enhancing food security:

5.1 Big Data and Cloud Computing

Big Data represents the primary resource for digital agriculture, allowing the collection and analysis of vast amounts of information related to climate, soil, market prices, and consumer behavior. This data enables the construction of predictive models that help farmers and decision-makers improve planning and production. Cloud computing also facilitates the storage and access of this data at a low cost, opening the way for small farmers to benefit from it. (OECD, Big Data in Agriculture: Opportunities and Challenges, 2021, p. 14)

5.2 Internet of Things (IoT)

The Internet of Things represents a network of connected devices and sensors that continuously monitor agricultural production factors such as humidity, temperature, and irrigation rates. Thanks to this technology, farmers can remotely control irrigation or fertilization, reducing costs and increasing resource efficiency. Experiments in India and Brazil have shown that smart irrigation systems based on the Internet of Things (IoT) have reduced water consumption by more than 30% (FAO, IoT Applications for Smart Agriculture, 2022, p. 21).

5.3 Artificial Intelligence and Machine Learning

AI offers extensive potential in analyzing satellite and drone imagery to monitor plant growth and detect diseases and pests early. Machine learning algorithms are also used to predict crops and accurately estimate expected production volumes, helping governments plan grain stocks and imports (WB, Artificial Intelligence for Agriculture Innovation, 2023, p. 18).

5.4 Drones

Drones are among the most widely used digital tools in modern agriculture. They capture high-resolution images of farms and detect problems invisible to the naked eye, such as nutrient deficiencies or pest infestations. They can also be used to spray pesticides and fertilizers locally, reducing costs and limiting environmental pollution (FAO, Drones for Agriculture. , 2020, p. 9).

5.5 Agricultural Robots

Robots are used in automated harvesting operations, especially for crops that require high precision, such as fruits and vegetables. It is also used in irrigation and fertilization, reducing reliance on seasonal labor. Robots have proven successful on dairy farms through robotic milking systems that have improved milk productivity and quality. (Lely, Robotic Milking Systems: Case Studies, 2022, p. 5)

5.6 Block chain

Although block chain is typically used in the financial sector, it has important agricultural applications. It ensures the traceability of agricultural products from farm to end consumer, enhancing transparency and reducing commercial fraud. It also allows for secure and reliable

documentation of commercial transactions between farmers, distributors, and consumers. (UNDP, Blockchain for Food Security, 2021, p. 12)

5.7 Smartphone Applications

Smartphone applications represent a practical and effective tool for transferring agricultural knowledge to farmers, especially in rural areas. These applications provide real-time information on input prices and markets, and alert farmers about weather conditions or the appearance of certain pests. This tool is important in Algeria, where a large percentage of farmers own smartphones despite poor internet coverage in some areas. (GSMA, 2020, p. 7)

6. Case Studies from Around the World and the Arab World

6.1 India – Aqua connect Platform

India is a country heavily dependent on agriculture, with the agricultural sector accounting for more than 40% of the workforce. However, farmers face challenges such as limited financing and a lack of accurate data. The Aqua connect platform not only provides technical recommendations, but also creates an integrated system that includes:

• Data Analysis: Using artificial intelligence to provide personalized advice for each aquaculture farm.

• Marketing: Providing direct sales channels to restaurants and factories without intermediaries.

• Agricultural Insurance: Providing micro-insurance policies linked to farm productivity.

Thanks to this platform, the average productivity of some fish farms has increased by 25%, and farmers have been able to access new markets inside and outside India. (Aquaconnect, 2023, p. 4)

6.2 The Netherlands – Precision Agriculture and Robotics

Despite its small geographical area, the Netherlands is the second largest exporter of agricultural products in the world after the United States. The secret lies in extensive investment in technology. In dairy farms, Lely has revolutionized the industry with its automated milking systems. These robots:

• Milk cows without human intervention.

• Collects accurate data on milk production and cow health.

• Allows for personalized feeding for each cow according to its needs.

As a result, milk yields increased by 15%, and labor costs decreased significantly.

The Netherlands also developed smart greenhouses that rely on artificial intelligence to determine the ideal temperature and humidity, resulting in significantly more vegetables per square meter than the global average (Lely, Robotic Milking Systems: Case Studies from the Netherlands, 2022, p. 6).

6.3 Morocco – SOWIT

In Morocco, SOWIT helped introduce digital solutions based on remote sensing. The company targets small farmers who lack advisory services. Its most prominent services include:

• Satellite images to assess soil and crop conditions.

• Practical recommendations for irrigation and fertilization plans.

• Predictive yield models.

The company also provided a database for banks and insurance companies to assess risks, opening the way for farmers to obtain loans for which they previously did not qualify. (SOWIT, 2021, p. 10)

This experience demonstrated that digitization is not just a technical tool, but a lever for financing and rural development.

6.4 Egypt – Digital Extension Platform

Egypt launched the Digital Extension Project in partnership with the FAO and the World Bank. The platform provides: (FAO, Digital Advisory Services in Egypt, 2022, p. 9)

- Daily weather forecasts and crop prices.
- Training videos for farmers.
- Alerts on agricultural pests.
- Mobile phone advisory services.

More than one million Egyptian farmers have used this platform, helping reduce water use by 15% and increase productivity in some crops such as cotton and wheat.

6.5 Jordan – Hydroponics and Vertical Farming

Jordan suffers from severe water scarcity, with per capita water availability not exceeding 100 cubic meters per year. Therefore, it has turned to innovative solutions such as hydroponics and vertical farming. These systems: (UNDP, Hydroponics and Vertical Farming in Jordan, 2021, p. 13)

- Are fully managed via digital platforms that monitor nutrients and lighting.
- Consume 70% less water than traditional agriculture.
- Produce high-quality vegetables (such as lettuce and tomatoes) year-round.

Some farms in Amman are also using mobile applications to monitor plant growth remotely.

The Jordanian experience is important because it demonstrates how technology can compensate for natural constraints.

6.6 China – Large-Scale Smart Agriculture

China is a huge country with a population of over 1.4 billion, making food security a strategic issue. China has invested in:

- Internet of Things: installing millions of sensors in fields.
- Drones: for spraying pesticides and monitoring crops.
- Artificial Intelligence: for predicting crops and monitoring markets.
- Blockchain: for tracking produce from farm to consumer.

The Chinese government also operates a national agricultural data platform that aggregates information from all provinces and aids central planning. (OECD, Smart Agriculture in China: Policies and Practices, 2022, p. 22)

This level of digitization has allowed China to reduce its imports of some agricultural products and increase its domestic production.

6.7 UAE – Agriculture in Arid Environments

The UAE is a prominent example of the use of technology in a desert environment. Prominent initiatives include: (MOCCAE, 2022, p. 15)

• Enclosed vertical farms: producing lettuce and herbs using smart LED lighting.

• Hydroponic systems: reducing water consumption by 90%.

• Investments in global startups, such as Plenty, an American company specializing in vertical farming.

The UAE's experience demonstrates how technology can overcome climate constraints and transform the desert into a source of food production.

From these experiences, it can be concluded that agricultural digitization is not limited to technology, but includes:

• An innovative financing framework, such as microloans or digital insurance.

• Farmer training: Technology only succeeds if the end user embraces it.

• Digital infrastructure: Internet and electricity are essential.

• International partnerships: between governments, the private sector, and international organizations.

• Sustainability: Digitalization must balance productivity with environmental protection.

7. Challenges and Digital Governance in Agriculture

7.1 Technological Challenges

Despite significant progress in agricultural digitization, there are technical obstacles that limit its spread: (MPT, 2023, p. 5)

• Poor internet infrastructure: especially in rural areas where agricultural activity is concentrated. In Algeria, broadband internet coverage does not exceed 60% in villages.

• Lack of unified data standards: Many digital platforms are incompatible, hindering information exchange.

• High costs of hardware: such as drones and sensors, which remain prohibitively expensive for small farmers.

7.2 Economic and Financial Challenges (WB, Financing Digital Agriculture in MENA, 2022, p. 17)

• Initial investment costs: Acquiring modern technology requires significant capital, which is not available to small farmers.

• Weak bank financing: Financial institutions often consider agriculture a high-risk sector, making them reluctant to grant loans for the acquisition of digital technologies.

• Lack of tax incentives: In many countries, there are no policies that encourage farmers to invest in digitization through tax exemptions or direct financial support.

7.3 Social and Cultural Challenges (FAO, Bridging the Digital Literacy Gap in Rural Communities, 2021, p. 9)

• Digital Illiteracy: A large percentage of farmers in developing countries do not have the skills to use smartphones or applications.

• Cultural Resistance: Some farmers prefer traditional methods of agricultural work and consider technology complex or unnecessary.

• Generational Gap: Young people are quicker to adopt technology than older people, potentially creating a gap within rural communities.

7.4 Legal and Institutional Challenges (OECD, Institutional Coordination for Digital Agriculture, 2020, p. 12)

• Data Protection: Digital agriculture collects vast amounts of data (on soil, crops, weather), but there are no clear legal frameworks to protect this data from illicit commercial exploitation.
• Intellectual Property: Some technologies are owned by global companies, limiting the ability of developing countries to develop local alternatives.
• Weak Institutional Coordination: The lack of coordination between ministries (Agriculture, Communications, Trade) leads to fragmented initiatives.

7.5 Environmental Challenges (UNEP, 2022, p. 14)

• Energy Impact: Operating digital devices (servers, aircraft, sensors) requires electrical energy, which can increase emissions if the source is not renewable.
• E-Waste: Frequently replacing devices generates waste that is difficult to dispose of.
• The Sustainability Problem: Some digital solutions may focus on quick profits without considering the long-term environmental impact.

7.6 Digital Governance as a Solution

These challenges pose the need for effective digital governance, which can be summarized in the following elements: (T.I., 2021, p. 19)

8. Establishing legislative and regulatory frameworks

• Clear legislation to protect agricultural data.
• Laws that encourage local innovation and reduce dependence on foreign companies.
• Establishing unified national standards for digital platforms.

B. Support and Financing Policies

• Providing tax exemptions for investors in digital agriculture.
• Establishing national funds to finance digital agricultural projects.
• Encouraging public-private partnerships to reduce costs for farmers.

C. Building Human Capacity

• Training programs for farmers on the use of technology.
• Integrating digitalization into agricultural education curricula.
• Encouraging scientific research and innovation at universities.

D. Transparency and Accountability

• Mechanisms to monitor the use of funds allocated for digitalization.
• Civil society participation in monitoring agricultural digitalization projects.
• Periodic reports on progress in achieving national food security goals through digitalization.

7.7 The Future Vision

Many countries are moving toward building integrated smart agricultural systems (Smart Agro-ecosystems) based on:

• Using artificial intelligence to forecast demand and consumption.
• Connecting farmers to markets via digital platforms.
• Enhancing transparency through block chain technologies.
• Linking digital agriculture to the energy transition (solar and wind energy).

If this vision is adopted in Algeria within an effective governance framework, it could represent a quantum leap toward achieving sustainable food security (FAO, Smart Agro-ecosystems for Food Security, 2023, p. 25).

8. CONCLUSION

The study demonstrated that food security represents a major strategic issue for Algeria and other developing countries, due to its direct link to social, economic, and political stability. Despite the country's significant natural and human resources, it remains dependent on foreign markets, particularly for grains, oils, and sugar. This situation renders food security fragile and vulnerable to global fluctuations, whether due to climate change, geopolitical crises, or fluctuating raw material prices.

The analysis demonstrated that digital agriculture is not a technological luxury, but rather a development necessity dictated by global transformations. It enables increased agricultural productivity through precision farming, rationalization of water resources, reduction of post-harvest losses, and expansion of farmers' access to markets, in addition to supporting decision-makers with accurate data that aids strategic planning. International and Arab experiences have also demonstrated that digitization can open new horizons even in resource-poor environments, if accompanied by appropriate support and financing policies.

On the social level, digitization holds promising potential to promote justice and inclusiveness by empowering rural women, small farmers, and youth. However, it can also deepen the digital divide if not accompanied by training and qualification programs. On the economic level, digitization can create new jobs and attract investment, but it also requires a strong infrastructure and an effective institutional framework.

Accordingly, achieving food security in Algeria through digitization is not just an option, but a strategic path that requires clear political will, sustainable investments, and profound reforms in agricultural governance patterns.

Practical Recommendations

At the National Level

- Develop a national strategy for digital agriculture: This strategy includes clear objectives and measurement indicators, and is integrated with agricultural, water, and energy strategies.
- Improve digital infrastructure: Expand high-speed internet coverage in rural areas and ensure farmers have access to affordable digital services.
- Innovative financing mechanisms: Establish support funds for digital agriculture and provide affordable microloans for the purchase of equipment and technology.
- Integrating digitalization into agricultural education: Develop curricula in agricultural universities and institutes focused on digital applications, along with training programs for farmers.

- Modernizing legal frameworks: Enacting laws to protect agricultural data and ensure the transparency of digital transactions.
- Promoting scientific research: Supporting universities and research centers to develop local digital solutions tailored to the Algerian context.
- Developing national digital marketing platforms: To directly connect producers with consumers and reduce the role of intermediaries.

On the social level :

- Digital literacy programs: Targeting older farmers and rural women.
- Empowering rural women: Allocating initiatives that encourage the inclusion of women in digital agriculture projects and providing them with training and financing opportunities.
- Youth engagement: Encouraging the creation of agritech startups through business incubators and financial support.
- Bridging the digital divide: Through cooperative support for small farmers to share costs and collectively benefit from technology.

On the environmental level :

- Disseminating smart irrigation systems: To address water scarcity and climate change.
- Moving towards a circular economy: by recycling agricultural waste and converting it into energy or fertilizer.
- Balancing technology and the environment: Encouraging the use of renewable energy sources to power digital equipment.

On the international level

- Enhancing regional cooperation: with countries in the Maghreb and Africa to exchange experiences and best practices.
- Partnerships with international institutions: such as the FAO and the World Bank to leverage funding and technical expertise.
- Openness to global experiences: studying successful models (India, the Netherlands, China) and adapting them to the Algerian reality.

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