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The Role of Smart Agriculture in Enhancing Food Supply in Algeria: Crop-Production Trends and Prospects (2020–2026)

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Le rôle de l'agriculture intelligente dans le renforcement de l'approvisionnement alimentaire en Algérie : tendances et perspectives de la production végétale (2020–2026)

Dr. Habbes Noura*[1],
Hassiba Benbouali University of Chlef, Faculty of Economics, Commercial Sciences and Management Sciences, Chlef, Algeria, Euro-Mediterranean Economic Research and Studies Laboratory,
Email: n.habbes@univ-chlef.dz

Dr. Ahlem Henni[2],
Hassiba Benbouali University of Chlef, Faculty of Economics, Commercial Sciences and Management Sciences, Chlef, Algeria,
Email: a.henni@univ-chlef.dz

Dr. Bouali Razika[3],
Hassiba Benbouali University of Chlef, Faculty of Economics, Commercial Sciences and Management Sciences, Chlef, Algeria,
laboratory of financial systems and economic policies
Email: r.bouali@univ-chlef.dz

Dr. Mohamed Hammou[4],
Hassiba Benbouali University of Chlef, Faculty of Economics, Commercial Sciences and Management Sciences, Chlef, Algeria,
Euro-Mediterranean Economic Research and Studies Laboratory,
Email: m.hammou@univ-chlef.dz

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Abstract:

This study examines the role of smart agriculture in strengthening food supplies in Algeria by analysing crop-production trends during 2020–2026, with particular attention to cereals, vegetables, fruits, and pulses. The central question is: To what extent can smart agriculture contribute to strengthening food supplies in Algeria in light of crop-production developments during 2020–2026? The study adopts a descriptive, analytical, and prospective approach based on available official statistics from the Algerian National Office of Statistics, the Food and Agriculture Organization, Algerian government sources, and the scientific literature.

The findings indicate substantial volatility in Algerian crop production, particularly cereals, due to rainfall variability and drought, while vegetables, especially potatoes, provide a comparatively stronger domestic supply base. Algeria is also moving from administrative digitalisation toward more integrated agricultural information systems, including sectoral digital platforms and a national agricultural information system launched in 2026. Nevertheless, smart agriculture is not yet a generalized production model and remains constrained by digital infrastructure, cost, skills, and data quality. The study argues that its principal contribution lies in improving water and input efficiency,

raising productivity, reducing losses, and strengthening production and risk forecasting, provided that digital technologies are integrated into coherent agricultural, water, and institutional policies.

Keywords: Smart agriculture; Food supply; Food security; Precision agriculture; Artificial intelligence; Remote sensing; Crop production; Algeria.

Résumé:

Cette étude examine le rôle de l'agriculture intelligente dans le renforcement de l'approvisionnement alimentaire en Algérie en analysant les tendances de la production végétale durant la période 2020–2026, avec une attention particulière portée aux céréales, aux légumes, aux fruits et aux légumineuses. La question centrale est la suivante : dans quelle mesure l'agriculture intelligente peut-elle contribuer au renforcement de l'approvisionnement alimentaire en Algérie à la lumière de l'évolution de la production végétale durant la période 2020–2026 ? L'étude adopte une approche descriptive, analytique et prospective fondée sur les statistiques officielles disponibles de l'Office National des Statistiques, de l'Organisation des Nations Unies pour l'alimentation et l'agriculture, des sources gouvernementales algériennes et de la littérature scientifique.

Les résultats indiquent une forte volatilité de la production végétale algérienne, notamment des céréales, en raison de la variabilité des précipitations et de la sécheresse, tandis que les légumes, en particulier les pommes de terre, constituent une base d'approvisionnement intérieur comparativement plus solide. L'Algérie évolue également d'une numérisation administrative vers des systèmes d'information agricoles plus intégrés, notamment des plateformes numériques sectorielles et un système national d'information agricole lancé en 2026. Néanmoins, l'agriculture intelligente ne constitue pas encore un modèle de production généralisé et demeure limitée par les infrastructures numériques, les coûts, les compétences et la qualité des données. L'étude soutient que sa principale contribution réside dans l'amélioration de l'efficacité de l'utilisation de l'eau et des intrants, l'augmentation de la productivité, la réduction des pertes et le renforcement de la prévision de la production et des risques, à condition que les technologies numériques soient intégrées dans des politiques agricoles, hydriques et institutionnelles cohérentes.

Mots-clés : Agriculture intelligente ; approvisionnement alimentaire ; sécurité alimentaire ; agriculture de précision ; intelligence artificielle ; télédétection ; production végétale ; Algérie.

Introduction:

Food supplies have become a strategic issue that goes far beyond merely increasing production volume, as they are intrinsically linked to the agricultural system's capacity to provide food consistently in the face of drought, price volatility, climate shocks, and supply chain disruptions. This challenge is particularly acute in arid and semi-arid countries facing intense competition among various uses of water and land. Within this environment, smart agriculture has emerged as a paradigm combining agricultural knowledge, digital technologies, remote sensing, data analytics, and automation to optimize production decisions.

Literature indicates that smart agriculture represents an evolution from precision agriculture and digital farming. Practices have shifted from the use of global positioning systems and field mapping to interconnected systems capable of capturing, analysing, and acting upon real-time data concerning soil, crops, weather, and water. Wolfert et al. (2017, pp. 69–71) emphasize that the value

of agricultural data depends not on its volume, but on the system's capacity to integrate and translate it into actionable decisions. Furthermore, Klerkx et al. (2019, pp. 1–5) demonstrate that digitalisation reshapes the relationships among producers, advisors, institutions, and markets.

Algeria faces severe water and climatic pressures that make efficient production management an imperative priority. The Food and Agriculture Organization (FAO) notes that Algeria suffers from extreme water stress, exacerbated by climate change and population growth, making improved water productivity a central challenge for resilient agriculture (FAO, 2026). Consequently, exploring smart agriculture in Algeria should not be confined to technical dimensions; rather, it must be linked directly to food supply dynamics and the capacity of domestic production to mitigate deficits.

The period 2020–2026 underscores this critical linkage. Cereal production experienced a sharp decline in 2020/2021, followed by a recovery in 2021/2022 and subsequent fluctuations, whereas vegetables—most notably potatoes—achieved high production levels. In June 2026, the FAO projected cereal production approaching five million tonnes, representing roughly 30% above average, supported by favourable rainfall between December 2025 and April 2026 and improved reservoir levels (FAO GIEWS, 2026). This suggests that Algerian cereal production can improve substantially under favourable climatic conditions, while remaining highly vulnerable to climatic variability, yet remains highly vulnerable to climatic volatility.

Problem Statement:

To what extent can smart agriculture contribute to strengthening food supplies in Algeria in light of crop-production developments during 2020–2026?

Research Sub-Questions:

1. What is smart agriculture, and what are its core characteristics and technologies?
2. What is the concept of food supply, and what are its key determinants in the Algerian context?
3. How did the production of cereals, vegetables, fruits, and pulses evolve during the study period?
4. What is the current level of digital transformation and technology adoption in the Algerian agricultural sector?
5. How can precision agriculture, remote sensing, artificial intelligence, and smart irrigation be harnessed to enhance food supplies?
6. What are the primary challenges and future requirements for scaling this digital transition?

Research Hypothesis:

The study posits that scaling the adoption of smart agriculture technologies can enhance food supplies in Algeria by improving water and input use efficiency, increasing crop yields, reducing losses, and enhancing production and risk forecasting. However, the magnitude of this impact remains contingent upon the expansion of digital infrastructure, data quality, producer skills, and the contextual suitability of deployed solutions.

Objectives of the Study:

1. To ground the conceptual framework of smart agriculture and distinguish it from digital and traditional farming.

2. To analyse trends in Algerian crop production during 2020–2026.
3. To diagnose the trajectory of digital and technological transformation in the agricultural sector.
4. To examine the mechanisms through which smart technologies contribute to cereals, vegetables, fruits, and pulses.
5. To propose actionable requirements for expanding smart agriculture to support food supply stability.

Methodology and Data Sources:

The study employs a descriptive, analytical, and prospective methodology. The descriptive component relies on data from the National Office of Statistics (ONS), the FAO, and official Algerian governmental sources, while the analytical framework bridges production, water, climate, technology, and loss metrics. The prospective analysis focuses on the gap between potential and application, alongside expansion requirements.

It is vital to note the divergence between calendar years and agricultural campaigns; thus, data cannot be aggregated without harmonizing temporal definitions and units. Additionally, since 2026 was ongoing during the preparation of this study, related figures are presented as estimates or projections where sourced accordingly.

Methodological rigor dictates that specific production increases are not directly attributed to smart agriculture due to the absence of a national census measuring adoption rates and causal impacts.

1. Conceptual Framework of Smart Agriculture and Food Supplies

1.1. Concept and Evolution of Smart Agriculture

Smart agriculture can be defined as an agricultural management paradigm utilizing data, connectivity, sensing, analytics, and automation to optimize decisions regarding land, water, crops, inputs, and supply chains. It transcends the mere application of standalone digital tools, denoting an interconnected ecosystem where data flows from the field to analytical platforms to inform decisions and execution.

The concept originated within the context of precision agriculture, which initially focused on spatial variability within fields. With the proliferation of satellite imagery, smartphones, the Internet of Things (IoT), and cloud computing, the concept expanded to encompass real-time data management and the integration of fields with markets and institutions. Klerkx et al. (2019, pp. 1–5) emphasize that this transition entails profound technical, organizational, and social dimensions.

Smart agriculture is characterized by precision, flexibility, proactivity, and integration. It is precise because it targets exact locations and times; flexible because it adjusts decisions to dynamic conditions; proactive via forecasting and early warning systems; and integrated because it connects soil, water, climate, production, and market data.

Key Technologies:

- **Artificial Intelligence (AI):** Utilized for yield forecasting, disease detection, image classification, water stress estimation, and irrigation scheduling. Liakos et al. (2018, pp. 6–10) review the expansion of machine learning in agriculture, emphasizing the necessity of robust local datasets.
- **Internet of Things (IoT):** Connects sensors, meters, and controllers to measure soil moisture, temperature, salinity, and water levels, converting raw measurements into alerts or automated operational commands.
- **Remote Sensing:** Enables the large-scale monitoring of crops and water resources. The FAO's WaPOR initiative in Algeria exemplifies the application of remote sensing for water productivity and resource management.
- **Unmanned Aerial Vehicles (Drones):** Provide high-resolution imagery for monitoring stress and diseases and mapping fields, though expansion remains constrained by cost, regulation, and technical competencies.
- **Smart Irrigation:** Integrates soil moisture, weather data, and crop requirements to determine irrigation timing and volume—making it one of the most pertinent applications for Algeria's environment.
- **Data Analysis:** Transforms production, input, inventory, and weather data into indicators that support planning, forecasting, and decision-making.

Table 1. Comparison of Traditional, Digital, and Smart Agriculture

Dimension	Traditional	Digital	Smart
Data	Experience and observation	Digital collection	Collection, integration, and analysis
Decision-Making	Manual	Report-supported	Predictive and potentially automated
Irrigation	Fixed schedules	Digital monitoring	Sensors and demand-driven models
Monitoring	Field-based	Platforms and imagery	Remote sensing and artificial intelligence
Primary Goal	Increase production	Administrative digitalisation	Efficiency, resilience, and sustainability

Source: *Authors' elaboration based on Klerkx et al. (2019), Wolfert et al. (2017), and Liakos et al. (2018).*

1.2. Concept of Food Supplies and Determinants

Food supplies refer to the capacity of a food system to provide required products in appropriate quantities and continuity through domestic production, imports, inventories, and flow management. While closely tied to food security, food supplies focus primarily on the supply side. The FAO defines food security comprehensively across four pillars: availability, access, stability, and utilization (FAO, 2006, p. 1).

In Algeria, food supplies comprise domestic production, imports, and strategic reserves, with particular emphasis on cereals and high-consumption staples. FAO projections for 2026 estimate cereal import requirements for the 2026/2027 season at approximately 14.5 million tonnes, notwithstanding an anticipated domestic harvest improvement (FAO GIEWS, 2026).

Supplies are determined by productivity, water availability, arable land, climatic conditions, technology, post-harvest losses, inputs, and markets. As no single technology addresses all these determinants, smart agriculture must be viewed as part of a broader systemic framework.

Table 2. Mechanisms through Which Smart Agriculture Can Enhance Food Supplies

Mechanism	Technology	Expected Impact
Yield Enhancement	Precision agriculture	Increased land productivity
Water Conservation	Smart irrigation	Higher water productivity
Early Warning	Weather apps & AI	Loss reduction
Input Optimization	Variable rate application	Waste reduction
Forecasting	Data analytics	Improved planning
Loss Reduction	Monitoring & smart storage	Supply stability

Source: *Authors' elaboration based on Wolfert et al. (2017), Liakos et al. (2018), FAO (2026), and World Bank (2018, 2024).*

Cereals (soft wheat, durum wheat, and barley) form the cornerstone of food security in Algeria. Throughout 2020–2026, this sector experienced clear structural and climatic volatility linked to precipitation patterns and recurring droughts across North Africa (ONS, 2022).

2. Evolution of Crop Production and Food Supplies in Algeria (2020–2026)

2.1. Cereals

Cereals are a strategic component of Algeria's agricultural production and food-supply system, playing a central role in domestic consumption and food security. During 2020–2026, cereal production fluctuated considerably due to variations in rainfall, water availability, temperature, and other climatic factors, highlighting the sector's vulnerability to climate pressures. In this context, smart agriculture can improve cereal production through remote sensing, precision irrigation, digital monitoring, and data-driven crop management, supporting more efficient use of water and agricultural inputs. Table 3 presents the evolution of cereal production and provides a basis for assessing the potential contribution of smart agricultural technologies to strengthening Algeria's food supplies.

Table 3. Evolution of Cereal Production in Algeria, 2019/2020–2026

Period	Production	Unit	Statistical status
2019/2020	43.9	million q	Realized campaign production

2020/2021	27.6	million q	Realized campaign production
2021/2022	~41	million q	Government-reported production
2022/2023	30	million q	Reported campaign figure
2023	3.468	million tonnes	FAO estimate
2024	4.118	million tonnes	FAO estimate
2026	~5.0	million tonnes	FAO forecast

Source: *Authors' compilation based on Office National des Statistiques (ONS, 2022), Algerian government statements, and FAO GIEWS (2026).*

The data reveal substantial interannual volatility.Production peaked at 43.9 million quintals in 2019/2020, dropped to approximately 27.6 million quintals in 2020/2021, and rebounded to roughly 41 million quintals in 2021/2022. The ONS confirms that cereals were among the crops most severely impacted by drought during 2020/2021 (ONS, 2022).

For 2026, the FAO projected production near five million tonnes—about 30% above historical averages—benefiting from rainfall recorded between December 2025 and April 2026 and elevated reservoir levels. Simultaneously, import requirements were estimated at 14.5 million tonnes (including 8.5 million tonnes of wheat), underscoring that domestic production gains do not eliminate the supply gap (FAO GIEWS, 2026).

These trends illustrate that cereals represent a core arena for smart agriculture deployment. Remote sensing can identify stress zones, climate models assist in optimal planting schedules, precision irrigation optimizes water application, and artificial intelligence improves yield estimation and disease prediction.

2.2. Vegetables

Vegetables constitute a vital foundation for domestic food supplies due to geographical and seasonal diversification. According to official data for the 2022/2023 campaign, declared vegetable production reached approximately 156 million quintals in 2023, including 42 million quintals of potatoes (Horizons, 2023).

Potatoes exhibit multiseasonal production capacity, with desert wilayat such as El Oued emerging as major production hubs. In 2024, El Oued allocated 33,000 hectares for off-season potato cultivation (2024/2025) with high projected yields, reflecting the importance of irrigation and agricultural technology in arid environments (Radio Algérienne, 2024).

These characteristics render vegetables highly suitable for smart greenhouses, sensor-based automation, environmental control systems, and computer vision for early disease detection.

2.3. Fruits

Fruits include citrus, stone fruits, pome fruits, and dates. Data from the 2022/2023 campaign indicates that stone and pome fruits reached approximately 17.3 million quintals (growing by over 7%), while dates reached 13.6 million quintals (an increase exceeding 26%) (Horizons, 2023).

Smart agriculture supports orchards through soil moisture sensors, climate tracking, image analysis, and disease forecasting—gaining heightened relevance amid rising temperatures and shifting rainfall patterns.

2.4. Pulses

Pulses represent an essential component for dietary diversification and reducing reliance on external plant protein sources. Production rose from approximately 0.9 million quintals in 2021 to 1.18 million quintals in 2022, representing an increase of nearly 19% (Le Chodalgerie, 2022).

Smart agriculture opportunities in this sector include soil testing, seeding density optimization, irrigation calibration, crop rotation management, and integrating weather data into farming decisions.

2.5. Comparative Overview of Crop Production

Algeria's crop production comprises diverse groups that contribute to domestic food supplies to varying degrees. The available indicators reveal differences in production levels, stability, and the strategic importance of each crop group. While cereals remain particularly vulnerable to climatic fluctuations, vegetables, potatoes, fruits, dates, and pulses provide important contributions to domestic supply and agricultural diversification. A comparative view of these major crop groups helps identify variations in production performance and highlights areas where smart agricultural technologies could support productivity, resource efficiency, and greater resilience.

Table 4. Comparative Overview of Major Crop Groups in Algeria

Crop Group	Selected Production Indicator	Implication
Cereals	27.6M quintals (2020/2021); 41M (2021/2022)	High volatility
Vegetables	156M quintals (2023)	Broad domestic supply base
Potatoes	42M quintals (2023)	Core staple crop
Stone & Pome Fruits	17.3M quintals (2023)	Notable growth
Dates	13.6M quintals (2023)	Robust expansion
Pulses	1.18M quintals (2022)	Improvement over 2021

Source: *Authors' compilation based on ONS (2022), FAO GIEWS (2026), and Horizons (2023).*

3. The Role of Smart Agriculture in Enhancing Food Supplies in Algeria

3.1. Current State of Adoption in Algeria

In October 2025, the Ministry of Agriculture announced projects to develop a sectoral information system via dedicated platforms for agricultural sectors to track input requirements, equipment, and production/storage volumes (APS, 2025). In July 2026, the launch of the National Agricultural Information System marked a key institutional milestone toward unifying agricultural data (Radio Algérienne, 2026).

The FAO's WaPOR initiative in Algeria offers another model, utilizing remote sensing for water productivity while building national capacities in precision agriculture and water resource management at the plot level in collaboration with multiple Algerian institutions (FAO, 2026).

These efforts remain distinct from comprehensive smart agriculture; possessing a digital platform does not automatically translate into on-farm AI usage, nor does modern irrigation become "smart" without integration with sensors, data streams, and analytics.

3.2. Role in Cereal Production

- **Precision Agriculture:** Utilization of soil and crop maps to apply variable-rate fertilizers and seeds, minimizing input excess and maximizing resource efficiency.
- **Crop Monitoring:** Satellite imagery and drone surveys to identify stress zones and prioritize field interventions.
- **Disease Forecasting:** AI analysis of imagery and weather data to estimate infection risks, requiring calibration against local data.
- **Optimized Irrigation & Fertilization:** Integration of soil moisture, weather, and crop requirements for precise irrigation scheduling.
- **Yield & Loss Mitigation:** Enhanced production forecasting, optimal harvest timing, and storage monitoring to increase actual supply and minimize post-harvest loss.

3.3. Role in Vegetable Production

Smart greenhouses equipped with digital sensors automate temperature, humidity, carbon dioxide, and substrate moisture control, adjusting irrigation and ventilation according to plant demands. Computer vision assists in early symptom detection, while digital platforms link production data with inventory and market demand. Climate-smart agriculture literature emphasizes that enhancing productivity, resilience, and resource efficiency relies on technology packages (World Bank, 2018; World Bank, 2024).

3.4. Role in Fruits and Pulses

In orchards, soil moisture sensors are linked with weather data to determine irrigation timing, while imagery tracks color and canopy density changes. For pulses, precision agriculture aids soil testing, seeding density, water requirements, and crop rotation data integration, transforming agricultural intelligence into holistic resource management.

3.5. Smart Agriculture and Bridging the Supply Gap

Smart agriculture can contribute to reducing food-supply gaps by improving efficiency, resource management, and coordination across the agricultural supply chain. Its potential extends from production planning and precision farming to smart irrigation, crop protection, harvesting, storage, and

market coordination. Data-driven tools can support more accurate supply estimation, optimize the use of water and agricultural inputs, reduce production and post-harvest losses, and improve the alignment between supply and demand. These applications are particularly relevant in contexts where climatic variability, resource constraints, and supply-chain inefficiencies affect food availability.

Table 5. Potential Contribution of Smart Agriculture Across the Food Supply Chain

Chain Stage	Smart Tool	Expected Outcome
Planning	Data analytics	Better supply estimation
Production	Precision farming	Efficiency gains
Water Management	Smart irrigation	Higher water productivity
Protection	Early warning	Reduced disease losses
Harvesting	Maturity prediction	Minimized waste
Storage	Digital monitoring	Supply stability
Market	Digital platforms	Reduced supply-demand mismatch

Source: *Authors' elaboration based on FAO (2026), World Bank (2018, 2024), Klerkx et al. (2019), and Liakos et al. (2018).*

3.6. Challenges to Implementation

- **Cost:** Sensors, platforms, drones, and connectivity require capital investment and maintenance, potentially hindering smallholder adoption.
- **Skills:** Ownership of equipment is insufficient; producers and advisors require data literacy and interpretation skills (World Bank, 2018).
- **Data:** AI applications require accurate, regular, and interoperable data alongside cybersecurity and privacy safeguards.
- **Digital Infrastructure:** Connectivity, energy, and digital service quality vary across regions, constraining continuous utilization.
- **Institutional Coordination:** Smart agriculture requires coordination among agriculture, water resources, scientific research, telecommunications, and the private sector.
- **Climate:** Technology mitigates risks but cannot eliminate droughts and heatwaves, necessitating integration within broader climate-smart strategies.

Results and Future Prospects

1. Key Findings

- Cereal production in Algeria exhibits high volatility and appears strongly sensitive to climatic and water conditions.
- Vegetables, particularly potatoes, constitute an important component of domestic food supplies.

- Substantial potential exists in fruits, dates, and pulses, though improving efficiency requires rigorous water, disease, and input management.
- Algeria has progressed incrementally toward agricultural digitalisation, highlighted by sectoral platforms and the National Agricultural Information System in 2026.
- Significant applications of remote sensing and water productivity exist, yet fully integrated smart agriculture is not yet generalized.
- The core value of smart technologies lies in resource efficiency, loss reduction, and forecasting improvements rather than nominal production growth alone.
- The gap between potential and application stems from cost, skill deficits, digital infrastructure limits, data quality, and institutional coordination.

2. Impact on Food Supplies

The available evidence indicates substantial potential for smart agriculture to contribute to food-supply resilience; however, its national impact cannot yet be quantified as a fixed percentage due to the absence of comprehensive data linking technology adoption rates directly to aggregate agricultural production. Future impact assessments will require comparative analyses between farms using specific smart technologies and appropriate control groups, while controlling for differences in soil, climate, and farm size.

3. Gap Between Potential and Application

Despite the growing potential of smart agriculture to improve agricultural productivity, resource efficiency, and food-supply management, its application in Algeria remains uneven across technological domains. Remote sensing has significant potential for large-scale agricultural monitoring, while its practical use is still concentrated mainly in projects and pilot initiatives. Similarly, artificial intelligence offers opportunities for forecasting, data analysis, and decision support, but its application remains limited and experimental. Smart irrigation is being adopted at varying levels, with further integration of sensors and automated systems needed to improve water productivity. Digital platforms are developing rapidly, although greater interoperability and data integration are required. The use of drones remains relatively limited, despite their potential for precision monitoring, while shortages in data-analysis and digital skills continue to constrain wider adoption.

Table 6. Gap Between the Potential and Current Application of Smart Agriculture in Algeria

Domain	Potential	Current Status	Priority Action
Remote Sensing	Broad coverage	Projects & pilots	Scale expansion
Artificial Intelligence	Forecasting & analysis	Limited/experimental	Local database creation
Smart Irrigation	Water productivity	Variable adoption	Sensor integration
Platforms	Data integration	Rapid evolution	Interoperability
Drones	High precision	Limited diffusion	Shared service models
Skills	Data analytics	Training needed	Digital extension

Source: *Authors' elaboration based on FAO (2026), World Bank (2018, 2024), Klerkx et al. (2019), and Liakos et al. (2018), with authors' synthesis.*

4. Development Requirements

- Establish a unified national agricultural data architecture with interoperability and security standards.
- Develop digital maps for soils, water resources, crops, and climate zones.
- Expand smart irrigation projects and evaluate water productivity impacts.
- Establish shared drone and image-analysis service models for smallholders.
- Build local Algerian databases for diseases, weather, soils, and crop varieties to train AI models.
- Integrate smart agriculture into higher education, vocational training, and extension services.
- Scale successful trials into viable programs complete with cost-benefit metrics.
- Link production, storage, logistics, and markets to digitalize the entire supply chain.

5. Future Prospects

Remote sensing, water management, and AI will grow increasingly critical, particularly alongside the maturation of the agricultural information system. Priority will be directed toward solutions addressing direct bottlenecks such as water scarcity and yield constraints. Desert regions present prime domains for integrating irrigated agriculture, solar energy, remote sensing, and water management, provided rigorous groundwater monitoring is maintained. Transitioning from technology acquisition to building an innovation ecosystem bridging academia, research, extension, finance, and the private sector remains vital.

Conclusion:

This study concludes that enhancing food supplies in Algeria relies less on expanding acreage and more on the agricultural system's ability to produce more stable yields using constrained resources. The 2020–2026 period reveals that cereals remain highly sensitive to climate shocks, whereas vegetables and potatoes constitute important components of the domestic food-supply base.

Smart agriculture provides a technological and institutional layer capable of optimizing existing agricultural policies through crop monitoring, water management, disease forecasting, yield estimation, and supply-chain integration. Initiatives such as WaPOR, agricultural platforms, and the National Agricultural Information System indicate a progressive institutional shift.

Nevertheless, existing evidence does not permit attributing specific national production surges directly to smart agriculture, as technology diffusion and causal impact measurement remain limited. Consequently, scientific and policy priorities must focus on measurable, evaluated programs targeting water productivity, yield stability, loss reduction, and input efficiency.

Recommendations:

1. Formulate and implement a national strategy for smart agriculture that integrates digital transformation with food security and water governance, establishes national indicators for measuring technology adoption, water productivity, yields, and post-harvest losses, and ensures

rigorous assessment of the financial, economic, and socio-environmental impacts of agricultural technologies before large-scale deployment.

2. Expand smart and precision agriculture technologies, particularly remote sensing, water-productivity monitoring, smart irrigation, drones, and digital analytics, with priority given to water-stressed regions and the development of shared technology-service models accessible to smallholder farmers.
3. Strengthen the digital and knowledge infrastructure of the agricultural sector by developing national agricultural databases to support localized artificial intelligence applications, integrating digital literacy and data analysis into the training of farmers and extension officers, and strengthening collaborative research among universities, the Ministry of Agriculture, and the private sector.
4. Develop an integrated digital agricultural ecosystem connecting production, storage, distribution, and markets through unified digital platforms, while linking data generated by smart technologies directly to agricultural extension services to improve decision-making, resource efficiency, and the stability of food supplies.

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