

Toward Smart Agriculture in the Arab World: An Indication of Some Successful Experiences

التوجه نحو الزراعة الذكية في الوطن العربي: إشارة لبعض التجارب الناجحة

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Abstract:

The agricultural sector in the Arab world faces many problems and challenges that constitute an obstacle to achieving food security and its sustainability. Consequently, adopting smart agriculture has become an inevitable and indispensable approach aimed at advancing the agricultural sector. This study seeks to address the reality of the agricultural sector in the Arab world and to highlight the importance of smart agriculture as an innovative approach to achieving agricultural development and maintaining its sustainability, through presenting the most important successful Arab experiences. The study concluded that smart agriculture represents a vital pathway to improving agricultural performance in the Arab world; however, it requires political coordination and investment in technology, infrastructure, and education to ensure an effective and sustainable transformation.

Keywords: Smart Agriculture; Agricultural Sector; Arab World; Climate Change.

JEL Classification Codes: Q16; N5; N55; N57; O10.

ملخص:

يواجه القطاع الزراعي في الوطن العربي العديد من المشاكل والتحديات التي تشكل عائقا لتحقيق الأمن الغذائي واستدامته، فأصبح انتهاز الزراعة الذكية أمرا حتميا لا غنى عنه بهدف النهوض بالقطاع الزراعي. تهدف هذه الدراسة إلى التطرق لواقع القطاع الزراعي في الوطن العربي وإبراز أهمية الزراعة الذكية كنهج مستحدث لتحقيق التنمية الزراعية والحفاظ على استدامتها، من خلال عرض أهم التجارب العربية الناجحة. وقد خلصت الدراسة إلى أن الزراعة الذكية تعتبر مسارا حيويا لتحسين أداء الزراعة في الوطن العربي، لكنها تتطلب تنسيقا سياسيا واستثمارا في التكنولوجيا والبنية التحتية والتعليم لضمان تحول فعال مستدام.

الكلمات المفتاحية: الزراعة الذكية، القطاع الزراعي، الوطن العربي، التغيرات المناخية.

تصنيفات JEL : Q16; N5; N55; N57; O10

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INTRODUCTION:

Agriculture in the Arab world faces increasing challenges at multiple levels, including water resource scarcity, climate change, population expansion, and growing pressure on food security. In light of these pressures, the need has emerged to adopt a modern agricultural model based on innovation and technology, known as smart agriculture.

Smart agriculture is considered one of the most prominent modern innovations in the agricultural sector, as it represents a point of intersection between traditional agriculture and advanced digital technologies. The need for this type of agriculture has arisen as a result of the major challenges facing the agricultural sector at the global level, including rapid population growth, increased demand for food, scarcity of natural resources, and climate changes that threaten food security and the sustainability of agricultural production.

It is based on the use of digital technology and big data to improve the efficiency of agricultural operations and enable farmers to increase crop productivity, improve food quality, and reduce losses and waste of natural resources.

With regard to the Arab world, smart agriculture is considered a strategic solution to confront water scarcity, desertification, and the degradation of agricultural lands, especially in countries characterized by desert and arid climates such as Saudi Arabia and the United Arab Emirates. It also contributes to improving local food production and reducing dependence on imports, thereby enhancing regional food security and lowering the economic costs associated with importation.

Study question:

To what extent have Arab countries succeeded in establishing smart agriculture?

Sub-questions:

- What is the reality of the agricultural sector in the Arab world?
- What are the most important technologies used in smart agriculture as a new trend supporting agriculture?
- What are the most important successful Arab experiences in the field of smart agriculture?

Study Hypothesis:

Smart agriculture is an integrated approach to future agricultural sustainability in light of population and climate pressures.

Study Importance:

The importance of this study lies in its alignment with the broad and recent interest in smart agriculture, as it is considered a fundamental pillar for achieving local and global food security, especially in regions facing severe environmental and climatic pressures such as deserts and semi-arid areas. It provides effective tools for adapting to climate change and enhances the capacity to produce food sustainably, ensuring the fulfillment of future food needs for growing populations. Therefore, Arab countries have moved toward adopting smart agriculture technologies to confront global challenges such as climate change and population growth.

Study Objectives:

The study aims to achieve the following:

- Diagnosing the reality of the agricultural sector in the Arab world.
- Introducing smart agriculture, its objectives, the requirements for its application, and the various practices adopted by countries under this approach.
- Identifying the most important successful Arab experiences in smart agriculture (Qatar, the United Arab Emirates, the Kingdom of Saudi Arabia, Egypt).

Study Methodology:

Given the nature of the subject under study and in order to answer the proposed research problem, the descriptive-analytical approach was adopted. The descriptive approach was used to clarify the objectives of smart agriculture, the requirements for its application, and the practices followed in implementing it, as well as when presenting some successful Arab experiences in the field of smart agriculture. The analytical approach was relied upon to analyze figures, indicators, and statistics adopted by Arab and international institutions such as the Arab Organization for Agricultural Development and the World Bank, in order to assess the reality of the agricultural sector in the Arab world.

1. The Theoretical Framework of Smart Agriculture

Climate-smart agriculture supports the way agricultural sectors adapt to expected climate changes, enhances the capacity of production systems, and confronts various climatic difficulties. Based on what was stated by the Food and Agriculture Organization (FAO), and with the aim of achieving food security in the context of climate change, a new approach was developed and given the term climate-smart agriculture. It was presented in 2010 at the Hague Conference on Agriculture, Food Security, and Climate.

The Global Alliance for Climate-Smart Agriculture was launched to address the challenges of food security and agriculture during the United Nations Climate Summit held in September 2014 in New York, in cooperation with FAO and the World Bank, with the aim of establishing partnerships in the field of climate-smart agriculture. In 2017, the United Nations General Assembly also called for emphasizing the local context of the impact of climate-smart agriculture according to temporal and spatial diversity, and for the need to expand the scope of biotechnology in agriculture and focus on research and development in this field in order to improve food security (UNGA, 2017, p. 22).

1.1. Definition of Smart Agriculture

It is a new concept that aims to provide the agricultural industry with an important foundation to benefit from advanced technologies, including big data and Internet tools, to monitor machine sensing and analyze operations, and it is referred to as precision agriculture (Hailu & Campbell, 2013, p. 01).

The Food and Agriculture Organization (FAO) defined it as an ecological agriculture to sustainably increase productivity, enhance the resilience of livelihoods and protect ecosystems, reduce or eliminate greenhouse gases, and promote the achievement of food security as well as development (Tinashe, 2017, p. 03).

Climate-smart agriculture is the approach that helps guide the necessary actions to transform and reorient agricultural systems to support development effectively and ensure food security in the presence of a changing climate.

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1.2. Principles of Climate-Smart Agriculture

Smart agriculture contributes to achieving food security and ensuring its sustainability through the principles on which it is based, which include (Nadia & Dalila, 2023):

- Preserving and protecting the environment: through better management of natural resources, sustainable use of resources, improving land and water sustainability, using technologies that reduce the use of chemical materials, improving land mapping, and enhancing water management.
- Improving productivity: this applies to productivity in terms of yield as well as increasing the efficiency of asset management.
- Enhancing innovation in the agricultural field: smart agriculture technologies allow the adoption of innovative production methods in both animal and plant sectors, and across various stages of production from land to market.
- Attracting new investments: due to natural diversity and climatic conditions in most Arab countries, which in turn encourages investors to resort to new agricultural technologies in difficult and harsh environments.
- Creating green jobs: enabling adaptation to climate change and reducing greenhouse gas emissions.
- Reducing hunger and poverty: through increasing production and improving the quality of agricultural crops.
- Converting animal waste into biogas: as an alternative and renewable source of energy.
- Establishing fisheries and aquaculture capable of withstanding climate change: through storm-resistant fish cages and ponds and adaptable fisheries management.
- Increasing revenues: greater transparency of the value-added chain will raise the standard of trust in food safety with traceability, leading to increased market value.
- Creating job opportunities: new jobs will be created as entrepreneurs and new players join the relatively new smart agriculture sector.

1.3. Importance of Smart Agriculture

In recent years, smart agriculture has become one of the most important modern trends in global agricultural policies, as it represents a direct response to the increasing challenges imposed by rapid population growth, climate change, and the scarcity of natural resources, especially in Arab countries. These countries face growing pressures to achieve food security amid limited agricultural land, declining water resources, and rising agricultural production costs.

Smart agriculture relies on employing modern technology, particularly artificial intelligence technologies, the Internet of Things, and big data analytics, in order to improve the efficiency of agricultural production, rationalize resource use, and reduce risks associated with unpredictable climatic conditions. This approach represents a radical shift from traditional agricultural methods, as it depends on continuous monitoring of crops and soil, early prediction of diseases and pests, and making agricultural decisions based on accurate and timely data.

The importance of smart agriculture lies in achieving sustainable agricultural production capable of meeting present needs without compromising the ability of future generations to meet their own needs. It also aims to improve the quality of agricultural products and increase their returns, while reducing the environmental impact resulting from excessive use of chemical

fertilizers and pesticides. In addition, smart agriculture contributes to reducing production costs through optimal use of water and energy, thereby enhancing farmers' incomes and improving their living standards (Faiza, 2021).

Smart agriculture has particular importance in Arab countries, given that a large proportion of the population depends on agricultural activity as a primary source of income, in addition to the widening Arab food gap. Adopting this agricultural model would help reduce this gap, enhance food security, and support economic and social development, in line with sustainable development goals (Faiza, 2021, p. 361).

Accordingly, it can be said that smart agriculture is no longer a secondary technological option, but has become a strategic necessity imposed by global economic and climatic transformations, especially in the Arab region, which calls for adopting supportive policies and encouraging investment in this vital field.

1.4. Objectives of Smart Agriculture

Smart agriculture represents a turning point in addressing the challenges that hinder the development and advancement of the agricultural sector. It is a modern technology aimed at confronting increasing population growth and unfavorable climatic conditions in order to eliminate poverty and hunger. According to Alexander Müller, Assistant Director-General for Natural Resources at FAO, the transition to smart agriculture methods contributes to protecting farmers from the harmful effects of climate change, provides multiple methods to reduce greenhouse gas emissions and sequester carbon in the soil, improves the quality and type of crops, and raises the income levels of agricultural households. Accordingly, the objectives of smart agriculture can be summarized as follows:

- Enhancing agricultural innovation;
- Creating green jobs;
- Preserving and protecting the environment through better management of natural resources;
- Adapting to climate change;
- Reducing greenhouse gas emissions;
- Reducing hunger and poverty;
- Increasing production and improving the quality of agricultural crops;
- Applying sustainable management of natural resources;
- Improving soil management and fertility;
- Converting animal waste into biogas as an alternative and renewable source of energy;
- Establishing fisheries and aquaculture capable of withstanding climate change.

2. Technologies Used in Smart Agriculture

Among the most prominent technologies used in smart agriculture are the following:

2.1. Modern Agricultural Technologies Related to Equipment

Modern agricultural technologies related to equipment include:

2.1.1. Use of Unmanned Aerial Vehicles (Drones):

They are among the technologies adopted in smart agriculture for monitoring and evaluating crops, photographing agricultural land and mapping it, and measuring air components, in addition to spraying crops with pesticides in a fast and safe manner, and sending data instantly to software that analyzes it and guides farmers to implement the best procedures. Drones are also used to identify damaged plants so that the necessary remedial measures can

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be taken. Farmers can also spray diseased crops using drones with substances to restore them to life, as drones can spray fertilizers at a rate 40 to 60 times faster than doing so by hand. It is also expected that the market for drones in agriculture will reach 480 million dollars by 2027.

2.1.2. Reliance on Robots in Smart Agriculture:

Smart agriculture has increasingly relied on robots, and it is even expected in the future that they will invade fields and farms, with farmers turning into programmers, data analysis experts, and robot developers. What has encouraged reliance on robots is their ability to work around the clock, in addition to collecting huge amounts of data and performing a large number of tasks, which opens horizons for increasing production and improving its quality while reducing the use of pesticides and fertilizers in large quantities.

2.1.3. Self-Driving Tractors:

This technology operates without the need for human labor, as self-driving tractors carry out all agricultural work starting from plowing the land through to harvesting. There are also no concerns related to public safety and security in this modern agricultural technology, due to the absence of people or other vehicles that could collide with them.

2.1.4. Electric Drive Systems:

This is a new step toward development in the field of agricultural technology, through the invention of electric drive systems that enable agricultural vehicles, spraying machines, and other vehicles to generate electrical energy to operate auxiliary tools and attachments.

2.1.5. Automated Grain Unloading:

This technology is based on navigation systems that automatically guide grain carts side by side with harvesters in order to improve cart filling. High harvesting efficiency can also be achieved through improved unloading.

2.2. Modern Agricultural Technologies Related to Information Technology

The entry of information technology into modern agricultural techniques has brought about a breakthrough in the agricultural field. These technologies include the following:

2.2.1. Reliance on the Internet of Things (IoT):

This involves the process of connecting any device to another device via the Internet, from mobile phones to machines used in agricultural fields, so that they can be operated, controlled, and data can be sent to and received from them via the Internet. Among the most prominent applications of the Internet of Things in agriculture are sensors, remote control systems, and self-operating machines. Approximately 12 million agricultural sensors had been installed worldwide by 2023.

2.2.2. Reliance on Mobile Phones:

Mobile phones top the list of digital technologies transforming agriculture, as they have experienced the fastest adoption rates ever among technologies invented during the past century. As of 2019, about 5.2 billion people—two-thirds of the world's population—were current active users of mobile phones. There is also significant reliance by farmers on mobile phones to receive market information and monitor weather forecasts.

2.2.3. Satellite Images:

The use of satellites in agriculture has become widespread in recent times, as they are used for remote crop monitoring, which saves a great deal of money and time. This technology can also be integrated with soil, water, and crop sensors; thus, whenever there is a risk or a

shortage of resources, the farmer can receive a notification. One of the most important roles of satellites is weather forecasting, which enables farmers to determine the timing of seed planting or postpone harvesting, among other decisions.

2.2.4. Digital Security:

Through this technology, there will be a record that documents the journey of food from the farm to the consumer's table, which helps reduce spoilage and waste and identify areas with the greatest need.

2.2.5. Remote Sensing Devices:

Remote sensing devices have become available, easy to use in the agricultural field, and low in cost and accessible to farmers. Agricultural equipment is equipped with sensors, which enables farmers to read everything about plant health and water needs. Irrigation is considered the most recent area of application for these devices, as sensors measure water requirements and help improve water use and avoid crop loss due to agricultural pests.

3. The Reality of the Agricultural Sector at the Level of the Arab World

Before the 1970s, the agricultural sector in the Arab world was able to provide most of the population's food needs. However, after this period, the Arab world entered a food crisis, as a result of which agriculture became at the top of the list of priorities facing Arab countries. The rapid increase in population numbers and the improvement in living conditions led to increased demand for foodstuffs, which caused a deficit in meeting this demand locally, thus forcing Arab governments to resort to external sources.

3.1. Agricultural Resources in Arab Countries

Agricultural resources in the Arab world are considered one of the fundamental pillars for achieving economic development and food security, given the vital role played by the agricultural sector in providing food, creating job opportunities, and supporting social stability. Despite the vast geographical area of the Arab world and the diversity of its climatic regions, the exploitation of these resources still faces multiple structural and environmental challenges.

3.1.1. Agricultural Land

Table (01): Agricultural areas during the period (2022–2023)

Unit: million hectares

Item	2022	2023	Growth rate (%)
Total agricultural area	76.652	76.770	0.2
1. Permanent agricultural land	13.500	13.481	-0.1
a. Rainfed agriculture	9.317	9.179	-1.5
b. Irrigated agriculture	4.183	4.302	2.9
2. Seasonal agricultural land	63.152	63.289	0.2
a. Rainfed agriculture	36.685	36.133	-1.5
b. Irrigated agriculture	13.056	13.488	3.3
c. Fallow land (idle/bare)	13.411	13.668	1.9

Source: Arab Monetary Fund, available through the website: www.amf.org, consulted on: 20/08/2025

Based on the data available from the Arab Monetary Fund website, the total agricultural area recorded a slight increase in 2023 compared to 2022, amounting to approximately 0.1 million hectares, while the area actually cultivated in 2023 witnessed a decrease estimated at about 139 thousand hectares compared to 2022, i.e., approximately 0.2%.

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It is also noted from these data that most of the total agricultural area in Arab countries (82.4%) consists of seasonal lands, and that the largest share of the area actually cultivated in 2023 is rainfed agricultural land (permanent and seasonal), which amounted to approximately 45.3 million hectares (i.e., 71.8% of the actually cultivated area).

It is also observed that there was a decline in the area of rainfed and seasonal agricultural lands between 2022 and 2023, amounting to approximately 552 thousand hectares, which is equivalent to more than half of the abandoned land area between 2022 and 2023. This is due to the low rainfall in 2023.

3.1.2. Natural Rangelands

Natural rangelands occupy about 30.9% of the total area of Arab countries. Their area declined slightly in 2023 compared to 2022, from about 414.7 million hectares to approximately 189.5 million hectares. The largest proportion of rangeland areas is located in the Arabian Peninsula region at 48.2%, followed by the Central and Maghreb regions at 24.4% and 24% respectively, and then the Mashreq region at 3.4%.

Five countries account for more than 85% of the area of natural rangelands in Arab countries, namely Saudi Arabia (46%), Sudan (13%), Somalia (11%), Algeria (9%), and Morocco (7%).

Table (02): Areas of natural rangelands by regions during the period (2022–2023)

Unit: million hectares

Region	2022	2023
Mashreq (Jordan, Syria, Iraq, Palestine, Lebanon)	14.00	14.00
Arabian Peninsula (GCC countries and Yemen)	199.68	1.50
Central region (Egypt, Sudan, Djibouti, Somalia, Comoros)	100.92	74.00
Maghreb (Libya, Tunisia, Algeria, Morocco, Mauritania)	100.08	100.00
Total	414.68	189.50

Source: Arab Monetary Fund, available through the website: www.amf.org, consulted on: 20/08/2025

3.1.3. Water Resources

The Arab world relies on several sources of water resources, including traditional sources such as rainfall, groundwater, and surface water. The quantities of available water resources in the Arab world are estimated at about 274 billion cubic meters. The average per capita share at the level of the Arab world was approximately 640 cubic meters in 2019, declining to about 628 cubic meters in 2020. The average share during the period from 2021 to 2024 reached approximately 480 cubic meters, which is lower than the global water poverty line set at about 1,000 cubic meters annually. Surface water resources constitute 81.2%, while groundwater represents 14.1%, whereas the rate of exploitation of renewable water annually within the Arab region reaches about 77%.

The data in Table No. 03 on water use in the Arab region show that the agricultural sector accounts for 84% of consumed water. Estimates indicate that the rate of water waste used in agriculture ranges between 25% and 30% due to traditional irrigation systems.

Table (03): Levels of exploitation of water resources in Arab countries

Share of annual withdrawal	Countries
Less than 10%	Comoros
10–25%	Mauritania
26–70%	Somalia
71–100%	Algeria
101–200%	Oman
201–500%	Bahrain
1000–1200%	Libya
More than 1200%	Kuwait
(Not shown under a percentage band in the original layout)	Djibouti; Lebanon; Iraq; Syria; Yemen; Saudi Arabia; United Arab Emirates; Palestine; Sudan; Jordan; Qatar; Morocco; Tunisia; Egypt

Source: Arab Monetary Fund, available through the website: www.amf.org, consulted on: 20/08/2025

4.1.4. Population and Labor Force

Agricultural labor in the Arab world in 2020 was estimated at about 22,249.41 million people, representing approximately 17.7% of the total labor force. In 2021, it reached about 23,000.79 million, equivalent to 16.7% of the total labor force. In 2022, it reached about 21,589.48 million people, corresponding to 15.1% of the total labor force. As for 2023, according to the report of the Arab Organization for Agricultural Development, the total share of the agricultural sector from the total labor force in the Arab world was 16.11%. There is no specific statement for the year 2024.

Table (04): Labor force in the agricultural sector in the Arab world during the period (2020–2022)

Unit: million people

Category	2020	2021	2022
Total labor force	135353.81	137618.26	142134.64
Agricultural labor force	22249.41	23000.79	21589.48

Source: Arab Organization for Agricultural Development, available through the website: www.aoad.org, consulted on: 21/08/2025

Table (05): Total and local population numbers in the Arab world during the period (2020–2024)

Unit: million people

Category	2020	2021	2022	2023	2024
Total population	43825	449117	457880	492559	492600
Rural population	177186	179901	181466	185000	185400

Source: World Bank data available through the website: www.worldbank.org, consulted on: 21/08/2025

This decline is due to several reasons, most notably the increase in waves of migration from rural to urban areas, the shift toward employment in other economic sectors, as well as the relative decline in wages in the agricultural sector. This led some of the agricultural workforce to move to work in other sectors, whether in urban areas or in artisanal mining areas in some Arab countries.

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3.1.5. Gross Domestic Product and Gross Agricultural Output

Table (06): Gross domestic and agricultural product of the Arab world during the period (2020–2024)

Category	2020	2021	2022	2023	2024
Total GDP (trillion USD)	2520318	2855979	3467925	3500000	37400000
Total agricultural output (billion USD)	147917	150883	162564	182000	190000

Source: World Bank data available through the website: www.worldbank.org, consulted on: 21/08/2025

According to the data shown in Table No. 06, it is clear that the gross domestic product of the Arab world experienced contraction in 2020 due to the COVID-19 pandemic, which struck global and local activity. Its impact appeared in the decline of tourism activity, reduced demand for services, and the slowdown of trade. Countries dependent on tourism (Egypt, Morocco, and Tunisia) and those with advanced service activities were severely affected, while oil-producing countries witnessed variation depending on the decline and volatility of oil prices in 2020. In 2021, the recovery of global demand and the reopening of economic sectors pushed toward positive growth. At the beginning of 2022, oil and gas prices rose, giving a noticeable boost to reducing deficits in some exporting countries and improving their external balances; this was reflected in an increase in the nominal value of total output for the group of exporting countries. Meanwhile, 2023 and 2024 witnessed mixed performance, between improved oil revenues for a number of countries and pressures on real growth from inflation and rising living costs, in addition to the slowdown in growth of energy-importing countries.

As for gross agricultural output, in 2020 demand for logistics services, tourism, and market sales declined, leading to disruptions in supply chains and pressure on farmers' incomes in countries that rely on local markets. Some storable crops were affected by distribution problems. In 2021, due to the reopening of economies and export activities, demand movement returned, but the recovery was uneven. Countries producing grains and basic agricultural products recovered faster than countries exporting fresh vegetables and fruits affected by logistics. During the period 2020–2023, the war in Ukraine led to higher prices of grains, fertilizers, and energy. This increased the nominal value of production of some crops but narrowed farmers' profit margins due to input costs. Food-importing countries suffered from increased import bills. In 2024, some prices declined from their peaks, but climate problems (recurrent drought) and lack of investment in water and irrigation infrastructure allowed long-term risks to persist. Production indicators recorded limited improvement in some countries, but not a decisive recovery at the regional level.

3.1.6. Average Per Capita Share of Gross Domestic Product and Agricultural Output

Table (07): Average per capita share of gross domestic product and agricultural output

Category	2020	2021	2022	2023	2024
Average per-capita share of total GDP (million USD)	5750.87	6358.09	7573.87	7482.00	7557.00
Average per-capita share of agricultural output (thousand USD)	337.52	335.96	355.04	354.02	310.09

Source: World Bank data available through the website: www.worldbank.org, consulted on: 21/08/2025

With regard to the average per capita share of gross domestic product during the period 2020–2024, as shown in the table above, per capita GDP in Arab countries experienced fluctuations linked to global economic crises and oil and gas prices. During 2020–2021, there was a relative decline in per capita share due to the COVID-19 pandemic, as the economies of oil-producing and service-based countries were more affected, which was reflected in a decline in the average Arab per capita share. During 2022–2023, there was a gradual recovery with rising oil and energy prices, which helped increase the average per capita share to about 7,482 dollars. In 2024, recovery continued and economic activities improved, but the gap between wealthy oil-producing countries and agricultural or less developed economies remained very clear.

As for the average per capita share of agricultural output, it shows a relatively low level in Arab countries compared to the per capita share of total gross domestic product. This is due to the weak contribution of the agricultural sector to the overall economic structure, as the share of agriculture in most Arab countries does not exceed 4–5% of GDP. This situation reflects the concentration of economic activity in other sectors such as oil, services, and trade, especially in Gulf countries.

The average per capita share of agricultural output is also significantly affected by population size, as rapid population growth in many Arab countries leads to a reduction in per capita share even when total agricultural production increases. This phenomenon is clearly evident in countries with high population density, where agricultural expansion does not keep pace with population growth, leading to increasing pressure on limited agricultural resources.

Agricultural productivity plays a decisive role in determining the level of this indicator, as limited use of modern technology, weak efficiency of irrigation systems, and the impact of climate change all limit the ability of the agricultural sector to raise value added, and thus to improve per capita share. In contrast, some countries that invested in modern agricultural technologies record relatively higher per capita shares despite limited natural resources.

4. The Reality of Smart Agriculture in the Arab World

Smart agriculture is expected to be an effective treatment and an indispensable strategic approach in raising the efficiency of agricultural resource use and increasing production and productivity in Arab countries, thereby contributing to the achievement of food security on the one hand and the preservation and sustainability of natural resources on the other. In addition, it plays a role in providing food that is safe for health and free from pollution, due to the absence of chemical fertilizers and pesticides harmful to health and the environment, as well as its importance in overcoming the negative effects of climate change on Arab agricultural systems (Haddada, 2018, p. 08).

4.1. Qatar's Experience in Smart Agriculture

The State of Qatar is considered one of the countries with difficult environmental conditions for agriculture, as it suffers from water scarcity, limited arable land, and high temperatures. Despite this, the state has adopted smart agriculture as a strategic option to enhance food security and reduce dependence on imports, especially after the challenges revealed by regional and global crises.

It is considered one of the leading countries regionally and globally in employing technology in agriculture. For years, it has been keen to adopt the latest technologies in the field

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of smart agriculture, through launching numerous initiatives and projects aimed at integrating artificial intelligence into agricultural operations.

The Qatar Smart Farms initiative reflects the extent of attention given to artificial intelligence in improving crop quality and increasing productivity. According to a report by the website Genetic Literacy Project, published at the beginning of last November, Doha succeeded in overcoming the high salinity levels in groundwater using agricultural technologies, in addition to using greenhouses, which granted it the ability to control temperatures.

The website indicated that the use of technology in agriculture in Qatar allowed farmers to achieve two main objectives: ensuring year-round production of various types of vegetables and fruits, and significantly increasing their production capacities, which enhances reliance on local products.

Qatar has relied on a set of modern technologies, most notably (Ministry of Environment, n.d.):

- Smart greenhouses equipped with automated systems for controlling temperature and humidity.
- Hydroponics and soilless agriculture, which significantly reduce water consumption compared to traditional agriculture.
- Smart drip irrigation systems connected to sensors to measure soil moisture.
- The use of solar energy to operate some agricultural projects.
- The employment of artificial intelligence and remote sensing to monitor production and improve efficiency.

In 2023, Qatar concluded agreements with Korean companies to develop technology that can be used in agricultural activity, foremost among them greenhouse technologies. The state began using this technology in recent months, and it is expected that 30% of the current vegetable and fruit production areas will be converted into smart farms by 2027.

Smart agriculture has contributed to:

- Increasing local production of fresh vegetables and reducing the import gap.
- Improving the efficiency of water use in an environment suffering from water scarcity.
- Reducing production costs in the medium term despite the high initial investment cost.
- Creating high-quality job opportunities in the fields of agricultural technology and smart farm management.

4.2. The Experience of the United Arab Emirates in Smart Agriculture

Innovative and smart agriculture in the United Arab Emirates is considered a strategic step toward achieving food security and environmental sustainability. Through clear objectives, advanced tools, effective partnerships, and sustainable financing, the UAE seeks to build a sustainable agricultural future that ensures meeting the needs of future generations. These efforts reflect the state's commitment to promoting innovation and achieving sustainable development across all sectors.

The United Arab Emirates has undertaken the following (Ministry of Climate Change and Environment, n.d.):

- Launching strategic initiatives to facilitate the use of agricultural technology and develop climate-smart food and agricultural systems.
- Introducing hydroponic farming into the country's agricultural system to increase the productivity of environmentally friendly and climate-adapted crops and reduce emissions.

– On June 22 in Abu Dhabi, the UAE made significant progress in developing climate-smart agricultural practices as part of its pursuit of its strategic goal of achieving climate neutrality by 2050 and the targets of the National Food Security Strategy by 2051, as well as reducing carbon emissions in the agricultural sector.

– The UAE has achieved important accomplishments in this context by adopting innovative agricultural technology projects such as the solar-powered Net House, and by mobilizing research efforts and financial resources for this purpose, making its experience in this sector an inspiring global model—especially as it hosts the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP28) from November 30 to December 12 of the current year in Expo City Dubai. This makes the global platform an ideal opportunity to showcase inspiring experiences and to bring about a qualitative shift in climate-smart agriculture to achieve sustainable food security.

The UAE uses a range of methods and technologies to achieve its goals in innovative agriculture, including:

– Vertical farming: The UAE relies on vertical farming technologies that allow crops to be grown in small spaces, increasing productivity and reducing water consumption.

– Hydroponic farming: Hydroponic systems are used to reduce soil and water use, contributing to improved production efficiency.

– Artificial intelligence: AI technologies are used to analyze agricultural data, helping farmers make informed decisions regarding cultivation.

– Robotics: Robots are used in farming and harvesting operations, increasing efficiency and reducing the need for manual labor.

Models of Innovative and Smart Agriculture in the United Arab Emirates:

– Dubai Food Tech Valley Pioneer of Agricultural Innovation: The new Food Technology Valley in Dubai is considered the world's first city specialized in agricultural technology, representing a pioneering step toward achieving food security and environmental sustainability. The valley is located in the Warsan area and covers a vast area of up to 18 million square feet, providing an ideal environment for developing innovative and sustainable agricultural methods. The valley aims to enhance Emirati exports of fresh products to regional and global markets, as it is expected to produce more than 300 varieties of crops using the latest available agricultural technologies.

– Innovative and smart agriculture in the UAE Vertical farming, an innovative model: Badia Farms is considered the first farm to rely on vertical farming technology in Dubai, extending over an area of 8,500 square feet. This farm relies on hydroponic technology to grow vegetables and herbs needed by local restaurants, contributing to the provision of fresh, high-quality products. Projects such as Badia Farms aim to achieve the concept of farm to table, enhancing Dubai's position as a global destination for fruit and vegetable production.

Dubai Industrial City also hosts a new vertical farm affiliated with Badia Farms, which operates with advanced technology. In a step reflecting the UAE's commitment to innovation, Emirates Flight Catering and Crop One are investing USD 40 million to build the largest vertical farming center in the world near Al Maktoum International Airport in Dubai World Central. This project is considered a strategic partnership with Crop One Holdings, a global leader in vertical farming headquartered in the United States.

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– Hydroponic farming The revolution of innovative and smart agriculture in the UAE: The UAE is working to promote the use of hydroponic technology among farmers. This technology relies on nutrient-rich water to grow plants using small amounts of soil or without soil. This method has revolutionized the agricultural sector, as it contributes to reducing water consumption by up to 70% and avoiding the use of harmful chemicals, which helps extend the growing season.

Hydroponic technology requires a smaller space to produce larger quantities of crops, making it an ideal option in a desert environment such as the UAE. This technology was first introduced in the country in 2009, and since then the number of greenhouses dedicated to hydroponic farming has seen a noticeable increase. High-quality seeds, greenhouses, and research and development services have also been provided to farmers, encouraging them to adopt hydroponic and organic farming.

– Emirates hydroponic farms extending between Abu Dhabi and Dubai: The hydroponic farms extending between Abu Dhabi and Dubai are considered among the largest producers of agricultural crops using hydroponic farming in the country. They include a group of experts in this field, including the company Pegasus Agritech in Dubai.

The Dubai Food Technology Valley represents a model to be emulated in the field of agricultural innovation, as it combines modern technology with sustainable practices to achieve food security. Through vertical farming and hydroponic farming, the UAE seeks to enhance its agricultural production and meet the needs of local and international markets, contributing to the achievement of sustainable development and strengthening its position as a leading country in agricultural technology.

4.3. The Experience of the Kingdom of Saudi Arabia in Smart Agriculture

The Ministry of Environment, Water and Agriculture is working to localize modern agriculture in the Kingdom and to support and encourage innovation and research in the agricultural sector, in order to achieve food security, reduce imports, and ensure the sustainability of natural and water resources while preserving the environment. This is done through the use of hydroponic technologies such as hydroponics, aquaponics, vertical farming, protected agriculture (greenhouses), and smart agriculture using artificial intelligence, which reduces water consumption, increases productivity, and improves the efficiency of natural resource use.

The desert environment in the Kingdom is no longer an obstacle to food production; rather, it has become a promising land for agricultural innovation, thanks to modern technologies that have brought about a qualitative shift in production methods and opened new horizons for investors and entrepreneurs. The importance of modern agriculture lies in providing food that is safe for health and free from pollution, due to its reduction in the use of chemical fertilizers and pesticides harmful to health and the environment, in addition to its ability to overcome the negative effects of climate change on agricultural systems. It also contributes to raising productivity rates and quality specifications without depleting natural resources, while reducing agricultural production costs, which ensures increased farmers' incomes and improved living standards.

Smart agriculture is expected to be an effective remedy and a vital, indispensable strategy for improving the efficiency of agricultural resource use and increasing production in the

agricultural sector. In this context, the Ministry of Environment laid the foundation stone for the smart agriculture project in Riyadh, in a step aimed at transforming the course of modern agriculture and enhancing innovation in the agricultural sector, thereby contributing to achieving food security and sustainable development in the Middle East region.

The Kingdom currently relies on a package of smart agricultural technologies that have proven their efficiency in arid environments, most notably: hydroponic agriculture (Hydroponics), which saves up to 90% of water compared to traditional agriculture; vertical farming (Vertical Farming), which enables the production of high-quality crops in limited spaces, with high control over product quality and reduced or zero use of insecticides and disease-control pesticides; as well as high-tech greenhouses equipped with climate, irrigation, and fertilization control systems (Ministry of Environment, n.d.).

The results of pilot projects carried out by the Ministry indicate that productivity in high-tech greenhouses exceeds that of traditional agriculture by varying percentages depending on the technology used in the greenhouse and the crop type, while significantly reducing water and fertilizer consumption. For example, experiments conducted at the Istdama Center in hydroponic agriculture demonstrated water savings of up to 90%, along with the production of high-quality vegetables suitable for local and global markets. Tomato production in high-tech glasshouses reached 99 kilograms per square meter, with water consumption of three liters per kilogram, and record efficiency in energy consumption.

Among the modern technologies that offer promising solutions for improving agricultural production and reducing water consumption is biofertilizer technology, which is used in desert agricultural systems and relies on the presence of beneficial microbes in the soil, contributing to improved crop growth efficiency and increased absorption of water and nutrients. Likewise, nanotechnology is considered one of the most prominent sustainable solutions, as nanomaterials are characterized by their extremely small size, opening wide horizons for improving agricultural processes and enhancing water-use efficiency by between 20% and 30%, making it a strategic tool to confront contemporary food and environmental challenges.

Biochar is considered a means to improve water management and increase agricultural productivity in some desert environments. Studies have shown that adding biochar reduces water loss through evaporation by between 9% and 11%, saves approximately 20% of irrigation water, and contributes to increasing agricultural productivity by 37%, confirming its effectiveness in enhancing crop growth and achieving agricultural sustainability in arid and semi-arid environments. In addition, the cultivation of seasonal winter fodder plays an important role in enhancing agricultural sustainability, especially in light of challenges related to water scarcity, as these fodder crops are characterized by their ability to benefit from seasonal rainfall during the winter, reducing dependence on groundwater. Duckweed is also considered one of the most promising alternatives for fodder in the last decade, due to its high protein content, which may exceed 40% of dry weight, making it an outstanding option in compound feeds for feeding livestock, poultry, and fish. It helps reduce reliance on imported soybeans. This plant is also distinguished by its flexibility in cultivation, as it can be produced in open fields or through hydroponic and vertical farming systems under artificial lighting, due to its low light requirements, which reduces land and water consumption compared to traditional fodder crops.

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The strategy of the Ministry of Environment, Water and Agriculture, which encourages the widespread use of modern technologies in the agricultural sector, represents an important step toward enhancing agricultural productivity, achieving food security, and ensuring the sustainability of natural resources, which are among the main targets of Saudi Vision 2030.

4.4. The Experience of Egypt in Smart Agriculture

The Egyptian agricultural sector has faced a set of challenges, most notably population density growth, in addition to water scarcity and the increasing encroachment on agricultural land. The total cases of encroachment on agricultural land reached approximately 79.1 thousand feddans during the period (2011–2019), in addition to the fragmentation of agricultural holdings, as the average holding is expected to decline to less than three feddans for about 80% of farmers. Consequently, agricultural returns are likely to decrease, and small farmers may resort to leaving land uncultivated and selling it as construction land to achieve higher returns. As a result, demand for food will increase and prices will rise, especially after studies indicated that rising temperatures will negatively affect crop productivity (Ministry of Agriculture, n.d.).

Accordingly, the Egyptian state has sought to enhance smart agriculture by activating its technologies in large holdings, such as the pivot irrigation technology that is remotely operated and controls water quantities in the New Delta Project. In addition, the Ministry of Agriculture and Land Reclamation, in cooperation with some relevant local and international institutions, launched the application of climate-smart agriculture to achieve the maximum possible benefit for farmers from artificial intelligence (AI). The application includes an information database on the four most important strategic crops, foremost among them wheat, and the database contains a detailed depiction of pests and insects that may affect the crop and effective methods for treating them. In addition, the smart assistant application for farmers, Hodhod, was launched in Arabic; it relies on artificial intelligence and aims to help farmers obtain agricultural consultations easily. The Ministry of Planning, Economic Development, and International Cooperation also launched a partnership with the World Bank Group in 2023 to enhance the utilization of the (EgCITE) project, funded by the Korean Green Growth Development Fund, which works on localizing best international technologies and practices to promote climate-smart agriculture in Cairo. Furthermore, the Ministry of Agriculture and Land Reclamation cooperated with the Food and Agriculture Organization (FAO) in implementing farmer field school projects to carry out approximately 105 projects in Kharga Oasis in the New Valley Governorate.

5. Conclusion:

Smart agriculture represents an advanced model of sustainable agriculture that combines technological innovation with efficient management of natural resources, and lays solid foundations for a more productive and resilient agricultural sector capable of confronting environmental, economic, and social challenges alike. Smart agriculture also contributes to achieving environmental and economic sustainability goals, as it reduces dependence on traditional water resources, limits the excessive use of pesticides and chemical fertilizers, and helps reduce carbon emissions resulting from traditional agricultural practices. At the same time, this type of agriculture supports rural economic growth by increasing farmers' financial returns and stimulating innovation in the agricultural sector, which contributes to the development of industries related to modern agricultural technologies.

Accordingly, establishing smart agriculture in Arab countries has become an indispensable strategic option in light of the increasing challenges facing the agricultural sector, foremost among them climate change, water resource scarcity, the widening food gap, and growing demographic pressures. This study has shown that smart agriculture represents an integrated framework that combines technological innovation with sound management of natural resources, thereby contributing to achieving agricultural sustainability and enhancing Arab food security.

The study concludes that the existing disparity among Arab countries in the level of adoption of smart agriculture calls for strengthening regional cooperation, exchanging expertise, and unifying agricultural visions and strategies, in a way that allows overcoming technical and financial obstacles. The Arab agricultural reality also necessitates integrating smart agriculture within comprehensive development policies and linking it to sustainable development goals, with special attention given to small farmers and rural areas.

Accordingly, establishing smart agriculture in Arab countries does not represent merely a technical option, but rather a comprehensive development pathway aimed at building a resilient agricultural system capable of adapting to future changes, thereby ensuring food security, protecting natural resources, and enhancing economic and social stability in the Arab region.

5.1 Study Results:

The study reached the following results:

- The agricultural sector in the Arab world suffers from low productivity and a high dependence on food imports, despite the availability of considerable natural and human resources. This is mainly due to water scarcity, climate change, and the dominance of traditional methods.
- Smart agriculture is a fundamental tool for improving agricultural productivity and rationalizing the use of resources, especially water and energy, in light of climate change.
- Smart agriculture is considered a necessity for preserving agricultural resources and ensuring their sustainability.
- Many Arab countries, such as Qatar, the United Arab Emirates, the Kingdom of Saudi Arabia, and Egypt, have succeeded in transitioning from traditional agriculture to smart agriculture based on modern technology, as an initial experience that has been crowned with success.

5.2 Study Recommendations:

Based on this study and the results reached, the following recommendations can be presented:

- Preparing an enabling political and legal environment to overcome the barriers that hinder the adoption of smart agriculture.
- Integrating smart agriculture into national agricultural strategies and linking it to food security and sustainable development goals.
- Increasing investments allocated to smart agriculture to create digital solutions that meet the needs of all actors in the agri-food system of Arab countries.
- Unleashing the capacities and energies of the private sector to invest in smart agriculture.
- Integrating climate change considerations into the planning and operations of national agricultural investments.

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- Supporting joint investments between sectors to expand the scope of smart agriculture practices and approaches and to provide higher returns on investments.
- Supporting scientific research and agricultural innovation and strengthening cooperation between universities, research centers, and the private sector.
- Empowering small farmers through training, financing, and technology transfer to ensure equity in the transition toward smart agriculture.
- Encouraging Arab integration and cooperation in the exchange of expertise, agricultural data, and successful experiences.

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