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The Role of Smart Agriculture in Promoting Sustainable Development - Successful International Experiences

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Abstract

The present study aims to shed light on the role and contribution of smart agriculture in achieving sustainable development by addressing the importance of modern technology in the agricultural sector to enhance sustainable development. This is done through presenting successful international experiences that have adopted modern technology strategies to improve the agricultural sector and promote sustainable development. The study clarifies the concept of smart agriculture and its areas of application, as well as the resulting advantages for the agricultural sector in Arab, African, and Asian countries. It also explores the various policies adopted by Africa at both continental and regional levels to support the implementation of smart agriculture. Moreover, the study highlights the challenges facing this significant transformation in the African agricultural sector.

Keywords: *Smart agriculture, sustainable development, technology, international experiences.*

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Introduction

The agricultural sector faces various challenges that differ from one country to another, yet they share many common factors, such as population growth, limited water resources, and climate change. With the global population projected to reach 9.6 billion by 2050, the demand for food is expected to rise significantly. In response, developed countries are utilizing digitalization and modern technologies to enhance agricultural productivity and meet increasing food demands. Consequently, there is a need for a vision rooted in sustainable development solutions, which includes the development of digital skills, support for agricultural entrepreneurship, promotion of a culture of innovation, and nurturing of talents capable of implementing digitalization in a way that benefits various sectors, ensures food security, improves nutrition, promotes sustainable agriculture, and conserves natural resources.

Definition of Smart Agriculture

Climate-smart agriculture (CSA) represents an evolution of the concepts of "sustainable agriculture," including green agriculture—an approach that guides the necessary actions to transform and redirect agricultural systems to effectively support sustainable development and ensure food security in the face of climate change. Smart agriculture refers to the technologies and agricultural practices aimed at improving productivity without polluting the environment or negatively contributing to climate change[2]. CSA promotes the adoption of agricultural systems that pursue green practices and are resilient to climate change. It also supports the achievement of internationally agreed-upon objectives, such as the Sustainable Development Goals (SDGs) and the Paris Agreement[3].

According to the Food and Agriculture Organization (FAO) of the United Nations, climate-smart agriculture aims to address three main objectives: (1) ensuring food security by sustainably increasing

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[2] Adornis D.Nciizah, " Climate Smart Agriculture : Achievements and Prospects In Africa" Journal of Geoscience and Environment Protection, 2015, PP.100-102 , Available at : https://www.scirp.org/pdf/GEP_2015082416392005.pdf

[3] ADEMOLA BRAIMOH , Climate-smart agriculture: Lessons from Africa, for the World, World Bank Blogs , JANUARY 17, 2018. , Available at : https://blogs.worldbank.org/nasikiliza/climate-smart-agriculture-lessons-from-africa-for-the-world

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agricultural productivity and income, (2) building resilience and adaptation to climate change, and (3) reducing greenhouse gas emissions where possible[4].

The Contribution of Smart Agriculture to Promoting Sustainable Development

Numerous experiences in developing countries have shown that empowering young farmers to use tools associated with smart agriculture can help them increase production and productivity in a way that improves their social conditions and injects new momentum into the local agricultural economic cycle—within a solidarity-based economy that considers local economic priorities and sustainable development principles.

However, civil society organizations engaged in local sustainable development have increasingly noted that while smart agriculture is being adopted in more cases, some actors use it to promote intensive agriculture models that are not necessarily aligned with food security or the preservation of natural resources. Many activists from various grassroots organizations today oppose the promotion of smart agriculture, arguing that this form of agricultural activity relies heavily on financial resources and technical skills that most small-scale or family farmers do not possess. They also criticize it as a veiled form of intensive agriculture[5].

For example, they point to Monsanto, a global company part of the international coalition advocating smart agriculture and specializing in the production and promotion of chemical fertilizers, as not being a genuine ally of small farmers. These critics argue that Monsanto is primarily focused on controlling farmers and pushing them to use its products, regardless of whether those products contribute to food, health, or environmental security.

Smart agriculture is described as "smart" because it effectively uses modern technology to optimize the use of natural resources, particularly water, and to manage the application of chemical fertilizers more efficiently. Proponents argue that while intensive use of such fertilizers is expensive and environmentally harmful, relying solely on organic farming—which typically avoids any chemical fertilizers—is not a realistic approach to meeting the growing food needs of the population[6].

This argument was one of the main reasons why the FAO adopted smart agriculture in 2010. The organization stated that the key objectives of this agricultural model are to increase production sustainably, adapt to climate conditions, reduce greenhouse gas emissions, improve food security, and contribute to achieving the Sustainable Development Goals[7].

In September 2014, an international alliance was formed in New York to advocate for "smart agriculture" on the sidelines of a climate summit organized by the United Nations. Since then, members of this alliance have actively promoted the idea of expanding the use of this form of agriculture[8].

Smart agriculture can contribute to achieving sustainable development through the following elements[9]:

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[4] Hanne Knaepen, Carmen Torres and Francesco Rampa , Making agriculture in Africa climate-smart. , European Centre for Development Policy Management, No.80 – November 2015, PP.2-3. , Available at : https://ecdpm.org/wp-content/uploads/BN80_CSA_Making_Agriculture_Africa_climate_Smart.pdf

[5] https://www.mc-doualiya.com

[6]

[7] International Atomic Energy Agency. (2022). Developing Climate-Smart Agricultural Practices. Available at: https://www.iaea.org/ar/almawadie/tatwir-mumarasat-ziraeiat-dhaki

[8] Tadesse, M., Simane, B., et al. (2021). The effect of climate-smart agriculture on soil fertility, crop yield, and soil carbon in southern Ethiopia. Sustainability, 13(8). p. 13. Available at: https://green-twigs.com/ar/blog

[9] https://green-twigs.com/ar/blog

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Ensuring Food Security

- Agriculture is the primary source of food, which is a fundamental necessity for survival.
- Promoting sustainable agricultural practices reduces resource waste and increases land productivity.
- Cultivating local crops reduces reliance on imports, thereby strengthening food security.

Boosting the Economy

- Agriculture provides a livelihood for millions of people around the world, particularly in rural areas.
- Developing small and medium-sized agricultural enterprises creates job opportunities and helps reduce unemployment.
- Investing in agriculture contributes to an increase in GDP, especially in developing countries.

Environmental Conservation

- Sustainable agriculture relies on technologies that reduce pollution, such as organic farming and the use of renewable energy.
- Tree planting and crop cultivation help reduce carbon emissions and combat climate change.
- Healthy soils and protected forests contribute to preserving biodiversity[10].

Promoting Social Stability

- Agricultural projects enhance community participation and promote equitable resource distribution.
- Empowering women in the agricultural sector is an important step toward achieving gender equality.

Examples of Successful Countries in Implementing Smart Agriculture and Its Role in Achieving Sustainable Development

The Experience of Arab Countries:

The Role of Smart Agriculture in Achieving Sustainable Development in the Kingdom of Saudi Arabia

Smart agriculture is an advanced agricultural system that relies on modern technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and data analytics to enhance farming operations and increase efficiency. This approach aims to achieve higher productivity while reducing the consumption of resources such as water and energy, thereby promoting the sustainability of the agricultural sector.

[10] Tadesse, M., Simane, B., Abera, W., Tamene, L., Ambaw, G., Recha, J. W., ... Solomon, D. (2021). The effect of climate-smart agriculture on soil fertility, crop yield, and soil carbon in southern Ethiopia. Sustainability, 13(8). https://doi.org/10.3390/su13084515

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The Importance of Smart Agriculture in Saudi Arabia

Saudi Arabia faces significant agricultural challenges, most notably water scarcity and high temperatures. Smart agriculture offers effective solutions to address these issues through[11]:

- **Efficient Water Management:** Smart irrigation technologies and soil moisture sensors are used to optimize water usage and reduce waste.
- **Increased Productivity:** Data analytics and AI help determine the best times for planting and harvesting, leading to improved crop yields.
- **Cost Reduction:** Automation and continuous monitoring technologies reduce operational costs and increase farmers' profitability.
- **Environmental Preservation:** Smart agriculture contributes to reducing environmental impact by using resources sustainably and lowering carbon emissions[12].

Smart Agriculture Technologies Used in Saudi Arabia

Smart agriculture relies on a set of innovative technologies that contribute to improving the performance of the agricultural sector. Key technologies include:

- **Hydroponics and Vertical Farming:** These methods allow crops to be grown in controlled environments without traditional soil, saving space and significantly reducing water consumption[13].
- **Sensors and the Internet of Things (IoT):** Used to monitor environmental conditions such as temperature, humidity, and light levels, enabling informed agricultural decisions.
- **Artificial Intelligence and Data Analytics:** These tools analyze large volumes of agricultural data to enhance operations and predict potential problems before they occur.
- **Robotics and Smart Agricultural Machinery:** Deployed to automate farming processes such as planting and harvesting, thereby improving efficiency and reducing the need for manual labor.

Benefits of Smart Agriculture for Saudi Farmers and Society

Smart agriculture offers numerous advantages for both farmers and society, including:

- **Increased Agricultural Income:** By boosting productivity and reducing costs, farmers can enhance their profits and achieve financial sustainability.
- **Improved Crop Quality:** Smart technologies enable precise monitoring of environmental conditions, resulting in high-quality agricultural produce.
- **Enhanced Food Security:** With increased productivity and more efficient resource use, smart agriculture supports the Kingdom's food security goals.

[11] https://www.najdagritech.com/ar/post

[12] FAO (Food and Agriculture Organization). 2018. Climate-Smart Agriculture. Training Manual. A Reference Manual for Agricultural Extension Agents (Policy 333 Support and Governance). Rome: Food and Agriculture Organization of the United Nations.

[13] FAO (Food and Agriculture Organization). 2018. Climate-Smart Agriculture. Training Manual. A Reference Manual for Agricultural Extension Agents (Policy Support and Governance). Rome: Food and Agriculture Organization of the United Nations.

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- **Creation of New Job Opportunities:** The adoption of smart technologies in agriculture requires new skills, leading to job creation in technology and data sectors[14].

Challenges Facing the Adoption of Smart Agriculture in Saudi Arabia

Despite its many benefits, the adoption of smart agriculture in the Kingdom of Saudi Arabia faces several challenges, including:

- **High Investment Costs:** Smart technologies require substantial initial investments, which may pose a barrier for small and medium-scale farmers.
- **Lack of Technical Expertise:** Farmers need training and skill development to use smart technologies effectively.
- **Infrastructure Requirements:** Implementing smart agriculture demands advanced infrastructure, including reliable and widespread internet networks and continuous technical support.
- **Adaptation to Change:** Farmers must be flexible and willing to adapt to new methods and technologies, which often involve significant changes to traditional practices.

The Future of Smart Agriculture in Saudi Arabia

Current trends indicate that smart agriculture will receive increasing support from both the government and investors in Saudi Arabia. Continued innovation in this field is expected to transform the agricultural sector into a more efficient and sustainable industry. Furthermore, government initiatives will likely provide financial and technical support to farmers, facilitating the adoption of smart technologies and strengthening their ability to overcome future challenges[15].

Experience of African Countries

African Policies to Make Agriculture Climate-Smart

The focus on smart agriculture has steadily increased from the mid-2000s to the late 2010s, with particular attention to the links between agriculture and climate change during the Durban COP (Conference of the Parties) in 2011. This focus continued at COP 22 in Marrakech in 2016, which some called the "Conference of the Parties for Agriculture." The global Sustainable Development Goals (SDGs) agreed upon in 2015 explicitly acknowledged the integrated and indivisible interconnection between sustainability goals, highlighting the relationship between food, water, energy, and climate change as a prime example of the need to maximize synergies to achieve them jointly.

Within this framework, African interest in green agricultural development increased. At the regional level, in July 2009 during the 13th African Union Summit in Sirte, Libya, African leaders emphasized the urgent need to address the multiple goals of food security, development, and climate change. This led to the adoption by the African Union Commission–New Partnership for Africa's Development (AUC-NEPAD) of the Climate-Smart Agriculture framework in 2010. This was in response to the 2003 Maputo Declaration of the African Union in Mozambique, which launched the Comprehensive Africa Agriculture Development Program (CAADP) in 2003. CAADP is the African Union's flagship program aimed at accelerating agricultural transformation across the continent, striving to balance economic growth and sustainability. The framework provides African countries with a clear set of principles, best practices, guidelines, and

[14] Kofi Akamani,(2021). An ecosystem-based approach to climate-smart agriculture with some considerations for social equity. Agronomy, 11(8), 1564. http://dx.doi.org/10.3390/agronomy11081564

[15] Todd S. Rosenstock Christine Lamanna Sabrina Chesterman Patrick Bell Aslihan Arslan Meryl Richards Akinwale O. Akinleye and others,(2016)," The Scientific Basis of Climate-Smart Agriculture: A Systematic Review Protocol; Working Paper No. 138; Consultative Group on International Agricultural Research (CGIAR): Montpellier, France.

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targets through which national agricultural strategies and plans can be aligned with local realities and capacities [9]. Also notable is the 2014 Malabo Declaration of the African Union, which issued the Sustainable Agricultural Transformation Strategy in Africa and set a goal to achieve climate-smart agriculture use by no less than 25 million farming households by 2025[16].

At the level of regional economic communities in Africa, in 2009, the Common Market for Eastern and Southern Africa (COMESA) Heads of State and Government Summit was held in Zimbabwe to approve the "Regional Climate Change Framework," which strengthened the role of agriculture, forestry, and land use in climate adaptation and mitigation. COMESA also launched the "COMESA Climate-Smart Agriculture Partnership" platform to initiate climate-smart agriculture programs in member states. Another program was developed including three regional economic communities: COMESA, the Southern African Development Community (SADC), and the East African Community (EAC), focusing on climate-smart agriculture. This resulted in the launch of a regional strategy and action plan to promote climate-smart agriculture operations. Additionally, the Economic Community of West African States (ECOWAS) adopted a green agricultural investment plan to adapt to climate change. On June 20, 2015, ECOWAS organized a regional forum in Bamako to monitor agricultural practices and their alignment with environmental conservation principles.

Practical Cases of Climate-Smart Agriculture Applications in Africa

South Africa

A project is being implemented to promote climate-smart agriculture technologies in many rural communities in the Eastern Cape and KwaZulu-Natal provinces. The project focuses on ensuring sustainable land use and natural resource management while enhancing food production, developing enterprises, and creating job opportunities. The project has seen increases in maize production, especially in the Eastern Cape province. Additionally, there are more state-funded agricultural projects, particularly those related to smallholder farms.

The Food and Agriculture Organization (FAO) has conducted extensive training and implementation for small-scale ecological farms employing around 27,000 people annually, along with other capacity-building programs focused on natural resource harvesting, assisting communities in harvesting rainwater for home gardens, and reducing soil erosion. It is estimated that about 40,000 people have directly benefited from these programs. Similarly, the South African Department of Agriculture, Forestry, and Fisheries consistently promotes projects that incorporate climate-smart agriculture principles throughout the country.

Ethiopia

Ethiopia is considered one of the African countries most vulnerable to the impacts of climate change. Therefore, it aims to build a middle-income economy by 2025 that is resilient to the adverse effects of climate change, while also improving food security, the income of farmers and pastoralists, and protecting and rehabilitating forests for their economic services and ecosystems [12]. Among the programs Ethiopia has adopted in the field of climate-smart agriculture applications are: the Sustainable Development and Poverty Reduction Program (2005–2012), the Plan for Accelerated and Sustained Development to End Poverty (2005/2006–2009/2010), and the Growth and Transformation Plan (2010/2011–2014/2015). Ethiopia has pursued integrated watershed management, sustainable land management, agricultural critical

[16] Victor O. Abegunde , & Ajuruchukwu Obi, The Role and Perspective of Climate Smart Agriculture in Africa: A Scientific Review, 2022 , Available at : https://www.mdpi.com/2071-1050/14/4/2317/htm

Hanne Knaepen, Carmen Torres and Francesco Rampa , Op.cit , PP.5-6.

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areas, and organic agricultural waste management, increasing the area of farmland relying on organic fertilizers instead of chemical ones by 3 to 5 times[17].

- **Zimbabwe:**
  The Zimbabwean government adopted a national program based on the principles of climate-smart agriculture to conserve resources in an effort to enhance food security and self-sufficiency. This program serves about 1.8 million smallholder farmers to increase production and productivity, making them more resilient to climate change shocks [14].

- **Kenya:**
  Kenya has a Climate-Smart Agriculture Program (CSAP 2015-2030) aimed at sustainable, climate-resilient, and low-carbon agriculture contributing to national development goals aligned with Kenya Vision 2030. The program unites efforts from two ministries: the Ministry of Environment and Mineral Resources and the Ministry of Agriculture, Livestock, and Fisheries. It receives technical and financial support from various sources including the NEPAD Climate Fund, the Common Market for Eastern and Southern Africa (COMESA), the East African Community (EAC), and the CGIAR research program on climate change, agriculture, and food.

Kenya's CSAP focuses on four strategic priorities:
• Establishing national systems to promote best practices, technologies, and CSA approaches,
• Developing value chain systems where both public and private sectors are key players,
• Supporting demand-driven research for development and innovation,
• Improving and sustaining agricultural advisory services.

Kenya has achieved positive outcomes in climate-smart agriculture including:

- Increased maize productivity by 2 to 4 hectares through soil fertility conservation and organic farming practices,

- Increased productivity of various crops via biological pest control methods,

- Training 500 smallholder farmers in CSA techniques, which doubled their farm productivity and increased their income by up to 40%.

- **Tanzania**
  The Tanzanian government has aligned its climate change responses and promotion of climate-smart agriculture with broader investment strategies under its 2025 sustainable development vision. Initiatives include the Agricultural Sector Development Program (2017–2026), which integrates climate change considerations, an environmental action plan for agriculture aimed at sustainable production, the climate-smart agriculture program, and the Tanzania Agricultural and Food Security Investment Plan that recognizes climate change as a critical issue.

Six strategic priorities for agricultural development and growth under changing climate in Tanzania are:

1. Improving productivity and income,

2. Building resilience and associated mitigation benefits,

3. Integrating value chains,

4. Research for development and innovation,

[17] Aweke Mulualem Gelaw, Climate-Smart Agriculture in Ethiopia. CSA Country Profiles for Africa Series. International Center for Tropical Agriculture (CIAT); Bureau for Food Security, United States Agency for International Development (BFS/USAID), Washington, 2017, P.6

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5. Improving and sustaining agricultural advisory services,

6. Enhancing institutional coordination.

- **Rwanda**
  Over the past decade, the Rwandan government has heavily invested in climate-smart agriculture practices such as land cultivation, water harvesting, and hillside irrigation to increase climate adaptation capacity, reduce water erosion and soil loss, halt land degradation, and increase land productivity. Emission mitigation programs have also been implemented, including initiatives such as one cow per poor household, zero grazing, and using waste for domestic biogas production in intensive livestock systems. Agroforestry has been promoted, with the government committing to restoring two million hectares mainly through agroforestry. Government initiatives also include the development of the National Climate Change and Low Carbon Economy Strategy in 2011 and the establishment of the Green Fund (FONERWA) to support Rwanda's green growth over the next 50 years while positioning the country as a key hub for Africa and the world.

- **Cameroon**
  In northern Cameroon, local varieties such as yellow maize and millet suffer from water scarcity, declining rainfall, and drought. However, the National Agricultural Research Institute of Cameroon, supported by the Food and Agriculture Organization (FAO), has developed improved varieties of these crops. Projects involving farmers have been established to produce and redistribute seeds ("planting materials"), currently yielding good crop results.

Challenges to the Adoption of Climate-Smart Agriculture in Africa

Despite the positive contributions of climate-smart agriculture to Africa's agricultural system, its widespread adoption and integration still face several challenges, mainly:

- **Shrinking farmland holdings:** Small landholdings are common, where many farmers live. These plots usually suffer from degradation and low productivity, making it difficult to adopt modern agricultural technologies that require larger land areas. Most farmers are resource-poor and often own marginal lands. More than 3 million smallholder farmers in sub-Saharan Africa own less than 1.3 hectares of marginal land with low yields[18].

- **Access to agricultural land** can be complicated due to customary and institutional factors, as well as political and security conditions that may lead to the displacement of many residents of farming communities.

- **Lack of knowledge:** The lack of information and skills is a major obstacle to adopting climate-smart agricultural methods. This often requires access to agricultural research information and extension services, which may be difficult for most farmers who have low education levels or are largely illiterate. Low education levels among farmers are also a significant barrier to adopting new technologies.

- **High costs associated with climate-smart agriculture:** African farmers generally cannot manage the risks associated with adopting new technologies because of increased costs. Many are restricted in access to credit or microfinance. Additionally, many African countries require new investments to absorb CSA, but financing plans for such investments have not been designed despite their high costs.

[18] ADEMOLA BRAIMOH , Climate-smart agriculture: Lessons from Africa, for the World, World Bank BlogsJANUARY 17, 2018. , Available ahttps://blogs.worldbank.org/nasikiliza/climate-smart-agriculture-lessons-from-africa-for-the-world

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- **Relatively long timeframe to reap benefits:** Climate-smart agriculture often requires 3 to 7 years to realize benefits, needing large initial investments that may be costly for smallholders, potentially leading them to abandon sustainable practices.

- **Insufficient labor:** Labor demand in many African countries often exceeds supply, posing a significant challenge to the agricultural system, especially since adopting CSA practices in some areas involves labor-intensive activities such as deep digging to break soil crusts and weed removal.

- **Weak availability of data, analytical tools, and mastery of CSA approaches:** Even when some data exist, they are not easily accessible, scattered, and there is a lack of long-term data on climatic levels and natural phenomena. This leads to insufficient comprehensive knowledge of the current and potential impacts of climate change in African countries.

- **Weak infrastructure needed to absorb CSA in related agricultural systems:** Farmers need water management structures, communication facilities, storage and processing facilities, and market access. When these structures are missing, they become major obstacles to CSA adoption[19].

Experience of Asian Countries

After South Korea adopted smart agriculture as a way to cope with limited resources and climate change, it now seeks to share its experience and export its technological innovations to the world to secure a position in the future market.

By 2050, the global population will reach 10 billion people, a fact that poses a threat to food security worldwide. With technological advancement, scientists and experts have developed agricultural technologies capable of securing food at lower costs and in larger quantities, changing the equation that has prevailed since the emergence of agriculture.

Each country adopts its own agricultural model according to its priorities, needs, and capabilities. In South Korea, authorities aim to achieve an ideal balance between meeting local demands, preserving cultural heritage, achieving technological development, adapting to conditions, and maintaining rural livelihoods in a country where only 22% of the land is arable compared to 78% mountainous and urban areas[20].

Korean agricultural production has faced many challenges over the years. According to 2019 statistics, the cultivated area in Korea shrank by about 29% since 1975, accompanied by a 7.2% increase in greenhouse cultivation areas. These figures are attributed to several factors such as urban and industrial expansion, limited and low-quality water resources, climate change threatening production stability, and the rapid shrinking and aging of rural communities, where more than 46% of farmers are over 65 years old, posing a real threat to food security. When farmers participated in a recent export fair, they requested government assistance in finding stable sales sources, strategies to keep up with ever-changing market demands, and mechanisms to overcome legal and tax obstacles in importing countries, which often differ greatly from South Korea's regulations[21].

All of this alerted the Korean government, through the Ministry of Agriculture, Food and Rural Affairs, to the importance of catching up with the new revolution known as smart or digital agriculture. This means employing modern technologies in every aspect related to crop production and distribution, starting from seed sowing to managing supply chains.

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[19] Peter Newell , et.al , Climate Smart Agriculture? Governing the Sustainable Development Goals in Sub-Saharan Africa , August 2019 ,PP.2-4, Available at https://www.frontiersin.org/articles/10.3389/fsufs.2019.00055/full

[20] https://www.zawya.com/en/projects/industry/korean-consortium-awarded-first-smart-farm-project-in-oman-tm2pls9k

[21] https://www.koreatimes.co.kr/www/tech/2022/09/419_336030.html

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The concept of smart agriculture is based on key elements, combining big data analytics, algorithms, information and communication technology, the Internet of Things (IoT), edge and cloud computing, geographic information systems (GIS), robotics, satellite imagery, and drones.

To achieve global leadership, the government developed five-year economic plans, supported comprehensive smart agriculture solutions, invested in social capital within the technology sector, and launched a national innovation system to develop regional economies and lead research and development[22].

Developing the Korean model of the smart farm is at the top of policymakers' priorities. Since 2018, authorities have encouraged startups and established industrial infrastructure, while the Rural Development Administration under the ministry seeks ways to secure the technologies and necessities required to manage a fully smart process.

While the ministry supports young farmers to prevent them from abandoning their work and strives to re-promote agriculture, it previously set 2022 as the final deadline to convert 7,000 hectares of fields and orchards alongside more than 5,700 livestock farms into digital facilities.

In the same context, the government plans to form a team of specialists from eight key governmental agricultural and trade institutions, including the Rural Development Administration and the Korea Trade-Investment Promotion Agency. This team will work to accelerate the export of smart agriculture by attracting consultations from both public and private sectors, enhancing globally renowned Korean smart technologies, achieving competitive standards in quality and cost, identifying potential buyers in any country, and providing local companies with market information in those countries[23].

For example, in 2021, the ministry collaborated with a leading company to build a smart farm in the United Arab Emirates, where the project relied on a mist cooling system that reduces water consumption while maintaining an optimal temperature for crop growth. The Omani government also imported two Korean-made agricultural containers, each 12 meters long, to be used for smart vegetable farming. Korea exported 10 smart greenhouses to the Philippines to build the capacities of local farmers and train them to use modern technologies for producing mushrooms, tomatoes, and other high-value crops.

However, establishing smart agriculture as a new reality requires radical changes in rural lifestyles, which present many challenges. Besides concerns over data privacy, cybersecurity, and intellectual property protection, farmers in remote areas often face difficulties accessing the internet — the fundamental element on which the smart farm concept relies. Therefore, the government worked on establishing advanced communication infrastructure by increasing bandwidth capacity and the number of secure servers, making internet access available in 99.5% of Korean homes.

Yet, internet access alone is insufficient. Accessing a "smart farm" requires complex and costly technologies, and training farmers to operate them may require a long learning period. This can be a burden for smallholder farmers and may foster resistance to adopting this new technology.

The Korean smart farm model remains a long-term project aimed at providing independent technologies qualified for global competition in the agricultural production market, establishing a replicable experience for other countries, and capable of overcoming climate and demographic challenges to achieve food security and sustainability[24].

Conclusion

Many countries have faced numerous challenges in meeting food needs amid a constantly changing climate, especially with water scarcity and increased frequency of floods. This has led to soil quality degradation,

[22] https://www.agroberichtenbuitenland.nl/actueel/nieuws/2022/08/16/how-smart-is-south-koreas-smart-agriculture-time-for-an-upgrade

[23] https://olc.worldbank.org/content/digital-ag-series-fostering-digital-agriculture-ecosystems-and-smart-farming-korea-case

[24] https://www.zawya.com/en/projects/industry/korean-consortium-awarded-first-smart-farm-project-in-oman-tm2pls9k

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thereby increasing the need for adaptation measures to these changes. It has become essential to seek alternatives, which is where climate-smart agriculture (CSA) emerged as a viable solution. However, climate-smart agricultural practices remain context-specific in many countries, and the impacts of climate change are characterized by unpredictability. The policy gaps between "climate" and "agriculture" cannot be easily bridged. There remains a significant challenge in scaling up CSA across Africa, alongside weak initiatives to increase agricultural productivity.

Thus, it requires farmers to first invest in learning a greater diversity of environmentally sustainable agricultural practices and measures. New technologies often demand different solutions for large and small farms regarding market access and input use. It is also necessary to mainstream climate-smart agricultural practices within national agricultural policies. Such policies must encourage the private sector to make climate-smart investments in agriculture and ensure adequate financial support and funding to overcome implementation gaps.

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