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Review of Tech-Driven Transitions in African Agrifood Systems, Innovations, Impacts, and Pathways to Sustainability

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ABSTRACT

The development of African agrifood systems is increasingly influenced by technological advancements to increase production, long-term viability, and adaptability. This analysis examines the changing landscape of technology-driven transitions in African agriculture, with an emphasis on innovations such as digital platforms, precision agriculture, biotechnology, and renewable energy integration. These technologies are rethinking production processes, market linkages, and resource management, providing scalable answers to decades-old problems such as climatic variability, poor productivity, and poor value chains. The review also emphasizes the economic advantages of these innovations, such as increased livelihoods, youth participation, and gender inclusion. However, technology adoption remains inconsistent due to infrastructure, legislative, and capacity limitations. To fully realise the potential of technology-driven agrifood systems, the report emphasizes the importance of comprehensive policy frameworks, investment in electronic infrastructure, and stakeholder collaboration across both private and public sectors. This analysis provides practical information for politicians, researchers, and development professionals seeking to build a more equitable and resilient agrifood future in Africa by outlining paths for long-term innovation integration.

Keywords: technology-driven transformations, African agrifood systems, agricultural innovation, precision agriculture, sustainability, climate resilience, and digital platforms.

1.0 Introduction

African Agrifood Systems

In Africa, agrifood systems include all aspects of the production, processing, distribution, and consumption. These systems are inextricably linked to the continent's economic stability and welfare, engaging more than sixty percent of the workforce and contributing greatly to GDP (World Bank, 2023). Smallholder farmers, who operate around 80% of farms in Sub-Saharan Africa, are the key movers of these structures, producing a substantial amount of the continent's food (IFAD, 2022). Despite their vital significance, these systems have inadequate productivity, unstable chains of supply, substantial post-harvest losses, and restricted access to capital and technology (Haggblade et al., 2021). A shortage of infrastructure, poor market links, and climate vulnerability compound these difficulties, producing a cycle of low output and long-term poverty in rural areas (Jayne et al., 2019). Furthermore, losses after harvest in Sub-Saharan Africa are expected to go above 37% for some crops, lowering farmer earnings and food supply (FAO, 2021). Furthermore, many smallholder farmers lack access to modern agricultural products, extension services, and financial loans, which reduces their productivity and resilience to market shocks (Diao et al., 2020). Taking care of these shortcomings is crucial for increasing the availability of food, lowering poverty in rural areas, and strengthening economic resilience (Sparling & Ruvuga, 2021).

Importance of Technological Innovation in Agriculture and Food Systems

The Value of Technological Innovation in Agriculture and Food Systems Technological innovation is often regarded as a crucial enabler of agricultural transformation in Africa. It has the potential to alleviate some of agrifood systems' most serious issues, including as low productivity, wasteful resource usage, and vulnerability to climate change (Pretty et al., 2020). Digital agriculture, for example, uses mobile technology, data analytics, and the Internet of Things (IoT) to optimise farming techniques, improve market access, and increase financial inclusion (Tambo et al. 2019). For instance, apps such as M-Farm and iCow provide small-scale farmers with immediate information on markets, weather forecasts, and agricultural guidance, reducing inconsistencies and boosting decision-making (Gakuru et al., 2016). Biotechnology, which includes better seed types and pest-resistant crops, has the potential to increase yields, minimize crop losses, and reduce the need for chemical inputs, thereby fostering sustainable intensification. Furthermore, renewable energy options like solar-powered irrigation, biogas, and small-scale wind turbines help farmers reduce their dependence on expensive fossil fuels, lower their carbon footprints, and promote climate-smart agriculture (Scholz et al., 2020). Collectively, these technologies allow for more efficient resource use, lower production costs, and higher overall farm profitability (Kamilaris et al., 2018). Furthermore, precision farming techniques such as GPS-guided tractors and drone-based crop monitoring have demonstrated the capacity to greatly increase outputs and efficiency of resources, particularly on industrial farms (Gebbers & Adamchuk, 2010).

Rising Pressure from Climate Change, Population Growth, and Urbanization

Africa's agricultural and food sectors are under increasing pressure from a variety of linked pressures. The impact of climate change is one of the most important elements influencing the yield of crops, supplies of water, and the severity of extreme weather conditions (Gebbers & Adamchuk, 2010). The United Nations Panel on Climate Change cautions that without significant adaptation, food yields in Africa might fall by up to 20% by 2050 (IPCC, 2021). For example, rising floods, irregular rainfall patterns, and heatwaves endanger agricultural production and push farmers into poverty (FAO, 2021). In addition to these climate issues, the continent's population is predicted to nearly quadruple by 2050, reaching 2.5 billion people, considerably raising food consumption and putting unprecedented demands on ecosystems (UN, 2023). This fast population expansion, combined with urbanization, is altering dietary patterns, pushing the need for more processed and high-value foods, further stressing agrifood systems (Juma, 2015). Furthermore, urbanization drives labour away from rural regions, resulting in labour shortages in agriculture and potentially higher production costs (Pretty et al., 2020). This trend also adds to the erosion of traditional agricultural expertise, as newer generations seek greater economic possibilities in cities (Jayne et al., 2019). Addressing these difficulties necessitates a transition towards more resilient, technology-driven agriculture techniques that can boost output while minimizing environmental damage (Pretty et al., 2020).

2.0 Conceptual framework and Definitions

2.1 Agrifood Systems: Definition and Components

Agrifood systems are interconnected networks that cover all aspects of food production, processing, distribution, consumption, and waste management. These systems include a variety of actors, including farmers, agribusinesses, legislators, and consumers, all of whom interact within an economic, social, and environmental framework (FAO, 2014). The main components of agrifood systems are

Production: This encompasses agricultural methods such as crop cultivation, animal production, and aquaculture.

Processing is the turning of crude agricultural produce into consumable commodities.

Distribution involves the movement and marketing of agricultural goods from farmers to consumers.

Consumption is the final utilization of food by people and societies.

Waste management refers to the collection and reuse of food-related materials at different phases of the system (IPES-Food, 2016).

A sustainable agrifood system aims to improve food security, minimize environmental impact, promote social fairness, and increase economic viability (FAO, 2014).

2.2 Sustainability in Agrifood Systems (SDG 2, 12, 13)

Sustainability in agrifood systems emphasizes on ensuring that food production fulfills current requirements while not jeopardizing the capacity of future generations to meet their own. This is closely associated with numerous United Nations Sustainable Development Goals (SDGs):

SDG 2 (Zero Hunger) aims to increase food security, improve nutrition, and promote sustainable agriculture. This goal seeks to guarantee that everyone has access to adequate, nutritious food, while also encouraging more sustainable and inclusive farming practices (United Nations,2015).

SDG 12 (Responsible Consumption and Production) aims to promote sustainable consumption and production habits. In agrifood systems, this goal focuses on decreasing food waste, increasing resource efficiency, and supporting sustainable practices throughout the food supply chain (Godfray & Garnett, 2014).

Sustainable Development Goal 13 (Climate Action): Taking immediate measures to address climate change and its consequences. In agrifood systems, this includes lowering food production's ecological impact, increasing resilience to climate change, and promoting sustainable farming methods that contribute to mitigation of climate change (Godfray and Garnett, 2014).To achieve sustainability in agrifood systems, practices must shift to prioritise long-term ecological, economic, and social balance (United Nations, 2015).

2.3 Technological Change: Types and Relevance

Technological change in agrifood systems refers to the introduction and implementation of innovations that improve food production, processing, distribution, and consumption. Technological advances can be classified as

Incremental Innovations: These are enhancements to current technology, such as more effective irrigation systems, genetically modified agricultural varieties, or enhanced storage procedures.

Radical Innovations: These are game-changing technologies like vertical farming, lab-grown meat, and precision agriculture with drones and sensors (Erenstein, Thorpe, & White, 2021).

Disruptive Innovations: These technologies transform the terrain of the agrifood system by implementing new ways of thinking or practicing, such as blockchain for supply chain transparency or AI-powered food production models (Christensen, 1997).

Technological development in agrifood systems is important because it has the potential to boost productivity, reduce environmental impacts, address food security issues, and contribute to larger sustainability goals (Erenstein et al., 2021).

2.4 Framing Technology as a Lever for Sustainable Transitions in African Agrifood Systems

Under the topic "Tech-Driven Transitions in African Agrifood Systems: Innovations, Impacts, and Pathways to Sustainability," technological breakthroughs are considered as essential enablers of sustainable transitions in African agrifood systems.

Innovations: Mobile farmer applications, climate-resilient crop varieties, and renewable energy sources for rural areas all provide new avenues for sustainable agriculture (World Bank, 2021). These technologies are especially essential in Africa since they improve food security, increase productivity, and reduce dependency on unsustainable farming practices (FAO, 2021).

Impacts: Technological advancements in African agrifood systems include greater food production, improved market access, improved traceability, and reduced environmental damage. However, there are also concerns, such as the digital gap, unequal access to technology, and the possibility of aggravating existing disparities (African Development Bank, 2016).

Pathways to Sustainability: To guarantee that these technologies drive long-term transformations, it is critical to incorporate local knowledge, strengthen capacities, provide fair access, and establish supportive policy frameworks. This might include encouraging ecological farming methods with technical developments to ensure that small-scale farmers and rural areas benefit from the changes (FAO, 2021).

Framing technology in this perspective emphasizes how it may be a valuable instrument in overcoming the issues faced by African agrifood systems, notably in terms of tackling climate change, enhancing productivity, and promoting social inclusion (African Development Bank, 2016).

3.0 Technological Innovations in African Agrifood Systems

3.1 Digital Agriculture

Digital agriculture makes use of new technologies to increase farming efficiency and connect farmers to resources and markets.

Mobile-based advisory platforms (such as FarmDrive and iCow): Farmers can access mobile-based advising services through platforms like FarmDrive and iCow. FarmDrive connects farmers to financial services, while iCow provides farming advice, market prices, and peer networking. These services have helped millions of smallholder farmers make better decisions by providing useful information about farming practices, financial planning, and market trends (iCow, n.d.; FarmDrive, 2023).

Market Linkages (e.g., M-Farm): Platforms such as M-Farm enable farmers to connect directly with buyers, removing the need for intermediaries. This technique enhances farmers' market access and pricing, assuring a fair income. It also promotes effective crop interchange and decreases losses after harvest (M-Farm, 2023).

E-commerce Platforms and Digital Marketplaces: Platforms like Twiga Foods in Kenya and Jumia in Nigeria help farmers reach new markets by automating logistics and allowing them to sell directly to customers. These e-commerce platforms improve farmers' access to markets, increasing earnings and minimising supply chain inefficiencies. (Twiga Foods, 2023)

Digital Extension Services: Digital platforms are revolutionizing extension services by providing farmers with real-time agricultural advice and technical support. These services, which use mobile phones and satellite technology, assist farmers in rural locations in accessing critical resources such as professional advice on pest control, crop management, and soil health (CABI, 2020).

Blockchain technology is being used to improve transparency and traceability in agricultural supply chains, allowing interested parties to track the source and path of agricultural products, to guarantee equity, and decrease fraudulent activity. This has major implications for industries such as cocoa and coffee in Ghana and Uganda (Agarwal et al., 2020).

3.2 Artificial Intelligence & Data Analytics

Artificial intelligence and data analytics are revolutionizing precision agriculture, allowing for more efficient farming and proactive resource management.

Precision Agriculture and Yield Prediction: AI-powered tools enable farmers to apply precision farming practices, which optimize the use of inputs such as water, fertilizer, and pesticides. These systems combine sensor and satellite data to anticipate agricultural yields, allowing farmers to better plan and manage their resources (Smit et al., 2021).

Early Warning Systems (Climate, Pests): Artificial intelligence systems are crucial for identifying and forecasting weather patterns, insect infestations, and disease outbreaks. Early warning systems enable farmers to take preventative measures, lowering crop losses and increasing food security (Tambo & Abdoulaye, 2016). For example, AI algorithms can analyze environmental data to predict pest outbreaks, allowing farmers to implement control measures in a timely manner.

AI-powered animal Management: AI apps are also used to manage animals. Sensors and AI-powered devices monitor animal health, behaviour, and productivity, helping farmers to manage livestock more effectively. This is especially important in countries like Ethiopia, where cattle production is crucial to the economy (Akinmoladun et al., 2021).

Data-Driven Soil Management: Data analytics and artificial intelligence tools improve soil management by giving farmers information about soil health, moisture levels, and nutrient deficits. This permits more efficient fertilizer usage and improved crop rotation techniques (Mlambo et al. 2020).

3.3 Remote Sensing & GIS

Remote sensing and Geographic Information Systems (GIS) enable improved land management, climate adaptation, and resource monitoring.

Land usage Mapping: Remote sensing and GIS technologies are extremely useful for monitoring land usage and managing agricultural land. These techniques aid in detecting land deterioration, urban growth, and deforestation, enabling governments and organizations to better plan agricultural land use (Tshibvumo et al., 2021).

Drought monitoring is an ongoing issue in many African regions, particularly the Sahel and East Africa. Farmers can use remote sensing instruments such as satellites to monitor soil moisture, vegetation health, and water availability. This data enables farmers to plan for droughts by applying water-saving methods and modifying agricultural schedules (Patil et al., 2018).

Satellite-enabled Climate-Smart Decision Tools: Satellite data is being utilised to create tools that will help farmers make climate-smart decisions. These tools help you track climate patterns and make informed decisions regarding planting, irrigation, and harvest timing. Farmers in Kenya and Ethiopia are using these technologies to adapt to changing climate circumstances (McCarthy et al., 2022).

Forest and Water Resource Management: GIS tools are critical for tracking forests and water resources. Deforestation and water shortages are major challenges in Africa, and Geographic Information Systems can help track illicit logging, regulate water usage, and plan for sustainable farming (Muindi & Kang'ethe, 2021).

3.4 Agricultural Biotechnology

Biotechnology improves crop adaptability, increases food security, and drives agricultural innovation.

Improved Seed Varieties: Biotechnology has enabled the creation of crops that are resistant to pests, diseases, and environmental challenges. For example, genetically modified Bt cotton has been introduced in numerous African nations to control insect pests such as the bollworm, while genetically modified Bt maize is used to combat the stem borer (Smyth et al. 2015).CRISPR technology and gene editing are gaining traction in Africa. These technologies enable the production of crops with characteristics such as drought tolerance, pest resistance, and increased nutritional value. Although gene editing is still in its early stages in Africa, it has promise for increasing agricultural output in the face of climate change (Haider et al., 2020).

Microbial Solutions for Sustainable Farming: Biotechnology also includes the creation of biofertilizers and biopesticides, which improve soil health and minimise the need for chemical inputs. For example, introducing nitrogen-fixing bacteria into soil reduces the demand for synthetic fertilisers, encouraging sustainable farming practices in Kenya and Uganda (Mushobozi et al., 2020).

3.5 Renewable Energy & Mechanization

Renewable energy and mechanisation are helping African farmers increase output while encouraging sustainability. **Solar-powered irrigation systems** are altering farming in arid and semi-arid countries by offering a cost-effective and long-term agricultural irrigation option. These systems are especially useful in places like Kenya and Ethiopia, where access to energy is limited (Gichuki et al., 2020).

Drone-Based Spraying:

Drones are transforming pest management and agricultural spraying. Drones equipped with precision technologies provide more efficient, accurate, and ecologically friendly pesticide, herbicide, and fertilizer applications. In nations like Nigeria, drone spraying is helping farmers reduce pesticide use and enhance agricultural yields (Oluwatayo & Oladipo, 2021). In addition to solar energy, wind and biomass energy are being used to power agricultural activities in rural areas. Wind turbines are utilized for irrigation in Kenya, and biomass energy from agricultural waste powers grain mills in Zambia, providing a renewable source of energy for rural farming communities (Bendz et al., 2020).

Automated Farm Machinery: Mechanized agricultural equipment, such as tractors and harvesters, is improving efficiency in African agriculture. In Nigeria, innovations like as Hello Tractor give farmers access to automated machinery via a smartphone app, allowing them to conduct activities like plowing, planting, and harvesting more efficiently (Browne & Kamara, 2020).

Smart Irrigation Systems: Smart irrigation technologies that employ sensors and artificial intelligence (AI) to track soil moisture levels are becoming more and more common, in addition to solar-powered systems. In water-scarce areas like Morocco and South Africa, these systems maximize water use and boost irrigation efficiency, which is especially crucial (Jia et al., 2019).

4.0 Impacts of Technological Change

African agrifood systems are changing due to technological advancements in several ways, including increased production, altered socioeconomic conditions, and environmental modifications. These effects have significant ramifications for rural communities, political systems, and agricultural sustainability throughout the continent.

4.1 Productivity and Resource Efficiency

Technological developments are enhancing resource efficiency and dramatically increasing agricultural yield.

Gains in Yield and Optimization of Input: Yields have increased as a result of the use of precision agricultural methods, which are fuelled by AI and digital platforms. Higher yields per unit of input are achieved by farmers using technologies like sensors and satellite imagery to optimize the use of water, herbicides, and fertilizers. In Kenya, for example, precision farming has increased maize yields by as much as 30%, enabling farmers to boost output without increasing their land area (Smit et al., 2021).

Better Land and Water usage: Innovations such as drought-tolerant crops, intelligent water management systems, and solar-powered irrigation are enhancing land management and water usage efficiency. These technologies assist farmers in areas where water is scarce, preserve soil health, and boost crop resistance to environmental stressors. In Ethiopia, for instance, the adoption of solar-powered irrigation systems has improved farming intensity and water use efficiency in arid areas (Gichuki et al., 2020).

4.2 Socioeconomic Impacts

Rural communities' socioeconomic fabric is changing due to technological advancement, but there are drawbacks as well, such as issues with labour relations and inclusion.

Impact on Livelihoods in Rural Areas: Technologies that increase market accessibility and productivity have the potential to greatly improve rural livelihoods. Farmers now have more power because of mobile systems like M-Farm and iCow, which give them access to financial services, market data, and farming guidance. These resources increase income levels and lessen sensitivity to market swings, especially for smallholder farmers. (M-Farm, 2023)

Digital Inclusion/Exclusion (Gender, Youth, Literacy): While digital technologies have the potential to help underprivileged communities, their acceptance has been uneven. Accessing these technologies is difficult for women, young people, and people with low literacy skills. Social inequality is frequently made worse by gender differences in digital literacy and technological access. To maximize the advantages of technology breakthroughs, it is imperative to ensure digital inclusion for women and young people (Akinmoladun et al., 2021).

Labour Dynamics and Employment Changes: Mechanization and automation are changing agricultural labour markets. Certain activities no longer require physical labour thanks to technologies like drones, autonomous tractors, and harvesters. This could result in job displacement, but it could also open up new opportunities in agriculture-related technologies, data analytics, and machinery management. Rural communities face difficulties adapting to these changes, which call for new skill sets (Oluwatayo & Oladipo, 2021).

4.3 Environmental Outcomes

The environmental outcomes of technological progress in agriculture have the potential to minimize negative impacts while boosting sustainability.

Reducing Deforestation and Emissions: By improving agricultural carbon efficiency and decreasing the demand for chemical fertilizers, technologies like CRISPR and genetically modified (GM) crops have the potential to lower emissions. Additionally, by maximizing land use and encouraging sustainable agricultural methods, advancements in land use monitoring and mapping made possible by GIS and remote sensing aid in the prevention of deforestation (Muindi & Kang'ethe, 2021). Precision farming also lessens excessive chemical input use, which lowers emissions of greenhouse gases.

Reducing Post-harvest Losses: Technological advancements in preservation, transportation, and processing are reducing losses, which are major difficulties in African agriculture. Cold storage systems, mobile applications for market linkages, and better techniques for processing ensure that more produce reaches the market in good condition. For example, advances in post-harvest handling in West Africa have reduced fruit and vegetable spoiling by up to 30% (Twiga Foods, 2023).

Enhancing Resilience to Climate Shocks: Climate-smart technologies, such as drought-resistant crops, weather prediction models, and satellite-enabled decision-making tools, are helping farmers adapt to shifting weather patterns. These tools help farmers make better decisions and safeguard crops by giving them access to real-time weather data and early warnings of extreme events like floods or droughts (Patil et al., 2018).

4.4 Governance and Institutional Transformation

Technological improvements also have important ramifications for governance and the institutional structure within African agrifood systems.

Role of Governments, Nongovernmental organizations (NGOs), and the Private Sector: To promote technical innovation in agriculture, governments, non-governmental organizations, and private sector actors are essential. While NGOs strive to guarantee that technology reaches smallholder farmers, governments offer incentives for innovation and regulatory frameworks. Infrastructure investments and the creation of agri-tech solutions are spearheaded by the private sector. Initiatives such as Techno-Serve in Nigeria and Agri-Tech Hub in

Kenya, for instance, are assisting in bridging the gap between farmers and technology developers (Techno-Serve, 2023).

Innovation Ecosystems and Agri-Tech Hubs: Agri-tech hubs that encourage entrepreneurship and innovation are becoming more prevalent in African nations. These hubs give farmers, researchers, and startups a place to work together to develop solutions for regional agricultural problems. Examples of these ecosystems that are promoting innovation in agriculture are the Cocoa Research Institute in Ghana and the Innovation Village in Uganda (Browne & Kamara, 2020).

Regional Cooperation: By lowering trade barriers, promoting free movement of goods, and strengthening regional cooperation in technology development and sharing, regional cooperation, like the African Continental Free Trade Area (AfCFTA), can hasten the adoption of agricultural technologies. By encouraging cooperation in agri-tech research and knowledge transfer, the AfCFTA has the potential to increase agricultural productivity throughout the continent (Kaunda & Mudzonga, 2021).

5.0 Barriers and Limitations to Technological Uptake

Despite the potential benefits of technology improvements in African agriculture, various impediments and restrictions hinder their widespread implementation. These issues are multi-faceted, involving infrastructural, economic, regulatory, educational, and socio-cultural factors.

Infrastructure Gaps

Inadequate infrastructure, especially in rural regions, is a major obstacle to the adoption of agricultural innovations in Africa.

Connectivity Issues: Farmers' access to digital platforms, agricultural apps, and online market links is restricted in rural areas due to unreliable internet and mobile network coverage. Implementing technologies that need continuous data transfer, including real-time monitoring systems and precision agricultural instruments, is further hampered by poor connectivity (Mlambo et al., 2020).

Power Supply: Many modern agricultural technologies, such as irrigation systems, cold storage, and digital platforms, rely on power. However, a significant barrier in rural areas is the frequent power outages and lack of access to the electrical grid. Despite being a promising substitute, solar-powered systems are not often within smallholder farmers' means (Bendz et al., 2020).

Financing Constraints

Another significant obstacle preventing many farmers from implementing contemporary technologies is access to financing.

High Capital Costs: Smallholder farmers frequently find the initial outlay necessary to implement technological advancements like drones, automated machinery, and precision farming instruments to be unaffordable. Due to collateral requirements and a lack of financial literacy, many farmers still struggle to get financing choices like microloans and subsidies (Agarwal et al., 2020).
Lack of Financing in Agri-Tech businesses: Although agribusiness businesses are gaining popularity, many agri-tech innovators find it difficult to get capital for their ventures. Innovation and the creation of affordable solutions suited to smallholder farmers' requirements are hindered by this lack of funding (Browne & Kamara, 2020).

Regulatory and Policy Fragmentation

The implementation of agricultural technologies is significantly hampered by the fragmented character of laws and policies in African nations.

Absence of Uniform Rules: Standards, laws, and regulations pertaining to agricultural technologies, such as pesticides, biofertilizers, and genetically modified organisms (GMOs), differ between nations. Cross-border trade, innovation, and technology transfer are made more difficult by this fragmentation (Kaunda & Mudzonga, 2021). For example, although some African nations have permitted the use of genetically modified crops, others have strict prohibitions, which hinders the spread of technologies throughout the continent.

Slow Policymaking Processes: Policymakers frequently fail to keep track with the swift growth of agricultural technologies. Slow policy responses, together with inconsistent enforcement, impede the general adoption of innovative technologies and generate uncertainty among stakeholders (Muindi & Kang'ethe, 2021).

Capacity Gaps

One of the main obstacles to the adoption of agricultural technologies is the lack of technical expertise and training among farmers and extension agents.

Limited Agricultural Training: Many smallholder farmers, particularly those in isolated rural regions, lack the technical know-how required to efficiently use cutting-edge agricultural technologies. The lack of official training programs and extension services to teach these new technologies restricts their usefulness, even though digital platforms and mobile applications can provide advice (Tambo & Abdoulaye, 2016).

Extension Services' Capacity: Conventional agricultural extension services frequently lack the necessary tools to facilitate the adoption of innovative technology. These services frequently lack the infrastructure, knowledge, and resources necessary to instruct farmers on digital tools, machine maintenance, and contemporary farming methods. The increasing number of farmers in need of assistance widens this disparity (Smit et al., 2021).

Trust and Cultural Factors

Adoption of agricultural advances is significantly influenced by cultural attitudes and confidence in new technologies. **Opposition to Change:** A strong cultural preference for conventional farming practices makes many farmers hesitant to embrace new technologies. Farmers in some places could think that new technology is unreliable or inappropriate for their particular circumstances. In order to overcome this reluctance, it is necessary to prove that technology is compatible with local practices in addition to highlighting its advantages (Bendz et al., 2020).

Trust in Technology Providers: Adoption depends on having faith in the businesses and institutions providing technical solutions. If farmers have had bad experiences with failing technology in the past or do not completely grasp how new technologies operate, they may be cautious about them. Overcoming these obstacles requires establishing trust via training, success stories, and demonstration (Mlambo et al., 2020).

6.0 Enabling Conditions for Scalable and Inclusive Innovation

Several enabling circumstances must be established in order to guarantee that technical advancements in African agriculture are inclusive and scalable. These prerequisites include establishing a supportive policy climate, encouraging cooperation between the public and private sectors, utilizing education and research, improving digital literacy, and making sure that gender equity is taken into consideration when designing technology.

Policy Coherence and Smart Subsidies

Coherent policies and tailored subsidies are necessary for technical advancements to spread throughout Africa.

Policy Coherence: To develop a cohesive strategy for agricultural innovation, governments must coordinate policies across industries like infrastructure, technology, education, and agriculture. Disjointed policies may make it more difficult for new technology to be adopted. Effective planning by farmers and technology providers is made possible by a clear, uniform policy framework that encourages long-term investment. In addition to addressing concerns like market access and land tenure, governments must support policies that advance digital agriculture, research, and development (Kaunda & Mudzonga, 2021).

Smart Subsidies: Farmers might be encouraged to embrace innovative techniques by receiving subsidies aimed at essential technology inputs like seeds, equipment, and fertilisers. To guarantee that they reach the intended recipients, particularly smallholder farmers, subsidies must be carefully planned. By encouraging the use of climate-sensitive technologies like drought-resistant crops and solar-powered irrigation systems, smart subsidies can also encourage the adoption of ecologically friendly behaviours (Agarwal et al., 2020).

Public-Private Partnerships
PPPs, or public-private partnerships, are essential for agricultural innovation and technology scalability.

Collaboration for Impact: More creative solutions may result from alliances between governmental bodies, commercial enterprises, and non-governmental organizations (NGOs). While governments offer access to rural markets and regulatory frameworks, the private sector contributes capital, technology, and expertise. For example, partnerships between mobile operators and agri-tech startups have led to the development of mobile platforms for market access, weather forecasting, and financial inclusion (Tambo & Abdoulaye, 2016). These collaborations help reduce barriers to technology adoption and promote large-scale rollouts.

Support for Agri-Tech entrepreneurs: Through financial assistance, infrastructure support, and regulatory incentives, governments and the private sector should also assist agri-tech entrepreneurs. More economical and efficient agricultural technology that are suited to regional requirements may result from this partnership (Browne & Kamara, 2020).

Roles of Higher Education and Research Institutions

Institutions of higher learning and research are essential for promoting innovation and supplying the technical know-how required for adoption.

Research and Development: The creation of context-specific technology depends on academic institutions and research centres. These organisations can support innovations that tackle regional issues, including pest control, soil health, and climate adaptation by funding agricultural research. Research is converted into workable solutions that farmers may utilize thanks to partnerships between academic institutions and agricultural extension services (Muindi & Kang'ethe, 2021).

Capacity Building: By providing training programs that foster the technical abilities required to run new technology, higher education institutions also play a crucial role in capacity building. A new generation of farmers and extension agents who are knowledgeable about digital tools, precision farming, and cutting-edge gear can be trained by agricultural institutions and universities (Tambo & Abdoulaye, 2016).

Digital Literacy and Local Language Adaptation

Improving digital literacy and localizing technology to local languages are essential for widespread adoption.

Digital Literacy: To use smartphone apps, precision agricultural equipment, and other digital solutions efficiently, farmers need to possess the requisite digital skills. Particularly in rural areas where literacy rates may be lower, governments, non-governmental organizations, and tech businesses should work together to offer training in digital literacy. Farmers have been successfully engaged by mobile-based agricultural platforms such as iCow, which offer easily comprehensible and accessible information (Mlambo et al., 2020).

Local Language Adaptation: By making sure that technologies are available in local languages, they can be tailored to the local context. For digital tools and apps to be useful, they must be provided in local languages, as many African farmers do not know English or French. Additionally, local language adaptation makes technology more relevant and effective in particular areas (Bendz et al., 2020).

Gender Responsive Technology Design

Given the particular requirements and difficulties experienced by women farmers, agricultural technology design must be inclusive.

Gender-responsive innovation: Although women play a vital role in African agriculture, they encounter particular obstacles to the adoption of new technologies, such as restricted access to resources, land, and training. Creating tools that are specific to women's responsibilities in agriculture, such as labor-saving devices that cut down on the amount of time women spend on home chores or mobile platforms for financial inclusion, is known as gender-responsive technology design (Akinmoladun et al., 2021).

Empowering Women through Technology: Reducing gender inequalities in agriculture should be the aim of technology design. Digital platforms that offer financial services, farming advice, and market access, for instance, can empower women by giving them the means to boost their economic status, make better decisions, and be more productive. Additionally, women should be included in the design and development of agricultural technologies to ensure their needs are addressed (Tambo & Abdoulaye, 2016).

7.0 Case Study

Case Study 1: Nigeria—The Role of Mobile Platforms in Agricultural Advisory Services

Mobile-based agricultural advising services have advanced significantly in Nigeria, a country with a sizable agricultural economy and various rural communities. A prominent illustration is Farmcrowdy, a website that links smallholder farmers with a network of investors and provides them with professional guidance on crop management, farming methods, and market accessibility. Another smartphone service, iCow, aims to enhance cattle production by giving farmers up-to-date information on marketing, illness prevention, and animal care.

Effect:
Enhanced Efficiency: These systems have assisted farmers in increasing crop yields and livestock output by providing personalized guidance and real-time updates. For example, Farmcrowdy has facilitated access to capital and professional guidance for thousands of smallholder farmers, resulting in improved resource management and increased output (Akinmoladun et al., 2021).
Market Linkages: The digital platforms also connect farmers directly with customers, lowering the number of intermediaries and providing better prices for produce (Mlambo et al., 2020).

Challenges:
Connectivity Issues: While mobile technology is widely available, poor internet connectivity in rural regions can restrict the efficiency of these platforms (Bendz et al., 2020).
Digital Literacy: Farmers may find it difficult to use these platforms efficiently if they have little prior experience using mobile phones (Agarwal et al., 2020).
Case Study 2: Ghana – Solar-Powered Irrigation Systems
Solar-powered irrigation systems have become popular in Ghana as a way to address the nation's erratic rainfall patterns and agricultural water shortage. Particularly in areas that are vulnerable to drought, solar-powered irrigation systems, like those marketed by businesses like Solar kiosk, provide an economical and environmentally friendly way to improve food security.
Effect:
Better Access to Water: Farmers can now effectively irrigate their crops even during dry seasons thanks to solar-powered irrigation, which has increased crop yields and decreased reliance on rainfall (Smit et al., 2021).
Sustainability: Solar energy is an environmentally friendly alternative since it lessens dependency on fossil fuels (Tambo & Abdoulaye, 2016).

Challenges:

Initial Costs: Despite the long-term advantages of solar-powered irrigation systems, smallholder farmers continue to face major obstacles due to the upfront costs (Browne & Kamara, 2020).

Technical know-how and maintenance: Farmers frequently lack the technical know-how necessary to maintain and repair solar irrigation systems, which can result in malfunctions and operating difficulties (Kaunda & Mudzonga, 2021).

Case Study 3: Kenya – M-Farm: Empowering Farmers through Market Linkages

M-Farm is one of the most effective platforms for enhancing market connections, and Kenya is a pioneer in the application of mobile technology in agriculture. By giving farmers direct access to buyers and real-time pricing information, M-Farm lessens the influence of middlemen and guarantees that farmers receive higher prices for their produce.

Effect:

Access to the Market: M-Farm has contributed to raising smallholder farmers' incomes in Kenya by giving them access to a wider market. In order to help farmers decide which crops to cultivate, the platform also offers data on demand trends (Mlambo et al., 2020).

Financial Inclusion: By facilitating mobile payments, the platform lowers the risks involved in cash transactions and gives farmers access to financial services (Akinmoladun et al., 2021).

Challenges:

Connectivity: Although mobile phones are widely used, certain rural areas still struggle with connectivity, which restricts the service's reach (Bendz et al., 2020).

Problems with Literacy and Trust: Some farmers, especially those in older generations, might find it difficult to use mobile devices or be wary of putting their trust in digital platforms for market transactions (Agarwal et al., 2020).

Case Study 4: Drone Adoption in Precision Agriculture in Nigeria

Drone use for precision agriculture has been increasing in Nigeria, especially among agribusinesses and large-scale farmers. Drones increase farming efficiency and lower labour costs by being used for crop monitoring, insect identification, and spraying.

Impact:

Precision Farming: By detecting problem areas, drones assist farmers in better field monitoring. Large-scale farm management and productivity enhancement have benefited greatly from this technology Smit et al., 2021).

Cost Efficiency: Drones help minimize the cost of labor, especially in tasks like pesticide application, which used to involve human labour and was often ineffective and harmful (Agarwal et al., 2020).

Obstacles:

Regulatory Barriers since the Nigerian Civil Aviation Authority has not yet completely regulated drone use in agriculture, there are still regulatory restrictions on this use (Kaunda & Mudzonga, 2021).

High Initial Costs: Smallholder farmers are unable to deploy drone technology due to the high cost of acquisition and upkeep, which mostly restricts its usage to bigger commercial farms (Browne & Kamara, 2020).

8.0 Conclusion:

Technological innovation's role in transforming African agrifood systems is both a huge potential and a difficult task. As demonstrated by this assessment, new technologies are revolutionizing the production, processing, and distribution of food throughout the continent. These technologies range from digital platforms and precision agriculture to biotechnology and renewable energy. These developments present viable answers to persistent problems, including low productivity, inefficient markets, and climate change susceptibility. However, achieving their full potential necessitates more than just having access to technology; it also calls for infrastructural investments, supporting regulatory frameworks, and inclusive policies that involve women, youth, and smallholder farmers. Collaboration across sectors and matching innovation to local needs and settings are essential for sustainable progress. Africa can create robust agrifood systems that can sustain food security, economic prosperity, and environmental sustainability for future generations by tackling these important issues.

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