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SMART AGRICULTURE, FOOD SECURITY, AND RURAL VULNERABILITY: A COMPARATIVE ANALYSIS OF THE UNITED KINGDOM AND AFRICA

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ABSTRACT: *Food insecurity and rural vulnerability are significant issues in high-income and developing environments, particularly when they are exposed to climate change and economic insecurity. The adoption of digital technologies such as artificial intelligence, precision farming, and data analytics has become a part of smart farming, which is expected to improve the productivity and sustainability of agriculture. To investigate how institutional capacity, infrastructure, and socio-economic factors contribute to the adoption and performance of smart agriculture, the paper conducts a comparative literature review to synthesize existing research on the adoption of smart agriculture in the study areas. The review indicates that the United Kingdom has favorable policy, funding, and internet infrastructure, which enable efficient adoption of agricultural technologies. Put differently, African countries are characterized by structural constraints, including funding, inadequate infrastructure, digital illiteracy, and access to data, which usually impede adoption, particularly among smallholder farmers. The paper argues that technological innovation is not the only way to address food insecurity. On the contrary, the governance framework, equal accessibility, and context-specificity determine the effectiveness of smart agriculture. It concludes that the inclusive policy design and equal partnership between the UK and Africa will be instrumental in enabling smart farming to contribute positively to food security and rural resilience.*

KEYWORDS: Food Security, Rural Vulnerability, and Smart Agriculture.

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INTRODUCTION

Food insecurity is one of the most endemic developmental issues affecting the world, which has been aggravated by the effects of climate change, environmental degradation, and population pressure (Lawrence & McMichael, 2014). In the developed and the developing world, the agricultural systems are becoming more vulnerable to extreme weather conditions, changing rainfall patterns, soil erosion, and global supply chain distortions (Ibragimova, 2024). The effects of these climate-induced stresses are not uniform, and the rural population is affected more than others, especially those who rely on smallholder farming. Although the adaptive capacities experienced by the high-income countries like the United Kingdom are better supported by institutional support, technological innovation, and social protection systems, several African countries still report compounded vulnerabilities in their systems, which are fueled by structural inequalities, inadequate infrastructure, and weak state capacity. Such a distinction highlights the pivotal role of agriculture as a source of food as well as a highly important factor of rural resilience and socio-economic stability. In response to these problems, smart agriculture has emerged as a promising approach to enhance productivity, sustainability, and climate resilience in agri-food systems.

Smart agriculture refers to the use of digital technology in the field of agriculture, like artificial intelligence, precision farming machinery, remote sensing, and digital extension services to computerise the agricultural decision-making process (Joshi et al., 2023). Such technologies are increasingly integrated into national agricultural policies, with strong data ecosystems, research centres, and innovation in the private sector in contexts such as the UK. However, as compared to a large part of Africa, the uptake of smart agriculture is unevenly distributed and sometimes must be mediated by external forces, programmes by donors, and pilot interventions. Although the technologies are promising in upgrading yields and minimizing risks posed by climate change, their application also poses important questions regarding access, affordability, and ownership of data, as well as the possibility of reproducing the inequalities of rural areas. It is on this backdrop that a comparative UK-Africa lens is analytically and policy-relevant. The comparison allows for interrogating the influences of the different governance structures, technological capabilities, and developmental paths on the results of smart agriculture interventions. Instead of viewing smart agriculture as a solution that can be applied universally, this paper places the concept of smart agriculture in a wider political, economic, and social context, emphasizing the role of power inequality in determining the beneficiaries and the vulnerable population. Comparing the UK and African cases, the paper aims at creating context-dependent knowledge and policy implications that can guide more equitable, inclusive, and sustainable solutions towards using smart agriculture to enhance food security and rural resilience.

Conceptual and Analytical Framework

Defining Smart Agriculture and Rural Vulnerability

The concept of smart agriculture has gained increased significance in the realm of contemporary agricultural scholarship as a response to mounting pressure on food systems. Generally speaking, smart agriculture means the implementation of the most recent digital and technological tools, including the Internet of Things (IoT), artificial intelligence (AI), data analytics, drones, and precision farming systems, into the production and control of agriculture. The technologies are designed to optimise the use of inputs, enhance decision-making, and

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general efficiency and productivity of a farm (Shamkuwar et al., 2024; Agrawal et al., 2024). Based on real-time data and predictive analytics, the farmers will be better equipped to monitor the conditions of the soil, regulate the use of water, use the fertilizers more precisely, and anticipate any changes in the climate to reduce the waste of resources and environmental harm. The literature also prioritises the sustainability aspect of smart agriculture, particularly since it has been demonstrated that it can ensure agricultural sustainability in the long term, with reduced ecological footprints (Shamkuwar et al., 2024; Ahmed et al., 2024). In tandem with these technological advances, the studies of rural vulnerability highlight the constraints of the structure and socio-economic factors that determine agricultural results. According to Ncube et al., (2016) and Ali et al., (2023), rural vulnerability is the exposure of rural households to the negative shocks (including climatic variability, economic uncertainty, inaccessibility of productive resources, etc.). Financial constraints are identified in the literature as one of the key factors; many rural families do not have enough capital to absorb climate-related losses or invest in adaptive technologies (Ncube et al., 2016). Demographic factors also contribute to vulnerability, whereby populations comprised of the elderly, female headed houses tend to be more vulnerable due to limited access to land, credit, and institutional assistance (Ncube et al., 2016). There is growing debate among scholars that climate-smart agriculture is a potential remedy in the form of adaptive measures that can be used to overcome these vulnerabilities. Such strategies can provide avenues to making rural areas less vulnerable to crisis by increasing diversified sources of income, better resource management, and resilience to shocks and environmental stresses (Ali et al., 2023). The literature, however, notes that technological innovation is not enough. The gains of smart agriculture may not be equally distributed without targeted actions to overcome the hidden socio-economic inequalities, which can serve to strengthen instead of decrease the rural disparities. Therefore, current literature suggests the necessity of combined options according to which technological progress should be adjusted to social inclusion and resilience-building in order to make sure that smart agriculture may play a significant role in fair rural development.

Food Security as a Multidimensional Concept (Availability, Access, Stability, Utilisation)

Food security is commonly understood to be a multidimensional construct that includes the inter-relational pillars of availability, access, utilisation, and stability. This framework offers a lens of analysis to understand the complexity of food systems and the differentiation of the food-related deprivation of regions and populations. It is through the fusion of these dimensions that scholars can transcend rather limited production-based understandings and instead analyse the structural, economic, nutritional, and systemic factors that influence food outcomes. Availability is the physical reality of adequate food under a given situation, and it depends upon domestic food production, food imports, and the market system's efficiency. Empirical literature proves that low food supply is frequently linked to incomplete energy and protein sources, especially in some African and South Asian regions, where production factor limitations and market failures still occur (Peng et al., 2023). Nevertheless, food is not secure just because it is available. Both financial and geographical access is decisive factors. Households need to have capacity to access food, income levels, transport infrastructure, and market accessibility, which play a key role in determining the capacity of households, with low GDP per capita and poor logistical systems being key impediments in the majority of developing nations (Peng et al., 2023). Other than access, there is utilisation that is based on the nutritional content of food and the capacity of the body to absorb and metabolize the nutrients properly. This dimension raises the focus on the variety of diet, health, sanitation, and

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care. The co-existence of malnutrition and obesity in different locations, such as the rural Ethiopian area, demonstrates the role that food insecurity can play in perpetuating malnutrition even where the caloric intake might seem adequate, thus highlighting the significance of nutritional adequacy over the mere quantity (Adem, 2021). The fourth pillar, stability, touches on the time aspect of food security, focusing on food resilience to highs and lows in weather, volatile economic conditions, and political upheaval. Countries are more prone to instability when it comes to food imports, and this is why the disruption of a global food supply chain results in policies that facilitate the ability to increase domestic production and strategic stocks (Huseynov, 2020). Notably, there is an emerging trend in scholarship towards the realization that food security is not only a technical or an economic challenge, but also a cultural and contextual challenge moderated by various factors. Local ideas of sufficient and safe food can be based on safety, nutritive value, or social meaning as well as availability. The case of Bidayuh community in Malaysia, which studies how food safety and nutritional issues are the core of the community's conceptualization of food security, can serve as one example (Henry et al., 2025). These insights support the existence of context-sensitive frameworks that incorporate the global indicators and local realities during policy development and execution.

Technology, Power, and Inequality in Agri-Food Systems

The role of technology and power at the intersection of inequality remains a growing focus of agri-food system scholarship, which has argued that digitalisation, which is usually described as efficiency-enhancing, can generate and even exacerbate structural inequalities. Inequality arises at various levels in digital agricultural space, such as technological development, access, and control. The design and possession of digital stages and infrastructure are often dominated by large companies, restricting any substantive involvement of smallholder farmers (Hackfort, 2021). Such a level of technological control also poses the issue of data sovereignty, as marginalised producers are not in control of agricultural data and, in fact, any decision-making process that defines how to use the data (Hackfort, 2021). Further, the lack of equal digital literacy expands the ability of vulnerable populations to enjoy the benefits of technological innovations, which strengthens existing socio-economic disparities. The historical experience of the modernisation of agriculture assists in comprehending the transformation in technology to generate unforeseen social consequences. The increased agricultural output as a result of the introduction of high-yielding variety (HYV) crops in the Green Revolution created inequality between the landowners and the rural labourers, which was associated with the likelihood of social unrest in some instances (Dasgupta, 2025). The increase in productivity was not absorbed into better wages or social mobility by labourers in areas with disproportionate land tenure systems, thus escalating tensions between classes and, in certain instances, crime and instability (Dasgupta, 2025). These processes emphasize the fact that technological changes that are not also accompanied by redistributive and protection interventions can only augment inequality but not diminish it. Modern food systems also represent the existence of structural power imbalances, as agro-industrial actors tend to have a disproportionate role in the production paradigm, market penetration, and policy priorities at the cost of indigenous and practices-based economies (Jacobi and Llanque, 2018). Locally controlled food systems, in turn, show different examples of collective control and food sovereignty, and how communal governance models can offset the exploitative relationships (Jacobi & Llanque, 2018). In general, the literature recommends that technological innovation in the agricultural sector should be critically placed within the large political and economic frameworks to make sure

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that productivity benefits do not perpetuate existing inequalities, but instead help achieve more inclusive and fairer food systems.

Smart Agriculture in the United Kingdom

The United Kingdom has a structured policy environment and robust institutional arrangements that promote technology innovation in the agricultural sector, and it has strong support for smart agriculture. The keys to efficiency, sustainability, and competitiveness are precision agriculture, data-driven farming system, usage of advanced digital technologies, such as Internet of Things, artificial intelligence, and machine learning (L. & Joshi, 2025). Government actions are core to this change, and subsidies, grants, and tax incentives are introduced to lower the financial hurdles and hasten the use of precision technologies (Khaspuria et al., 2024).

Improvement of infrastructure in rural areas, such as broadband, also makes it possible to implement digital solutions successfully, i.e., in other words, the introduction of precision technologies into the operation of farms becomes an easy matter (Khaspuria et al., 2024). According to the literature, these innovations have provided a measurable level of productivity and improved environmental performance. Precision agriculture will ensure maximum utilisation of inputs, reduced resource wastage, and reduced environmental impact (Khaspuria et al., 2024; Tyagi et al., 2024).

In addition to fiscal policies, institutional policies such as the agricultural extension and market systems with good structures promote the transfer of knowledge and involvement of farmers in smart farming (Khaspuria et al., 2024). The effective implementation of digital solutions, or, in other words, the ease with which precision technologies can be integrated into the operation of farms, is possible due to infrastructure improvement in rural areas, including broadband, as well (Khaspuria et al., 2024). The literature has credited these innovations to increased productivity and the enhancement of the environment. Precision agriculture applies the inputs in the most efficient manner, minimises the wastage of resources, and minimises the impact on the environment (Khaspuria et al., 2024; Tyagi et al., 2024). In addition, smart agricultural practices are sustainable because they help to save water, reduce greenhouse gas emissions, and enhance soil health (Khan and Babar, 2024). All these technological innovations are more advantageous in terms of risk management and bringing predictability and, thus, further support the profitability of farms and increased resilience to any climate-related uncertainty (Tyagi et al., 2024; John and Rose, 2024).

Smart Agriculture in Africa

Unlike more technologically modern agricultural systems, the implementation of smart agriculture in most of Africa has been imbalanced and structurally limited, especially among the smallholder farmers who are the main producers of food in Africa. Even though climate-smart agriculture (CSA) and precision agriculture (PA) have increasingly been adopted as the key solutions to enhance food security and boost resilience, their adoption is still hindered by the underlying socio-economic and institutional factors. The characteristics of the smallholder farmers include acute scarcity of resources, poverty, and limited agricultural advisory and extension services, which usually lead to low CSA practice adoption (Mutengwa et al., 2023). There is a distinguishable trend between the small-scale and commercial farming systems. Additionally, the large business farms usually have the capacity to embrace smart technologies because of a relatively higher availability of capital, expertise, and market connections (Bashiru et al., 2024). Much wider diffusion, however, is still hampered by systemic issues. Poor rural

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infrastructure also limits access to markets and digital systems, and lack of proper financing systems limits access to modern technologies among farmers (Kamara et al., 2019; Njoroge et al., 2025). The lack of digital literacy also makes it difficult to use smart farming tools, and limited access to accurate agricultural data makes it difficult to make informed decisions (Gichuki et al., 2024; Njoroge et al., 2025). These structural constraints have significant implications for food securityand rural vulnerability. Climate shock exposure of the smallholder farmers in combination with the lack of adaptive capacity contributes to food insecurity in the region (Mutengwa et al., 2023). Unless there are specific measures to overcome the shortage of infrastructure, financial marginalization, and the lack of capacity, rural population groups will still face continuous poverty and food shortages (Kamara et al., 2019).

Comparative Analysis

In the cases of the United Kingdom and Africa, smart agriculture takes a variety of forms, due to inequalities in technological and policy infrastructure, and social and economic backgrounds. Precision agriculture and digital farming technologies adoption in the UK is supported by a solid policy framework, institutional support, and properly developed infrastructure. Subsidies, grants, and tax incentives by governments lower the financial barriers and make farmers adopt IoT, artificial intelligence, and machine learning in agricultural activities (Khaspuria et al., 2024). To supplement these policies, the extension services and market structures help to spread the knowledge and use innovative techniques, whereas the investments in rural broadband and other infrastructure can guarantee a smooth integration of technologies. Such innovations not only enhance productivity by enhancing input management but also reduce environmental impact and enhance the climate resilience of livelihoods, therefore, raising the sustainability of economies and the environment (Tyagi et al., 2024; Khan &d Babar, 2024; John &Rose, 2024). In other words, structural and institutional constraints set the direction of smart agriculture in Africa. Whereas climate-smart and precision agriculture are considered essential in the process of enhancing food security and reducing rural vulnerability, their combination is still not balanced. Other resource and practical constraints to the smallholder farmers who control the agricultural industry include poverty, lack of access to advisory services, and the degree of digital literacy (Mutengwa et al., 2023; Gichuki et al., 2024). Poor rural roads and low connectivity are also infrastructure shortages, which obstruct access to markets and technology, and limited access to agricultural information limits the capacity of farmers to make informed decisions (Njoroge et al., 2025). The higher adoption rates in larger commercial farms are explained by greater access to capital and technological know-how (Bashiru et al., 2024), but generally, the absence of supportive policy frameworks and institutional capacity hinders the transformative potential of smart agriculture on a large portion of the continent. Consequently, the rural communities are at a high risk of climate shocks, which worsen the food insecurity and poverty (Kamara et al., 2019). The comparison between the UK and Africa highlights the role of institutional, financial, and infrastructural assistance in achieving the potential of smart farming. The UK farmers enjoy the advantages of an enabling environment that combines technology, policy, and market mechanisms, whereas the African smallholders are bound by systemic constraints. However, the African situation also presents the possibilities of innovative and context-adaptable interventions, such as modifying the low-cost digital technologies, services via mobile extensions, and long-term collaboration by both parties, which might increase productivity and resilience. This comparative prism is one of the points that smart agriculture is not a technological panacea but

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a complicated socio-technical system, the success of which is determined by the consistency of policies, fair allocation of resources, and the correspondence of innovation to the local socio-economic context.

Normative Position and Policy Implications

A comparative analysis of smart agriculture in the United Kingdom and Africa reveals that the application of technology should be adopted in a context-specific and fair way. Although there is a high potential of advanced agri-tech solutions in improving productivity, sustainability, and climate resilience in high-income settings, they cannot be universally applied. The interventions that overlook the local socio-economic realities are technology-based approaches that may strengthen the status quo, ostracize the smallholder farmers, and make rural people more vulnerable. This means that smart agriculture should be perceived as a human-focused system based on development rather than a technical one that matches innovation to the local needs, capacity, and environment. In this light, African states can learn policy lessons based on the UK experience, and not necessarily by copying but by modifying policies that create institutional support, infrastructure establishment, and market incentives to suit local realities. The goals of policies need to be to minimize financial and informational accessibility of smallholders, enhance the extension services, and increase access to digital technologies and climate-relevant information. Besides, ethical agri-tech partnerships can positively engage the UK and other international partners to support capacity building, co-innovation, and knowledge sharing to focus on local empowerment rather than on just commercial or donor interests. The key to reducing the rural exposure is South-North cooperation, which effectively reduces the exposure of rural locations to mitigate the potential of utilizing technological change to ensure food security and sustainable livelihoods. The forms of collaboration should be centered on the sphere of equal access, participatory design, and joint governance systems, which should address the local knowledge and socio-cultural issues within the smart agriculture programs. Instrumental to these solutions, foregrounding equity, context, and human-centred development makes smart agriculture an instrument of resilience and empowerment, rather than an instrument of technological marginalisation or environmental risk.

CONCLUSION

This position paper has demonstrated that smart agriculture cannot be approached as a uniform or purely technical solution to global food insecurity. In the comparative study between the United Kingdom and Africa, it has been revealed that the result of agri-technological interventions depends basically on governance capacity, institutional support, and socio-economic context. In the presence of these enabling conditions, smart agriculture is able to increase resilience and sustainability; in their absence, adoption of technology is likely to exacerbate the already existing rural inequalities instead of reducing them. It is argued in the paper that the main dilemma is not that agricultural technologies are available, but that political and developmental decisions dictate the ways of use and to whom they become effective. Smart agriculture, hence, is a place of power and policy intervention, which needs to be strategized to coincide with equity, inclusion, and long-term rural development goals. A comparison between UK and Africa helps highlight such asymmetries and reveal the constraints of technology-oriented solutions that lack connection to local realities. Finally, promotion of food security and mitigation of rural vulnerability require strategies that combine innovation with

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institutional fortification, moral alliance, and context-sensitive policy formulation. UK-Africa collaboration can be taken out of the short-term technological solutions by putting smart agriculture in a broader context of development and governance towards more sustainable, inclusive, and resilience-enriching agri-food systems.

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