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# Comparative Analysis of Mechanized Farming Policies and Agriculture Green Development in Nigeria, Saudi Arabia and China: Towards Sustainable Agricultural Productivity in the 21st Century

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## Abstract

*Sustainable agricultural productivity is an essential part of sustainable development goals (SDGs). Nigeria, China and Saudi Arabia have been striving to achieve sustainable agricultural productivity. However, less attention is given to comparative analysis concerning the utilization of mechanized farming in boosting agricultural productivity. This study therefore aims at exploring policies for adoption of mechanized farming practices in the aforementioned countries. The methodology employed in this study is content analysis of secondary data as integral part of quantitative research. The findings indicated that in the Nigerian context, mechanized harvesting and threshing, have been shown to significantly reduce food losses, increase yields, and positively impact socio-economic aspects. In China, agricultural mechanization plays a crucial role in reducing fertilizer input through increased agricultural mechanization investment, enhancing efficiency, and reducing pollution while in Saudi Arabia, mechanized farming policies have significantly evolved, driven by government initiatives aimed at fostering agricultural productivity and food security focusing on drought-resistant crops, water-efficient farming, and alternative protein. It is further shown that, comparatively, Nigeria China and Saudi Arabia differ in their agricultural policies, programmes, and structures, impacting their mechanization approaches. It is therefore suggested that policymakers should consider the demand-side factors influencing tractor adoption and the potential effects to drive comprehensive mechanization policies in order to boost agricultural productivity and encourage agripreneurs in the two countries.*

**Keywords:** Mechanized Farming, Agricultural Productivity, Sustainability, Agropreneurship, Green Development and Policies.

## Introduction

The early 1990s was a remarkable period that Nigeria, China and Saudi Arabia had expanded its engagement across various domains such as investment and commerce (Gold and Evelyn, 2018). Among the various bilateral relationships between China and African nations, none is progressing as swiftly as the one between Nigeria, China and Saudi Arabia (Alden, 2017). China has now emerged as a significant partner for Nigeria in terms of development, trade, and investment, displacing Europe and North America on Nigeria's development agenda (Nwabia, 2019). While the interactions between Nigeria, China and Saudi Arabia are not recent, they are currently predominantly driven by economic connections, trade, investment, economic relations and financial aspects rather than political affiliations (Anyanwu and Yameogo, 2015; Okonkwo, 2018; Atsiya and Tenuche, 2019). There is substantial evidence indicating that Nigeria has implemented several positive reforms that have attracted considerable attention from foreign investors, particularly those from China (Okonkwo, 2018).

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The growing presence of China in Nigeria, as well as other African regions, has led to extensive discussions regarding the framework of the emerging partnership model (Atsiya and Tenuche, 2019). China possesses a flourishing economy primarily centered around manufacturing operations. Consequently, China's primary interest in Nigeria since the late 1990s has been aimed at securing access to Nigeria's natural resources to sustain its expanding economy. The trade relations between Nigeria, China and Saudi Arabia predominantly revolve around the oil and natural gas sectors. Historically, prior to the boom in oil production post-1970s, agriculture stood as Nigeria's primary export sector. Subsequently, with the nation transitioning into a largely oil-dependent economy, agriculture took a backseat, although it continues to employ nearly 70% of the total working population (Nhamo, 2017).

Furthermore, United Nations Sustainable Development Goals (SDGs) have clamoured for zero hunger and different nations including Nigeria, China and Saudi Arabia which have been striving to foster their agricultural sectors through effective policies and frameworks (Stansfield, 2017). Literature identifies leadership, good governance, empowerment among others as important aspects for attaining sustainable development (Nwoye, 2018). The motivation for this study emerges through the initiative between Nigeria, China and Saudi Arabia to reduce 18 billion dollars trade gap with specific focus of attention in fostering agricultural exports. Studies have examined mechanised farming, agricultural green development, agripreneurship. Yet, there is a gap in the existing body of knowledge concerning the comparative analysis between Nigeria, China and Saudi Arabia in exploring agriculture green development and effective mechanized farming policies in achieving zero hunger as advocated for by the United Nations' Sustainable Development Goals (SDGs) (Stansfield, 2017 ; Nwoye, 2018).

The Saudi government's Vision 2030 initiative, which aims to diversify the economy, includes significant investment in the agricultural sector (Baig, et al. (2022). This includes funding for research, development of rural infrastructure, and support for agropreneurs. The National Agricultural Development Program (NADeP) has provided grants and incentives to promote agropreneurship. The agricultural sector in Saudi Arabia has undergone significant transformations since the 1970s, primarily driven by policy initiatives aimed at enhancing food security and managing water resources (Abdelbaki and Alzahrani, 2024). Recent investments, including partnerships for indoor vertical farming, reflect a strategic pivot towards technological advancements to bolster local agriculture despite challenging climatic conditions (Oxford Analytica, 2023; Abdelbaki and Alzahrani, 2024). Additionally, optimizing cropping patterns is essential for sustainable development, with strategies indicating potential increases in agricultural income while minimizing water consumption (Oxford Analytica, 2023; Abdelbaki and Alzahrani, 2024). Overall, the sector's evolution highlights the interplay between agricultural practices, policy frameworks, and global influences, necessitating ongoing adaptation to ensure food security and economic diversification (Baig, Shahid and Straquadine, 2013).

The agricultural sector in Saudi Arabia faces significant challenges, primarily due to its harsh climate, limited water resources, and the impacts of climate change. The arid environment necessitates heavy irrigation, which threatens the sustainability of natural resources and agricultural practices (Baig, Shahid and Straquadine, 2013). Despite achieving self-sufficiency in several products, including wheat and eggs, the sector's vulnerability to climate-induced risks, such as extreme temperatures and droughts, exacerbates these challenges (Chowdhury and Al-Zahrani, 2015; Elbashir, 2024). To address these issues, it is crucial to implement sustainable agricultural practices and enhance education and extension services for farmers, promoting

efficient water use and resilience to climate variability (Baig, Shahid and Straquadine, 2013; Chowdhury and Al-Zahrani, 2015; Elbashir, 2024). Additionally, leveraging advanced technology and private sector involvement can facilitate the transformation of traditional agricultural methods, thereby improving productivity and sustainability in the face of environmental constraints (Chowdhury and Al-Zahrani, 2015; Elbashir, 2024). Since then, a decline has been observed, aligning with sustainable agricultural practices under Saudi Vision 2030, which aims to diversify the economy and ensure food security while addressing water scarcity. Current mechanized farming policies in Saudi Arabia have significantly influenced agricultural productivity, particularly through government initiatives aimed at enhancing food security and modernizing agribusiness (Elbashir, 2024 ).

It is against the foregoing that this study therefore explores comparative analysis of agriculture green development and mechanised farming in fostering sustainable agricultural productivity and food security in the countries under investigation. The novelty of the study manifests from the fact that comparative analysis of Nigeria, China and Saudi Arabia's efforts and policies on agriculture green development and the use of mechanized farming to maximize agricultural productivity. The significant roles of Nigeria, China and Saudi Arabia in this regard are extensively elaborated despite the fact that overwhelming studies have identified various challenges.

## **Literature Review**

### **Theoretical Framework**

This part explains theoretical framework for agricultural policies and practices in Nigeria, China and Saudi Arabia. Undoubtedly, promoting sustainable development in Nigeria through agricultural practices and policies involves integrating agropreneurship initiatives to enhance economic growth and development, aligning agricultural policies with Sustainable Development Goals 1 and 2, ensuring the adoption of sustainable agricultural practices in value chains like Egusi farming, and decolonizing policy-making processes to incorporate indigenous aspirations for sustainable development as literature contends (Mgbada, Ohajianya, and Nzeh, 2016; Adesida, Nkomoki, Bavorova and Madaki, 2021; Amuda, 2022a). By focusing on capacity building, efficient policy implementation, land productivity, input subsidies, and market establishment, Nigeria can achieve food self-sufficiency, create employment opportunities, and drive rapid economic growth while safeguarding the environment and ensuring long-term sustainability in the agricultural sector (Oyeniyi and Cole, 2021; Oyetunde-Usman, Olagunju and Ogunpaimo, 2021). It is noted that an effective agricultural policy can bring about rural development in Nigeria despite the fact that there are challenges such as inadequate funds facing the sector as literature posits (Nchuchuwe and Adejuwon, 2012; Ojong and Anam, 2018; Adetuyi, Tarbert and Harrison, 2023).

Furthermore, promoting sustainable development in China involves a multidimensional approach focusing on economic, resource, environmental, and social aspects (Zhang, Qu and Zhan, 2023). Challenges to sustainable agriculture in China include economic, social, and environmental obstacles, with economic issues identified as the most significant barrier. Efforts to address these challenges include improving laws and regulations on soil resources and the environment, enhancing food safety measures, and establishing national agricultural high-tech industry demonstration zones (Zhou and Wen, 2023). China's pursuit of sustainable agricultural development emphasizes a shift towards greener and more ecological agriculture, with advancements in agricultural technology playing a crucial role in reducing carbon emissions and

promoting sustainability (Zou, Chen, Mishra and Hirsch, 2024). Public investments in irrigation and agricultural research and development have been shown to significantly enhance agricultural productivity, emphasizing the importance of effective policies to increase such investments for ensuring food security and sustainable development in China (Yu, 2020). Literature has established that the prime objective of China on agricultural efficiency is to promote green development (Lu, David and David, n.d). The theoretical basis for agricultural productivity in both Nigeria, China and Saudi Arabia is meant for converging policies for effective collaboration between the two countries in order to promote green development.

The theoretical framework of agriculture in Saudi Arabia is shaped by a combination of technological advancements, policy initiatives, and environmental challenges. The country has made significant strides in agricultural development since the 1970s, primarily driven by efforts to enhance food security through the establishment of extensive irrigation systems, such as center-pivot fields, which have increased agricultural output despite the arid climate (Hoteit et al., 2023). The integration of artificial intelligence in predicting crop yields has further optimized agricultural practices, allowing for better management of environmental factors like temperature and rainfall (Al-Adhaileh and Aldhyani, 2022). However, the reliance on irrigation has raised sustainability concerns, necessitating a shift towards more sustainable agricultural practices and education to ensure efficient resource use (Alhejaili, 2024). Overall, the framework emphasizes the need for innovative technologies and sustainable practices to address the unique challenges posed by the harsh climatic conditions of the region.

The growth of sustainable agriculture in Saudi Arabia is driven by several key factors, including the adoption of circular economy principles, advancements in agricultural technology, and a focus on education and extension services. The circular economy approach promotes sustainable food production practices, particularly in arid regions, by managing food loss and waste effectively, aligning with the Saudi Vision 2030 goals (Almulhim, 2024). Additionally, the kingdom has achieved self-sufficiency in various agricultural products through significant investments in facilities and services, despite its challenging climate (Almulhim, 2024). The integration of sustainable practices, such as crop rotation and integrated pest management, enhances soil health and reduces water usage, thereby preserving natural resources (Amuda, 2020; Abobatta and Fouad, 2024). Furthermore, educational initiatives are crucial for equipping farmers with the knowledge to utilize resources sustainably, ensuring long-term agricultural viability (Amuda, 2020; Abobatta and Fouad, 2024).

### **An Overview of Agricultural Sectors in Nigeria, China and Saudi Arabia**

Nigeria has been paying meticulous attention on the agricultural sector because it significantly contributes to its gross domestic product (GDP). Literature advocated for effective strategies and initiatives for agricultural sector (Amuda and Alabdulrahman, 2024). The adoption of policy that will enhance technologies for sustainable development has been stressed (Amuda, 2022b). Reiteratively, Nigeria possesses a total of 70.8 million hectares of agricultural land, where the primary crops cultivated include maize, cassava, guinea corn, yam beans, millet, and rice. In so doing, this can solve the problem of poverty and unemployment as the literature contends (Olomola and Adesugba, 2015; Ogbanga, 2018). The production of rice in Nigeria experienced an increase from 3.7 million metric tons in 2017 to 4.0 million metric tons in 2018 (Ogbanga, 2018). Nigeria's principal agricultural imports encompass commodities such as wheat, sugar, fish, and milk, whereas its primary agricultural exports consist of sesame seeds, cashew nuts, cocoa beans, ginger, frozen shrimp, and cotton. Sesame, cashew nuts, and cocoa collectively

represent more than fifty percent of the country's agricultural exports (Anabaraonye, Ewa, Anukwonke, Eni and Anthony, 2021). Agriculture in Nigeria is categorized into four main sectors, namely crop production, fishing, livestock, and forestry. The most significant portion is cropping production, contributing approximately 87.6% to the sector's overall output. Subsequently, livestock, fishing, and forestry account for 8.1%, 3.2%, and 1.1% respectively which can enhance opportunities for agripreneurship for sustainable economic development in the country (Shen, Zhu, Jiao, Ying, Wang, Wen, and Zhang, 2020).

China is a leading global producer in agricultural output. However, despite being the leading global producer in agricultural output, China is limited by the fact that only a mere 10% of its total land area is suitable for cultivation (Adesoye, Adelowokan, Maku and Salau, 2018). The country's arable land, accounting for just 10% of the global total, plays a crucial role in providing sustenance for over 20% of the world's population. Current agricultural practices and policies in China have shown both positive and negative impacts on sustainable development. Studies highlight significant factors influencing agricultural development, such as affected crop area, irrigation, labour force, and financial expenditure (Adesoye, Adelowokan, Maku and Salau, 2018).

In Saudi Arabia, agricultural development has experienced fluctuations; a contraction phase occurred from 1990 to 2010 due to policies aimed at phasing out wheat production, while a subsequent expansion from 2010 to 2016 was driven by the rise of fodder crops to support the dairy industry (Akmatova, Niyazbekova, Britvina, Karabaeva and Osmonova, 2023). Recent trends indicate a decline in agricultural acreage post-2016, attributed to sustainable practices aligned with Saudi Vision 2030, although a slight recovery was noted in 2021, likely influenced by global supply chain disruptions. Overall, these policies have shaped the agricultural landscape, balancing productivity with resource management challenges. Agricultural diversification and value addition play crucial roles in enhancing economic development by improving productivity, stabilizing incomes, and generating employment. Diversification, particularly towards high-value crops such as fruits and vegetables, can mitigate risks associated with crop failures, which have been a significant issue in regions like India, where traditional cropping systems have led to socioeconomic challenges (Akmatova, Niyazbekova, Britvina, Karabaeva and Osmonova, 2023). By adopting diversified cropping systems, farmers can enhance soil health and reduce environmental stresses, leading to sustainable agricultural practices (Akmatova, Niyazbekova, Britvina, Karabaeva and Osmonova, 2023). Furthermore, enhancing the agricultural value chain, as evidenced in Nigeria, demonstrates that investments in agricultural inputs and machinery significantly boost productivity and economic growth. This approach not only increases farm incomes but also creates job opportunities, thereby contributing to poverty alleviation and overall economic stability (Almahmoud, and Attar, 2023). Thus, strategic diversification and value addition are essential for fostering resilient agricultural systems and promoting broader economic development (Almahmoud, and Attar, 2023).

Technology plays a crucial role in enhancing the efficiency and productivity of agriculture in Saudi Arabia, particularly through the integration of IoT, precision agriculture, and remote sensing. The adoption of smart farming practices, including IoT technologies, allows farmers to monitor crop health and optimize resource use, addressing challenges such as water scarcity and adverse weather conditions (Alshehri & Alharbi, 2024; Jabbari et al., 2023). For instance, smart irrigation systems utilizing IoT can significantly improve water management by providing real-time data on soil moisture and crop needs, thus reducing water wastage and enhancing yield

(Alamri, 2023). Additionally, the integration of remote sensing technologies, such as Sentinel-2 imagery with crop models, enables precise estimation of water requirements and crop productivity, which is vital in arid regions like Saudi Arabia. Overall, strategic investments in these technologies can drive sustainable agricultural practices, improve market competitiveness, and support the Kingdom's Vision 2030 goals (Alamri, 2023).

Challenges to sustainable agriculture include economic, social, and environmental obstacles, with climate change and financial incentives being critical concerns. Issues like overexploitation of soil resources and chemical overuse have threatened agricultural sustainability, prompting shifts towards eco-friendly practices and regulatory improvements (Yi, Hao, Liu and Zhang, 2023). Research emphasizes the importance of risk perception and environmental regulation in promoting farmers' sustainable behaviours, with government policies playing a crucial role in incentivizing green agricultural production for rejuvenation of Chinese economic growth as literature contends (Yi, Hao, Liu and Zhang, 2023). Additionally, policies like high-standard farmland construction have shown promise in reducing carbon emissions and enhancing agricultural efficiency (Yi, Hao, Liu and Zhang, 2023).

Moreso, it should be noted that in both Nigeria, China and Saudi Arabia have been have partnership in various sectors whereby agricultural sectors play significant roles in the economic growth and overall sustainable development. This assertion can be further buttressed with the two countries' collaborative efforts to reduce an \$18 billion trade gap and improve agricultural exports. This partnership aims to tackle the substantial trade deficit between the two countries, which was recorded at \$18 billion by the conclusion of 2023. The joint efforts of both nations are focused on enhancing the export of agricultural products from Nigeria to China (Qian, Lu, Gao and Lu, 2022).

### **Agriculture Green Development in Nigeria, China and Saudi Arabia**

Agricultural green development in Nigeria focuses on the adoption of green technologies and sustainable agricultural practices to enhance productivity while mitigating environmental impact. Studies in Nigeria highlight the prevalent use of green technologies such as solar photovoltaic, wind energy, biofuel, and organic farming among farmers as strategies to address environmental degradation, ensure profitability and enhance overall economic growth [48]. Climate-Smart Agricultural Practices (CSAPs) like conservation agriculture and crop diversification are crucial for increasing agricultural yield and resilience in the face of climate change challenges in the country. Adoption of sustainable agricultural practices, including improved seeds and organic fertilizers, is essential for boosting crop productivity and lifting rural farmers out of poverty and contribute to employment (Onubuogu, G. C., & Esiobu, 2014). The intersection of agriculture, environment, and sustainable development underscores the need for environmentally sustainable practices like green concrete production using agricultural and construction waste materials to reduce ecological hazards and construction costs in order to transform the agricultural sector with an emphasis on promoting green economy (Onubuogu, G. C., & Esiobu, 2014).

Challenges of agricultural green development in Nigeria include cost intensiveness, lack of technical know-how, illiteracy among farmers, inadequate information on green technology applications (Takeshima, Nin-Pratt and Diao, 2013b). Additionally, the traditional and modern agricultural practices in Nigeria have led to environmental degradation, global warming, and a reduction in biodiversity, necessitating a shift towards green technologies for sustainability (Takeshima, Hatzenbuehler and Edeh, 2020). The country faces financing bottlenecks hindering

the transition to green agriculture, with a lack of emphasis on green finance. Furthermore, the effects of climate change and unsustainable farming practices pose significant obstacles to economic growth and food security, emphasizing the need for sustainable agriculture practices (Takeshima, Hatzenbuehler and Edeh, 2020). In regions like the Niger Delta, challenges in implementing green economy plans include environmental degradation from industrial activities and the need for a paradigm shift towards sustainable practices like biofuels and organic agriculture.

Moreover, agriculture green development in China is a crucial aspect of the country's economic transformation. Studies emphasize the necessity of green finance, innovative financial services, and improved efficiency to optimize the agricultural industrial structure for the performance of local economy (Huo, Ye, Wu, Zhang and Mi, 2022). Green finance also positively impacts China's agricultural import and export trade, expanding the scale of agricultural transactions and promoting regional development. Urbanization plays a strategic role in facilitating agricultural green development by addressing labour surplus issues and improving efficiency through various urbanization measures (Qing, Chen, Sheng and Huang, 2019). Additionally, the concept of eco-agriculture and green development practices have shown potential in increasing farmers' income and promoting sustainable rural development in regions like Guangdong province. Implementing green transformation in agriculture involves enhancing laws, promoting science and technology, and changing development models to achieve a sustainable and low-carbon agricultural sector (Wang, Yamauchi, Huang and Rozelle, 2020). Farmers in China transitioning to green agriculture practices face several challenges which include economic risks, limited market demand for green technology, and high diffusion costs, climate change and a lack of financial incentives hinder sustainable agriculture progress (Wang, Yamauchi, Huang and Rozelle, 2020). Reiteratively, China has made significant strides in promoting green food through the Green Food Strategy, challenges remain in optimizing the food supply chain, deep food processing, and utilizing food wastes (Wang, Yamauchi, Otsuka and Huang, 2016). To address these challenges, policymakers should focus on strengthening institutional support, increasing public awareness, and making technological investments to support sustainable agriculture and achieve the Sustainable Development Goals in China.

Agriculture green development in Saudi Arabia is increasingly focused on sustainable practices to address water scarcity and enhance food security, aligning with the Kingdom's Vision 2030. The implementation of smart irrigation systems utilizing IoT technology exemplifies this shift, optimizing water usage and improving agricultural productivity through real-time data management (Belouadah, Rahma Abdallah and Musa Mohammed, 2023). Additionally, historical analyses reveal significant changes in agricultural dynamics, with a notable contraction in center-pivot irrigation fields since 2016, driven by sustainable policy initiatives (Belouadah, Rahma Abdallah and Musa Mohammed, 2023). Strategies for optimizing cropping patterns have also been proposed, balancing economic revenue and water consumption, which could lead to substantial increases in agricultural income while conserving water resources (Belouadah, Rahma Abdallah and Musa Mohammed, 2023). Furthermore, investments in innovative agricultural technologies, such as indoor vertical farming, are being pursued to bolster local production despite challenging environmental conditions. Hence, the adoption of circular economy principles aims to minimize food waste and enhance sustainability within the food sector, supporting the overarching goals of environmental preservation and economic diversification are essential in Saudi Arabia (Rashid and Shahzad, 2021).

The necessity of green finance, innovative financial services, and improved efficiency is



paramount for optimizing the agricultural industrial structure in Saudi Arabia, thereby enhancing local economic performance. Green finance can facilitate the transition towards sustainable agricultural practices by providing necessary funding for projects that align with environmental and social goals, as highlighted in the context of Saudi Arabia's Vision 2030 initiatives (Almulhim and Abubakar, 2021). Innovative financial services are essential to overcome existing barriers, such as the lack of regulatory frameworks and high implementation costs, which hinder the adoption of green banking practices. Furthermore, enhancing resource utilization efficiency through green finance can lead to significant improvements in agricultural productivity and sustainability, as evidenced by studies indicating that effective financial structures can promote green technology development (Almulhim and Abubakar, 2021). Overall, integrating these elements is crucial for fostering a resilient agricultural sector that supports economic diversification and sustainability in Saudi Arabia.

The necessity of green finance, innovative financial services, and improved efficiency is paramount for optimizing the agricultural industrial structure in Saudi Arabia, thereby enhancing local economic performance. Green finance can facilitate the transition towards sustainable agricultural practices by providing necessary funding for projects that align with environmental and social goals, as highlighted in the context of Saudi Arabia's Vision 2030 initiatives (Almulhim and Al-Saidi, 2023). Innovative financial services are essential to overcome existing barriers, such as the lack of regulatory frameworks and high implementation costs, which hinder the adoption of green banking practices (Almulhim and Al-Saidi, 2023 [58]). Furthermore, enhancing resource utilization efficiency through green finance can lead to significant improvements in agricultural productivity and sustainability, as evidenced by studies indicating that effective financial structures can promote green technology development. Overall, integrating these elements is crucial for fostering a resilient agricultural sector that supports economic diversification and sustainability in Saudi Arabia (Almulhim and Al-Saidi, 2023).

Green agriculture practices in Saudi Arabia face several significant challenges, primarily due to the country's arid climate and limited natural resources. The implementation of sustainable agricultural methods, such as agroforestry and integrated pest management, is hindered by water scarcity and environmental fragility, which necessitate innovative solutions like drought-resistant crops and efficient irrigation systems (Elfeel, Abohassan and Kouyate, 2022). Additionally, the circular economy approach, while promising for enhancing food production sustainability, reveals gaps in current practices and highlights the need for holistic strategies to manage food loss and waste effectively. It aims to increase green cover and reduce carbon emissions, yet achieving these goals requires overcoming obstacles related to land use change, biodiversity loss, and the intensive use of agrochemicals (Elfeel, Abohassan and Kouyate, 2022). Furthermore, the economic viability of sustainable practices must be balanced with environmental preservation to ensure long-term agricultural success.

### **Mechanized Farming Policies in Nigeria, China and Saudi Arabia**

In Nigeria, mechanized farming policies are crucial for enhancing agricultural productivity and sustainability. It is noteworthy to posit that that literature identifies an effective policy for agricultural mechanization and technology in boosting and intensifying food security in Nigeria (Takeshima, Nin Pratt and Diao, 2013a). The adoption of mechanized farming practices, such as mechanized harvesting and threshing, has been shown to significantly reduce food losses, increase yields, and positively impact socio-economic aspects by freeing up time for women and creating opportunities for rural youth (Olatunji, Ogunkunle, Adisa and Taiwo, 2022). However,



challenges exist, including the need to improve available technologies, formulate effective policies, and address fears related to traditional land occupancy systems. Policymakers should consider the demand-side factors influencing tractor adoption and the potential effects on smallholders to drive comprehensive mechanization policies (Takeshima and Lawal, 2018).

Mechanized farming practices in Nigeria have shown significant impacts on the environment and agricultural sustainability. The adoption of mechanization has led to increased efficiency, productivity, and reduced food losses, positively affecting the environment by minimizing greenhouse gas emissions from food waste. Additionally, agricultural mechanization has influenced crop production, farmers' income, and the size of cultivated land, highlighting its role in enhancing farmers' economic status in particular agricultural sustainability in general (Takeshima and Lawal, 2018; Olatunji, Ogunkunle, Adisa and Taiwo, 2022). However, challenges such as the need for improved machinery utilization, maintenance, and the potential conflicts with traditional land occupancy systems have been identified, emphasizing the importance of balancing mechanization with sustainable land use practices for long-term agricultural viability and environmental preservation which has on overall economic development in Nigeria (Olaoye and Rotimi, 2010). Literature posits that mechanization pattern in the agricultural sector has positive effect on the practices of farming in Nigeria (Olaoye and Rotimi, 2010).

Furthermore, the evolution of mechanization in smallholder agriculture emphasizes the importance of self-reliance, appropriate mechanization theories, and pro-farmer policies for successful implementation (Dauda, Musa and Desa, 2012). Mechanized farming policy in China has rapidly advanced due to government initiatives aimed at modernizing agriculture and addressing labour shortages. Rural industrialization significantly contributes to agricultural mechanization, with a 10% increase in industrial enterprises per township correlating with a 1.05% rise in agricultural machinery power per arable land unit which has significantly contributed to the performance of local economy in the context of China (William and Jianbo, n.d.). Mechanization plays a crucial role in reducing fertilizer input through increased agricultural mechanization investment, enhancing efficiency, and reducing pollution (William and Jianbo, n.d.). However, the impact of agricultural mechanization on farmers' health varies regionally and by income level, suggesting the need for balanced development strategies in the sector.

Mechanized farming practices in China have both positive and negative impacts on the environment and agricultural sustainability. Mechanization enhances productivity, efficiency, and reduces labour costs. However, concerns arise due to the high equipment costs, lack of skilled operators, and environmental repercussions like greenhouse gas emissions from machinery and fertilizers which is considered as innovation in achieving farm productivity (He, Zhang and Li, 2021). The shift towards mechanization affects crop diversity, with grain crops benefiting while non-grain crops suffer, potentially leading to reduced sown areas of certain crops. Additionally, the development of agricultural mechanization influences agricultural carbon emissions and climate change, emphasizing the need for low-carbon agricultural policies and the promotion of sustainable practices (He, Zhang and Li, 2021). Overall, balancing mechanization benefits with environmental considerations is crucial for ensuring agricultural sustainability in China.

Mechanized farming policies in Saudi Arabia have significantly evolved, driven by government initiatives aimed at enhancing agricultural productivity and food security. The Saudi government

has implemented extensive subsidy programs, notably through the Saudi Arabian Agricultural Bank, which facilitated the acquisition of related agricultural equipment. These mechanization efforts are aligned with broader policy objectives that include increasing rural welfare, improving living standards, and fostering social modernization as literature contends (Sarrakh, Renukappa, Suresh and Mushatat, 2020). Furthermore, the integration of advanced technologies, such as artificial intelligence for crop yield prediction, underscores the commitment to optimizing agricultural practices and ensuring sustainability. Overall, these policies reflect a comprehensive approach to modernizing the agricultural sector, addressing both economic and social dimensions of development (Sarrakh, Renukappa, Suresh and Mushatat, 2020).

Mechanized farming practices in Saudi Arabia, particularly in the context of water scarcity and harsh climatic conditions, have significant implications for environmental sustainability. The integration of technologies such as IoT and precision agriculture is transforming agricultural practices, enabling farmers to optimize water usage and enhance productivity through smart irrigation systems and mechanized harvesting tools (El-Dukheri, 2024). However, challenges persist, including high costs and the need for education on these technologies. Additionally, the circular economy principles are being applied to manage food waste and improve resource efficiency, aligning with Saudi Arabia's Vision 2030 goals for sustainable development (El-Dukheri, 2024). In regions like Al-Ahsa, traditional practices are evolving, yet unsustainable waste management, such as burning date palm fronds, poses environmental risks. Thus, while mechanization offers potential benefits, it must be coupled with sustainable practices to mitigate environmental impacts and ensure long-term agricultural viability (El-Dukheri, 2024). Mechanized farming practices in Saudi Arabia significantly influence the country's food security and sustainability by enhancing agricultural productivity while addressing environmental challenges. The integration of artificial intelligence (AI) in predicting crop yields has proven effective, with models achieving high accuracy in forecasting the impacts of temperature, pesticides, and rainfall on crop outputs (Malashin, Tynchenko, Gantimurov, Nelyub, Borodulin and Tynchenko, 2024). Despite these advancements, the country still relies heavily on imports for food, meeting only 20% of its domestic demand through local production (Malashin, Tynchenko, Gantimurov, Nelyub, Borodulin and Tynchenko, 2024). Mechanization, while increasing efficiency, has raised concerns regarding resource depletion and environmental degradation, necessitating a shift towards sustainable practices (Khan, Shah, Yu and Tanveer, 2022). Initiatives such as indoor vertical farming and technology transfer aim to bolster local agriculture, thereby enhancing food security and contributing to economic diversification (Khan, Shah, Yu and Tanveer, 2022). Overall, while mechanization offers potential benefits, it must be balanced with sustainable resource management to ensure long-term food security in Saudi Arabia.

## **Materials and Methods**

The methodological approach used in this study is content analysis as part of qualitative research design. Several studies have utilized systematic literature review to establish links among previous studies (Kraus, Breier and Dasí-Rodríguez, 2020; Kraus, Breier, Lim, Dabić, Kumar, Kanbach and Ferreira, 2022). Less focus is given to SLR in various studies relating to agricultural sector especially in a comparative way. This study tries to bridge the gap in the existing body of knowledge in utilizing systematic literature review in comparatively exploring mechanized farming in Nigeria, China and Saudi Arabia. Indeed, different scholarly researches were extensively explored and elaborated in this study using content analysis (CA) and systematic literature review (SLR) (Rahim, Ong, Yatim, Yanan and Nizat, 2020; Kraus, Mahto,

Walsh, 2023). More significantly, studies relating to policies on mechanised farming in both Nigeria and Ghana were reviewed. Various databases, library sources and Google Scholar were comprehensively explored while searching for scholarly studies. Visualization of Similarities (VOS) was used to find relevant themes of this study. The language analysis utilized as searching strategies indicated four major themes namely: agriculture green development, sustainable agriculture productivity, measures in solving the challenges of agriculture green development (e.g., green technologies, farmers in policy-making, providing incentives for environmental conservation, implementing financing mechanisms to support green agriculture), mechanized farming (e.g., incorporating Internet of Things (IoT) applications in agricultural robotics and cyber-physical systems), mechanized farming. One hundred and eighteen (118) articles were explored as secondary sources for this research. The comparative analysis of this study is crystally or painstakingly explained to the findings of the study. Undoubtedly, this study immensely contributes to the expansion of cursory literature in the field of agriculture which offers a meaningful insight as well as provides direction for future empirical studies in the field of agriculture green development, mechanized farming and sustainable agriculture productivity in particular and overall agriculture in general in the context of Nigeria, China and Saudi Arabia.

## **Results and Discussion**

### **Comparative Analysis of Mechanized Farming in Nigeria, China and Saudi Arabia**

Mechanized farming in Nigeria, China and Saudi Arabia reflects distinct trajectories. Comparatively, Nigeria, China and Saudi Arabia differ in their agricultural policies, programmes, and structures, impacting their mechanization approaches. Understanding these differences and similarities is crucial for in the countries explored in this study to enhance food security and agricultural sustainability.

The adoption of mechanized farming in China has shown positive impacts on land productivity, especially with full mechanization, benefiting female-headed households and varying by region. China has rapidly embraced mechanization to modernize agriculture, driven by government policies. This is in agreement with a number of studies that affirmed that efficient policy on agricultural mechanization in China has enhanced food security in the country (Ntagu, Nyam and Promise, 2022). In contrast, Nigeria has enough land for agricultural productivity but the country faces challenges in agricultural mechanization due to misconceptions about its value in small-scale farming when compared to China where full mechanization is emphasized (Thephavanh , 2023). In the country, challenges such as low mechanization levels and rising labour costs persist, with tractor use linked to input-intensive crop production and nonfarm income activities which hinder the modernization of the agricultural sector (Thephavanh , 2023). It is essential that both Nigeria, China and Saudi Arabia to address labour shortages and enhance productivity despite the fact that there are differences in the approaches to mechanized farming in the two countries.

Conversely, China showcases a positive impact on land productivity through semi- and full-mechanized farming adoption, with female-headed households benefiting more and regional variations in productivity observed in the cursory literature (Oyewole and Sennuga, 2020). Contrarily, in Nigeria, the adoption of mechanized farming is not as high as its adoption in the context of China. Land use and its productivity and fertility cannot be underestimated in the country but traditional approach is predominant compared to when mechanized approach could be used as innovation for maximum productivity and food security. Overwhelming studies in Nigeria have advocated for supporting youth and women in mechanized farming adoption in

achieving sustainable development in Nigeria (Amuda and Alabdulrahman, 2023). Additionally, China's smallholder farmers outsource power-intensive stages like harvesting to specialized mechanization service providers, enabling them to enhance productivity and remain competitive. Literature posits that smallholder farmers contribute immensely to the overall economic growth in the country. Mechanized harvesting and threshing in Nigeria have shown significant reductions in food losses, increased yields, and positive socio-economic impacts, particularly benefiting women and youth, while constituting a positive business case for farmers (Soethoudt, Broeze and Axmann, 2021). However, it has not reached the level of outsourcing for power intensive as done in China.

Indeed, ensuring sufficient production of nutritious food for the growing global population while mitigating environmental harm stemming from food system operations poses a significant hurdle in various countries including Nigeria, China and Saudi Arabia. Current agricultural practices and policies in Nigeria are of paramount importance in advancing sustainable development, albeit with identified areas warranting enhancement. Research underscores the significance of sustainable agricultural practices (SAPs) such as the utilization of enhanced seeds, organic and inorganic fertilizers, and legume intercropping in augmenting productivity and mitigating climate variability (Oyebola, 2024). Nevertheless, obstacles persist, notably the inadequate utilization and substandard administration of irrigation schemes in the northern region of Nigeria, resulting in financial setbacks. To amplify effectiveness, it is imperative to concentrate on bridging gaps within the existing agricultural frameworks, ameliorating policy execution, furnishing adequate governmental assistance to farmers, and establishing domestic markets to optimize the marketability of agricultural commodities (Rath, Panda, Rao and Mohanta and Panda, 2024). Moreover, augmenting accessibility to agricultural extension services, broadening livelihood portfolios, and investing in infrastructural elements like transportation networks and credit accessibility can additionally bolster the adoption of sustainable practices and ensure enduring agricultural sustainability in Nigeria. Promoting the green transformation of farming in Nigeria through Agriculture Green Development (AGD) is crucial for sustainable agricultural practices (Ajekwe and Ibiamke, 2020). The adoption of green technologies like solar photovoltaic, wind energy, biofuel, biogas, and conservation agriculture can mitigate the adverse effects of conventional farming methods on the environment, leading to increased profitability and environmental sustainability. AGD aims to transition agriculture into a more resource-efficient and environmentally friendly sector, emphasizing high productivity, low environmental impact, and enhanced human well-being (Al-Ashkar, Sallam, Al-Suhaibani, Ibrahim, Alsadon and Al-Doss, 2022). Policy measures promoting the use of green technologies by farmers are essential to address challenges such as cost intensiveness, lack of technical know-how, and inadequate information on their application, ultimately ensuring a sustainable and profitable agricultural sector in Nigeria (Al-Ashkar, Sallam, Al-Suhaibani, Ibrahim, Alsadon and Al-Doss, 2022).

Agricultural transformations are underway in numerous regions worldwide, notably in China. The historical boost in food production across various countries has primarily relied on increasing resource inputs, consequently elevating the environmental impact of food production (Mujuru, Hyams-Ssekasi and Mushunje, 2022). China's agricultural progress has led to unparalleled environmental deterioration, driven by the persistent high demand for food and a focus on domestic self-sufficiency in food crop production. Urgent action is required to cultivate productive and environmentally sustainable agricultural systems, enhancing environmental, economic, and social resilience. The introduction of the green development concept in China as

a governmental priority in 2015 was followed by the detailed elaboration of agriculture green development (AGD) in 2017 (Mujuru, Hyams-Ssekasi and Mushunje, 2022). AGD aims to address diverse societal objectives such as bolstering food security, conserving resources, ensuring environmental sustainability, promoting social equity, revitalizing rural areas, and enhancing rural landscapes. In the last five years, policymakers and scholars have dedicated considerable efforts to advancing the principles and objectives of AGD and disseminating these ideas widely (Tawabini, 2023). This compilation comprising 15 articles showcases the progress achieved in this regard over the past five years. AGD encapsulates key principles and practices crucial for the advancement of regenerative and restorative agriculture globally. Given this perspective, literature offers an overview of noteworthy AGD initiatives and propose further research and development endeavours to enhance the implementation of sustainable agricultural practices at national and international levels (Tawabini, 2023). Additionally, specific studies delve into common food production and environmental challenges faced by various countries, presenting successful strategies in response to these challenges.

Saudi Arabia's agricultural sector faces significant challenges due to its harsh climate, arid conditions, and limited water resources. However, the country has made strides toward adopting innovative agricultural practices, including mechanized farming and green development initiatives, to promote sustainable agricultural productivity. Here are the key implications of these policies for achieving sustainability in Saudi Arabia's agriculture sector in the 21st century (Tawabini, 2023; Yusuf, Kooli, Khoj and Bajnaid, 2025). Mechanized farming refers to the use of machinery and automation to improve agricultural operations. The implications of mechanized farming policies in Saudi Arabia are multifaceted. For instance, mechanization allows for faster, more efficient planting, irrigation, harvesting, and processing. It reduces manual labour and increases the overall scale of production (Yusuf, Kooli, Khoj and Bajnaid, 2025). Modern machinery, such as GPS-enabled tractors and drones, can provide accurate data on crop conditions, soil moisture, and nutrient levels. This precision allows for more targeted interventions, optimizing resource use and improving yields. Mechanization can reduce the dependence on labour-intensive farming methods, which is crucial in a country with a limited local workforce for agricultural work. It may also attract skilled labour and create job opportunities in the maintenance and operation of machinery in agricultural development (Adisa, 2024; Yusuf, Kooli, Khoj and Bajnaid, 2025).

The introduction of new technologies requires farmers to develop new skills in machinery operation, data analysis, and crop management. This can foster knowledge transfer and increase the technical expertise of the agricultural workforce. Green development in agriculture focuses on environmentally sustainable practices that enhance the resilience of farming systems while minimizing their ecological. The Saudi government has integrated green development into its agricultural policies through initiatives like the National Agricultural Development Program (NADP) and the Saudi Green Initiative (Hadid and Ahmed, 2024).

Sustainable farming practices such as crop rotation, agroforestry, and reduced tillage can help maintain soil fertility and prevent erosion, particularly in arid environments. The combination of mechanized farming and green development offers significant opportunities for Saudi Arabia to achieve long-term agricultural sustainability. The use of big data, artificial intelligence (AI), and machine learning in agriculture can optimize resource allocation (e.g., water, fertilizers), reducing waste and ensuring that inputs are only used when necessary (Amuda, 2020). Mechanization in the form of automated machinery and robots can work in synergy with green development principles to create a more resource-efficient agricultural system. For example,

robots could be used for precision weeding, reducing the need for chemical herbicides and protecting soil health (Amuda, 2020). By increasing productivity and reducing resource wastage, mechanized farming coupled with green development practices can make agriculture more economically viable in the long term. This would help ensure food security and stability in prices, which is particularly important in a country with such harsh growing conditions.

### **Agropreneurship Practice in Nigeria, China and Saudi Arabia**

Agropreneurship, also known as agripreneurship, is the fusion of agriculture and entrepreneurship, aiming to transform traditional farming into a competitive business venture by incorporating modern business concepts. It encompasses a wide range of activities from farming, processing, distribution, marketing, and sales, all geared towards economic development and job creation (Ikebuaku and Dinbabo, 2023). Literature contends that entrepreneurship education is an important element for future workforce in the challenges of poverty and unemployment (Ikebuaku and Dinbabo, 2023). Agropreneurship plays a crucial role in addressing food security issues globally by engaging youth and women in agricultural enterprises, especially in regions with high levels of unemployment (Ikebuaku and Dinbabo, 2023). In countries like Nigeria, China and Saudi Arabia, agropreneurship is seen as a powerful tool for economic growth and development, offering solutions to challenges such as unemployment, poverty, and insufficient food production.

Agropreneurship practice in Nigeria is crucial for addressing youth unemployment and economic development (Yusoff, Ahmad and Abdul Halim, 2019). Overwhelming studies have explored the paramount importance of agropreneurship activities by bridging the gap between male and female farmers as well as youth that engage in agricultural entrepreneurship (Azeez, 2023). Studies have shown that Nigerian youths exhibit a positive perception and intention towards agripreneurship, with factors like course of study, family income, and infrastructure influencing their engagement in the agricultural sector (Waqas, Abd Rahman, Ismail, Kamal Basha and Umair, 2023). More importantly, agri-fresh produce is an integral part of entrepreneurship through agriculture in achieving sustainable agricultural development in the country (Fabian, Uchechukwu, Innocent and Victor, n.d.). However, challenges such as lack of land, funds, and government support hinder graduates from actively participating in agribusiness, emphasizing the need for practical agricultural education and increased government assistance to the young agropreneurs (Fabian, Uchechukwu, Innocent and Victor, n.d.). Additionally, research on agripreneurship among youth reveals that motivations include personal wealth acquisition, income enhancement, and self-employment desires, while profitability in ventures like rabbit production can be achieved despite constraints like inadequate support and diseases outbreak. Efforts to enhance agropreneurship in Nigeria should focus on improving youth involvement, providing necessary support, and creating a conducive environment for sustainable agricultural entrepreneurship (Nnamdi, Ikechukwu and Chukwudike, 2022).

Agropreneurship practice in Nigeria faces various challenges as highlighted in various studies which include economic and financial risks such as exchange rate fluctuations, high interest rates, and debt burdens faced by agripreneurs (Nnamdi, Ikechukwu and Chukwudike, 2022). Production agripreneurs encounter issues like inadequate storage and processing facilities, power supply interruptions, and outdated technology, hindering their efficient operations (Mustapha, Jung-Kim and Zapata, 2020; Usanga, 2021). Marketing agripreneurs struggle with frequent price fluctuations, high inflation levels, and intense market competition. Additionally,

the lack of government support, limited access to funds, and insufficient entrepreneurial skills exacerbate the hurdles faced by small-scale poultry farmers in Nigeria (Mustapha, Jung-Kim and Zapata, 2020; Usanga, 2021). Addressing these challenges through financial support, capacity-building programmes, and market regulation can enhance the resilience and success of agropreneurship initiatives in the country.

Agropreneurship practices in China encompass a variety of initiatives aimed at enhancing entrepreneurial behaviour and performance in the agricultural sector. Studies highlight the importance of interventions designed to improve the entrepreneurial performance of small regional agricultural firms, especially in areas like Yangling, where agricultural associations play a significant role in supporting member firms. The evolution of rural entrepreneurship in China, particularly through the development of Township and Village Enterprises (TVEs), has been a crucial aspect of agropreneurship, with TVEs contributing significantly to the national economy and employment sector (Sadan and Amuda, 2023). However, challenges persist in ensuring the sustainability and inclusivity of these initiatives, as reforms in the cooperative economy have favoured more entrepreneurial farmers, leaving behind those with fewer resources and opportunities. Understanding and implementing the marketing concept effectively is also crucial for Chinese agricultural businesses looking to internationalize and improve their branding capabilities (Sadan and Amuda, 2023).

Agropreneurship practice in China faces several challenges, including limited research on Chinese farmer entrepreneurs, underperformance of small regional agricultural firms due to lack of entrepreneurial behaviour, contradictions in traditional agricultural chains leading to high costs and low coordination, stagnation in agricultural R&D funding posing a threat to productivity and poverty reduction, and difficulties in developing sustainable food practices amidst diverse stakeholder expectations (Naz, Hashmi, Nazeer, Raza, Akhtar, Hussain and Ahmad, 2023). These challenges highlight the need for more comprehensive studies, interventions to enhance entrepreneurial behaviour, improved coordination in agricultural chains, increased investments in R&D, and better alignment with sustainable development goals to overcome the hurdles faced by agropreneurs in China.

Agropreneurship in Saudi Arabia is evolving rapidly with the integration of technology, sustainability practices, and strong government support. Entrepreneurs are at the forefront of adopting innovative agricultural practices that aim to solve the country's food security challenges while contributing to the national economic diversification. The adoption of agropreneurship practices in Saudi Arabia significantly enhances the country's food production and availability, aligning with its Vision 2030 goals of economic diversification and food security. Initiatives such as investments in indoor vertical farming and greenhouse projects, supported by the Public Investment Fund, aim to bolster local agriculture despite the challenges posed by arid conditions and limited water resources (Bank, Swarzenski, Duarte, Rillig, Koelmans, Metian and Ok, 2021). Furthermore, the commercialization of agriculture, particularly in regions like Al Jouf, emphasizes the need for sustainable practices to reduce food import dependency and improve local production. The integration of circular economy principles into the food sector promotes sustainable production and waste management, addressing environmental challenges while contributing to food security objectives (Bank, Swarzenski, Duarte, Rillig, Koelmans, Metian and Ok, 2021). Overall, these efforts not only aim to achieve self-sufficiency in key agricultural products but also enhance the livelihoods of rural populations, thereby reinforcing the agricultural sector's role in the national economy (Bank, Swarzenski, Duarte, Rillig, Koelmans, Metian and Ok, 2021).



Agropreneurship in Saudi Arabia has gained increasing importance as the country seeks to diversify its economy beyond oil and tackle challenges related to food security, sustainable agriculture, and rural development. The government, private sector, and local entrepreneurs are all focused on making agriculture a more viable and modern industry, particularly in the face of the region's harsh climate and limited water resources. There are some key agropreneurship practices in Saudi Arabia (Jabbari, Humayed, Reegu, Uddin, Gulzar and Majid, 2023). Smart Agriculture and Technology Integration such as: precision agriculture which involves using advanced technologies like sensors, drones, and GPS systems to optimize crop yields, monitor soil health, and manage water use more efficiently (Jabbari, Humayed, Reegu, Uddin, Gulzar and Majid, 2023). The use of Artificial Intelligence (AI) and machine learning in data analysis has allowed farmers to predict crop behaviour, weather patterns, and market demand more accurately. The use of Internet of Things (IoT) devices to monitor soil moisture, temperature, and humidity allows for more efficient irrigation systems, reducing water wastage, which is crucial in a water-scarce region like Saudi Arabia (Jabbari, Humayed, Reegu, Uddin, Gulzar and Majid, 2023).

Vertical Farming and Hydroponics as modern farming techniques are gaining traction in Saudi Arabia's urban areas, where space is limited and water conservation is a priority. Hydroponic systems use nutrient-rich water instead of soil, and vertical farms enable high-density, sustainable production of crops using smart technology for agricultural productivity (Baljon, 2023). Water conservation is part of sustainable farming practices whereby given the scarcity of water in the region, agropreneurs are focusing on water-saving techniques such as drip irrigation, rainwater harvesting, and wastewater recycling. Saudi Arabia is also investing in desalination technology to provide freshwater for agricultural needs. Subsidies for Water-efficient Technologies, the government offers subsidies and incentives for the adoption of water-saving technologies like drip irrigation systems. This support has helped encourage the use of more efficient and sustainable agricultural practices (Azeez, Alaka and Lawrence, 2023). Regarding, aquaponics and fish farming, Saudi Arabia is investing in fish farming (i.e., aquaculture) to meet the growing demand for seafood and reduce reliance on imports. This includes both traditional fish farming and the integration of aquaponics systems, which combine fish farming with plant production in a symbiotic environment.

### **Challenges and Measures in Addressing Mechanized Farming and Green Development**

Mechanized farming in Nigeria faces several challenges as highlighted in various studies and of such challenges include the inadequate utilization of tractors by smallholder farmers due to factors like lack of demand, problematic supply models, and failed mechanization programs (Lawal, Mustapha Abdulsalam and Sundararajan, 2023). Additionally, there are issues with environmental considerations in agricultural mechanization practices, such as the impact on land occupancy systems and traditional farming methods. Furthermore, the lack of access to long-term capital for modern farming equipment, inadequate inputs and storage facilities, weak agricultural extension services, and outdated sectoral infrastructure contribute to low agricultural productivity in the country (Lawal, Mustapha Abdulsalam and Sundararajan, 2023). Addressing these challenges requires a holistic approach that involves improving land occupancy systems, increasing demand for tractor services, supporting smallholder farmers with financing options for agricultural equipment, and enhancing environmental sustainability in mechanized farming practices (Lawal, Mustapha Abdulsalam and Sundararajan, 2023)..

To address the challenges of mechanized farming in Nigeria, measures such as promoting the

use of green technologies like solar photovoltaic, wind energy, and precision agriculture tools are crucial. Additionally, incorporating Internet of Things (IoT) applications in agricultural robotics and cyber-physical systems can enhance traditional farming methods, leading to improved food production and operational security. Agricultural mechanization has been shown to increase cultivated land, crop yields, and farmers' income in regions like Lagos State, emphasizing the importance of modern technologies in farming operations. By leveraging these technological advancements, Nigeria can enhance the sustainability and resilience of its food production systems, ensuring increased productivity, efficient resource management, and economic viability in the agricultural sector (Waktu Saptu, Ambad and Sumin, 2020).

Furthermore, promoting the use of green technologies such as solar photovoltaic, wind energy, biofuel, biogas, and organic farming, involving farmers in policy-making and providing incentives for environmental conservation, implementing financing mechanisms to support green agriculture and move away from nature-degrading practices, ensuring proper funding and marketing to enhance agricultural productivity through the development of a green economy (Falcone, 2023). Hence, strategizing a well-thought-out green action plan that considers environmental issues and promotes sustainable agricultural practices like biofuels and organic agriculture in regions like the Niger Delta can meaningfully foster agricultural green development in Nigeria (Odong, 2023). By integrating these solutions, Nigeria can progress towards sustainable agricultural practices, environmental preservation, and economic development.

Moreso, mechanized farming in China faces several challenges as highlighted in different researches which include the lack of empirical studies on the causal relationship between rural industrialization and agricultural mechanization, obstacles such as land fragmentation and lack of machinery training hindering farmers from adopting machinery, the impact of mechanization on different crop sown areas, with positive effects on grain crops but negative effects on non-grain crops (Liu, Ma, Shu, Hancke and Abu-Mahfouz, 2020). The influence of agricultural mechanization on farmers' health, showing regional and income disparities in its effects, and the low comprehensive mechanization level in stem and leaf vegetable production due to issues like poor machinery adaptability and low production efficiency. Addressing these challenges requires targeted policies to encourage mechanization adoption, improve training programmes, mitigate health risks, and enhance machinery efficiency in different agricultural sectors (Liu, Ma, Shu, Hancke and Abu-Mahfouz, 2020). In addition, strengthening institutional support, increasing public awareness, making technological investments, improving laws and regulations on soil resources and the environment, ensuring food safety, establishing national agricultural high-tech industry demonstration zones, enhancing ecological and environmental regulation, setting up an eco-incentive mechanism, promoting innovation in bottleneck technologies, and developing holistic solutions for sustainable management in ecologically fragile regions can boost agricultural green development in China (Liu, Ma, Shu, Hancke and Abu-Mahfouz, 2020). Additionally, the implementation of the Green Food Strategy, certification processes, and adherence to environmental and operational standards have significantly contributed to the advancement of green food production in China, offering a triple-win strategy for environmental protection, agro-economic development, and human health (Liu, Ma, Shu, Hancke and Abu-Mahfouz, 2020).

To address the challenges of mechanized farming in China, measures such as reducing the high cost of equipment, providing training for skilled operators, and mitigating the environmental impact are crucial. Technology plays a pivotal role in enhancing the sustainability and resilience

of food production systems globally. Innovations like robotics, artificial intelligence, nanotechnology, and gene editing are being utilized to improve the quality, safety, and sustainability of the food supply chain (Al-Dosary, 2022). Additionally, vertical farming, with advanced precision monitoring systems using the Internet of Things, presents an opportunity to mitigate global food security challenges, especially in urban areas. By integrating technological advancements and sustainable farming practices, such as vertical farming, China and other countries can work towards more efficient, resilient, and environmentally friendly food production systems. By focusing on these strategies, China can further optimize and upscale its agriculture green development initiatives (Al-Dosary, 2022 ).

Saudi Arabia is one of the most water-scarce countries in the world. Mechanized farming typically requires large amounts of water for irrigation, especially for crops like wheat, which has been historically grown in the country. This strains already limited water resources, especially in the arid regions. The country is increasingly shifting toward more water-efficient irrigation techniques, such as drip irrigation and hydroponics, as well as investing in desalination plants. Additionally, there's a push to use treated wastewater for irrigation purposes in certain agricultural areas (Alharbi, Felemban, Abdelrahim and Al-Dakhil, 2024). Moreover, over-cultivation, improper farming practices, and overuse of chemical fertilizers and pesticides can lead to soil degradation, which negatively impacts long-term agricultural sustainability. The government and private sector are adopting soil conservation practices, including crop rotation, organic farming, and the use of bio-fertilizers. The adoption of precision agriculture technologies also helps monitor soil health and optimize input usage to avoid degradation (Haq and Khan, 2022).

Furthermore, while mechanized farming can significantly increase productivity, the upfront costs for advanced machinery, technology (e.g., GPS-guided tractors, automated harvesting), and maintenance is high. For smaller farms, this could be a major barrier. Nonetheless, the government has introduced subsidies and financial incentives to promote the use of modern farming technologies. There is also a growing trend of forming cooperatives among farmers to pool resources for mechanized equipment and technology (Kim and van der Beek, 2018).

Saudi Arabia faces extreme weather conditions, such as heatwaves, droughts, and sandstorms, which can affect the yield and efficiency of mechanized farming. Rising temperatures and fluctuating precipitation patterns also pose a risk to agricultural stability. The government is investing in climate-resilient crops, biotechnology, and advanced irrigation systems. The introduction of vertical farming, controlled-environment agriculture (CEA), and greenhouses helps mitigate the impacts of extreme weather and ensure stable production year-round (Nwanojuo, Anumudu and Onyeaka, 2025). Enhancing policy and technological efficiencies can be instrumental attaining sustainable future agricultural productivity, socio-economic development as consequently contribute to reduction of poverty and the rate of unemployment (Amuda, 2022a; Amuda, 2022b; Amuda and Alabdulrahman, 2024). Smart agriculture is an integral part of monitoring and control strategies in utilizing and integrating agriculture with farming in order to enhance productivity (Rehman, Tanzila, Muhammad, Suliman, Saeed, and Chaudhry, 2022; Abunadi, Amjad, Khalid, Lorena, and Jaime, 2022). Literature further acknowledges the role of energy utilization and overall economic development in improving various sectors including agriculture in developing countries (Kim-Soon, Ng, et al., 2020; Uddin, et al. 2023). In overall, facilitation of trade activities and performance of agriculture can be meaningfully achieved when meaningful policies are formulated in attaining economic sustainability as literature suggest (Ibrahim, Yu, Hassan, Ajide, Tanveer, and Khan, 2022).

## Implications of the Study

Current agricultural practices and policies in Nigeria play a crucial role in promoting sustainable development, but there are areas for improvement. Studies highlight the importance of sustainable agricultural practices (SAPs) like improved seeds, organic and inorganic fertilizers, and legume intercropping in enhancing productivity and addressing climate variability. However, challenges such as under-utilization and poor management of irrigation schemes in northern Nigeria hinder economic gains despite their potential for food security and rural wellbeing. Evaluations of existing agricultural frameworks emphasize the need for viable policy implementation, land productivity, and government support to achieve food self-sufficiency and economic growth. To enhance impact, recommendations include improving access to agricultural extension services, diversifying livelihoods, investing in climate-resilient technologies, enhancing infrastructure, and strengthening institutions for effective water management and policy enforcement.

Current agricultural practices and policies in China have shown both positive and negative impacts on sustainable development. Studies highlight significant factors influencing agricultural development, such as affected crop area, irrigation, labour force, and financial expenditure. Challenges to sustainable agriculture include soil and water resource quality, regional imbalances, and overexploitation issues. Research emphasizes the importance of risk perception and environmental regulation in promoting farmers' sustainable behaviours in agricultural green production, with voluntary regulation playing a crucial role. Additionally, the impact of high-standard farmland construction policies on reducing agricultural carbon emissions by 12.3% underscores the potential for policy-driven improvements in green and low-carbon agricultural development. To enhance the effectiveness of current practices, policymakers should focus on strengthening institutional support, increasing public awareness, making technological investments, improving eco-incentive mechanisms, and promoting sustainable agricultural practices through regulatory measures and voluntary agreements.

The combination of modern farming techniques, investments in research, and the adoption of sustainable practices positions Saudi Arabia to be more self-sufficient in food production in the coming years. Saudi Arabia has been increasingly focused on modernizing its agricultural sector to meet its growing food security needs while transitioning towards more sustainable and green development practices. Mechanized farming, while an essential tool for enhancing agricultural productivity, brings a set of challenges that need to be addressed to align with Saudi Arabia's Vision 2030 goals of environmental sustainability and economic diversification. The government is encouraging private sector involvement in the development of sustainable agricultural technologies. Public-private partnerships are being used to scale up green technologies in farming, such as vertical farming, hydroponics, and aquaponics systems, which require less water and land. To encourage sustainable agricultural practices, the government provides financial incentives for farmers adopting environmentally friendly methods. This includes subsidies for water-efficient technologies, organic farming, and eco-friendly equipment.

Concerning Vision 2030 and the National Agricultural Strategy, Saudi Arabia aims to reduce its dependency on food imports and increase self-sufficiency in critical sectors like agriculture. The National Agricultural Strategy outlines objectives for sustainable food production, including the use of innovative technologies and environmentally friendly farming practices. A key focus is on reducing water usage while improving crop yields. Saudi Arabia is investing in agricultural

research to develop drought-resistant crops and improve farming methods suited to the harsh desert environment. This includes collaboration with international research institutions and universities. There is a need for continued research and development to adapt mechanized farming technologies to Saudi Arabia's unique environmental conditions. Additionally, there must be ongoing education and training programs to ensure farmers can effectively use new technologies and green practices. In some regions, traditional farming methods are deeply rooted, and farmers may be resistant to adopting mechanization or green development techniques. Public awareness campaigns and government support programs can help ease this transition.

## **Conclusion and Suggestions**

This study has explored mechanized farming through comparison between related policies and practices in Nigeria, China and Saudi Arabia. The detailed explanations have demonstrated that the countries have different policies, programmes and structures for the agricultural mechanization. More importantly, it is noteworthy to say that both Nigeria, China and Saudi Arabia emphatically stress the need for improving policies and practices of agriculture. However, in the Nigerian context, indigenous aspirations are given emphasis while in China, an emphasis is given to agricultural high-tech industry as one of multidimensional approaches that would enhance economic, social and resource aspects of human endeavours. The study has further explored the importance of agropreneurship practice in Nigeria, China and Saudi Arabia. It has been argued that the implementation of mechanized farming can boost the mindset for agripreneurship practices. Similarly, various challenges of mechanized farming and agricultural green development are identified and various measures in solving the challenges are identified. Nonetheless, the limitation of this study is that, it relies solely on secondary data. However, it has provided substantial direction for future study towards utilizing primary data for exploring mechanized farming and agricultural green development in Nigeria, China and Saudi Arabia. Therefore, following suggestions are made:

1. Nigeria, China and Saudi Arabia should emphasize on efficient and effective implementations of agricultural policies that will foster land productivity, input subsidies, and marketability of farm produces.
2. Nigeria, China and Saudi Arabia can achieve food self-sufficiency, create employment opportunities, and drive rapid economic growth through governments' support for mechanized farming.
3. Nigeria and Saudi Arabia with their resources for agricultural productivity should learn from the China's emphasis on agricultural high-tech industry which will boost the overall agricultural productivity in the two countries.
4. To promote mechanized farming effectively, Nigeria and Saudi Arabia must focus on balancing the growth of large agricultural machines with the improvement of land occupancy systems, ensuring sustainable agricultural development.
5. Modern techniques in animal husbandry should be used to improve productivity and efficiency in the meat and dairy sectors which includes the use of genetics, improved animal nutrition, and better veterinary care to raise healthier and more productive livestock.
6. It is paramount that Nigerian farmers should learn outsourcing for power intensive from Chinese and Saudi farmers in order to improve their productive and enable them to favourably

competitive at the international level.

7. By fostering agribusiness development through supportive policies and capacity-building initiatives, agropreneurship can drive industrial advancement, socio-economic progress, and sustainable economic development in various regions.

8. The investors in agricultural sector in both Nigeria and Saudi Arabia should increasingly adopt automation, efficient feed management systems, and biosecurity measures to boost production in poultry farming just like China.

9. There is a need to intensify effort by research institutions that involve in agricultural research by focusing on the effectiveness and efficiency of drought-resistant crops, water-efficient farming, and alternative protein sources in the countries of this study.

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