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Navigating the Nexus between Agricultural Transformation, Food Security, and Climate Change in Rural Development in Tanzania

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Abstract

The rural landscape is home to 65% of Tanzania's population, who heavily rely on agriculture as their main source of food and income. Agriculture employs 65% of the workforce and contributes 128% of food security. However, as the Household Budget Survey 2017/18 shows, some parts of rural areas are faced with extreme poverty, with a 31.3% poverty incidence and 9.7% extreme food poverty, compared to 15.8% and 4.4% in urban areas, respectively. This editorial uses a desk review of the literature and secondary data to synthesize the findings from the special issue in exploring the nexus of agricultural transformation, food security, and climate change. Smallholder-dominated agriculture, characterized by low productivity and rain-fed systems, struggles with climate variability, land tenure issues, and limited mechanization. Transformation towards market-oriented and climate-smart farming is critical. However, it is hindered by resource constraints and post-harvest losses among other things. Food insecurity, exacerbated by climate shocks, manifests in many different ways, including malnutrition and low dietary diversity, with 35% of under-five children stunted. Climate change threatens yields and pastoral livelihoods, potentially reducing economic growth. This editorial paper advocates integrated strategies, such as promoting climate-smart agriculture (CSA), irrigation, commercialization, and youth engagement, to enhance resilience and sustainability. Private sector involvement and mind-set shifts among farmers are essential for inclusive rural development, ensuring food security and climate adaptation in the evolving agricultural landscape.

Keywords: Commercialization, sustainable agriculture, food systems, end hunger, climate resilience.

1. Introduction

Tanzania is predominantly a rural country. During the 2022 National Population and Housing Census, the rural areas accounted for about 65% of the population (United Republic of Tanzania (URT), 2022). This rural population relies heavily on agriculture, which employs 65% of the workforce and contributes about 26% of GDP, 25% of export earnings, 65% of industrial materials, and 128% of food security (Mayaya et al., 2022; Mtui, 2023; World Bank, 2022, 2024a). The rural landscape is characterized by extreme poverty (National Bureau of Statistics (NBS), 2019; World Bank, 2020). As statistics show, the incidence of poverty is higher in rural areas (31.3%) than in urban areas (15.8%). Although the rural population is the main producer of food, extreme food poverty is more pronounced in rural areas (9.7%) than in urban areas (4.4%). In total, 81% of the people living in poverty in Tanzania reside in rural areas (NBS, 2019). Moreover, due to poor living conditions in rural areas, young people flee to urban centres to search for employment. However, the urban industrial sector is unable to absorb all of them either because it is not fully developed or because most of the rural youth are unskilled (Mayaya et al., 2022). Thus, rural development is pivotal in reducing poverty, driving economic growth, and achieving Sustainable Development Goals (SDGs). To achieve sustainable rural development, it is crucial to transform agriculture, particularly from subsistence farming, to modern market-oriented production, which ensures sustainable income and food security (Mpogole et al., 2020, 2023). Nonetheless, agricultural production and food security are significantly impacted by extreme weather events, which are caused by climate change. This necessitates an investigation of the interconnected challenges of agricultural transformation, food security, and climate change in rural context.

Agricultural transformation, food security, and climate change are crucial factors that shape the path to sustainable rural development in Tanzania (CIAT; World Bank, 2017). The rural agricultural sector is predominantly smallholder-based, characterized by low productivity, limited mechanization, and reliance on rain-fed systems (Mayaya et al.,

2022; Mpogole et al., 2020). Transforming the agricultural sector entails moving towards higher productivity, mechanization, climate-smart, and market-oriented farming to bolster incomes and livelihoods. However, such a transformation is not straightforward. Even when agricultural production increases, it does not directly translate into accessible food due to harvest and post-harvest losses, inefficient transportation and storage infrastructure, and nutritional issues (Bisheko & Rejikumar, 2024). Additionally, smallholder farmers who rely on rain-fed systems, face erratic rainfall, prolonged droughts, and rising temperatures (CIAT; World Bank, 2017; World Bank, 2024a). This undermines food security by reducing production and makes transformation more challenging, as farmers lack the necessary resources to adapt, rendering them highly vulnerable to the impacts of climate change (World Bank, 2024a). Climate-smart practices, such as agroforestry and irrigation systems, could enhance resilience but often require upfront costs that rural farmers are unable to afford, which stalls transformation. If food insecurity worsens due to climate shocks, rural communities have less capacity to adapt or innovate. This threatens not only their livelihoods but also national food security and rural development efforts.

The rural landscape is a critical component of the nation's agricultural and economic framework, particularly in the context of agricultural transformation, food security, and climate change. The purpose of this editorial paper is to synthesize key findings from the special issue, highlighting the interconnected dynamics of agricultural transformation, food security, and climate change, and propose a way forward for shaping sustainable rural development in Tanzania. It seeks to illuminate how these complex and interdependent challenges influence rural livelihoods, agricultural productivity, and environmental resilience. The paper further examines strategic pathways for navigating this nexus, emphasizing integrated, context-specific approaches that promote inclusive planning, climate adaptation, and sustainable agricultural systems to inform policy, research, and rural development practices in Tanzania's evolving landscape.

The special issue contributes to policy, practice, and ongoing discussions in the body of literature regarding the interplay between and among agricultural transformation, food security and climate change. The critical relevance of these interconnected dynamics lies in the need for holistic strategies that address multiple challenges simultaneously. Addressing these issues together rather than in isolation is key to achieving sustainable and inclusive growth in rural areas. Integrating these elements through coordinated policies and innovative technologies not only supports economic growth and wealth creation but also protects the environment, creating a robust foundation for long-term rural development.

2. Materials and Methods

This paper uses a desk review of literature and secondary data. The desk review of literature included published work and other grey literature about interactions between and among agricultural transformation, food security, and climate change in the context of rural development in Tanzania. This review was guided by an evidence template, a structured approach to organising and presenting the findings collected from literature reviews and other secondary sources. The evidence template was structured around four elements, including the current state of agriculture in Tanzania, drivers of agricultural transformation, food security dynamics, and climate change and its impact on food security and rural development. Firstly, for the current state of agriculture in Tanzania, the paper looked into several agricultural outcomes, including farmers' characteristics, land tenure dynamics, irrigation practices, commercialization of smallholder agriculture, mechanization and use of improved inputs, and access to extension services. These factors collectively shape agricultural production dynamics (Van Loon et al., 2020).

Secondly, for the drivers of agricultural transformation, the paper explored existing literature about changes occurring in farm practices and farmers' mindsets. This regards the ongoing debates in the body of literature about what is actually transformed between the farm and the farmer's mind-set and other multi-dimensional yet interrelated drivers of transformation, including urbanization and changing life styles and food preferences, population growth, advancement in technology, and policy reforms and investments. Thirdly, for food security dynamics, the paper explored literature on the current state of food security in terms of the four pillars, namely availability, accessibility, utilisation, and stability, and other elements

such as dietary diversity and nutrition issues. Additionally, the paper reviewed the interaction between agricultural transformation and food security. Fourthly, regarding climate change and its effect on rural development, the paper analysed how climate change affects food security and how agricultural transformation can increase resilience and adaptation to climate change.

The basic sources of secondary data were the National Sample Census of Agriculture 2019/2020 (NBS, 2021) and the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) v2.0 dataset. The National Sample Census of Agriculture 2019/2020 was used to characterising farmers, including types of agricultural activities, mechanisation, use of inputs, and access to extension services. The CHIRPS v2.0 dataset was used to obtain annual rainfall data for Tanzania from 2000 to 2020, which provides high resolutions precipitation estimates by combining satellite imagery and ground station data. The obtained data were plotted on a graph showing the variability of average annual rainfall data across Tanzania, aggregated at the national level.

3. Agriculture, Food Security and Climate Change

3.1 State of Agriculture in Tanzania

Agricultural production is dominated by smallholder farmers, contributing about 75% of the total agricultural output in Tanzania. About 85% of smallholder farmers are subsistence producers, with any surplus sold for income. These subsistence farmers cultivate on small, fragmented plots ranging from 0.9 to 3 hectares. It is estimated that there are 7,837,405 farming households (65.3% of all households), with 7,657,185 in Tanzania Mainland and 180,220 in Zanzibar (NBS, 2021). About 65% of all farming households are engaged in crop production only, about 33% are engaged in both crops and livestock production, and about 2% are engaged in livestock only as shown in Figure 1. Key food crops include maize, rice, cassava, sorghum, wheat, beans, potatoes, and fruits and vegetables. These food crops are crucial, particularly in ensuring food security, incomes, and overall wellbeing of the rural population. Low productivity due to poor agronomic practices, climate change, and smallholder farmers' shift from production of traditional food crops to horticulture, are some of the major threats to food security (Altieri & Koohafkan, 2008; Kapari et al., 2023; Saleem et al., 2024; Touch et al., 2024). Major cash crops include coffee, cotton, cashew nuts, tea, and sisal, which are vital for export. Additionally, horticultural products, including avocado and fresh vegetables are increasingly becoming significant export commodities (Msafiri & Mwombela, 2021). Overall, the current state of agriculture can be characterized in many different ways, including land tenure systems, farm size, mechanization, input use, productivity, irrigation, access to markets, commercialization, storage and harvest and postharvest losses, and rural and urban interactions.

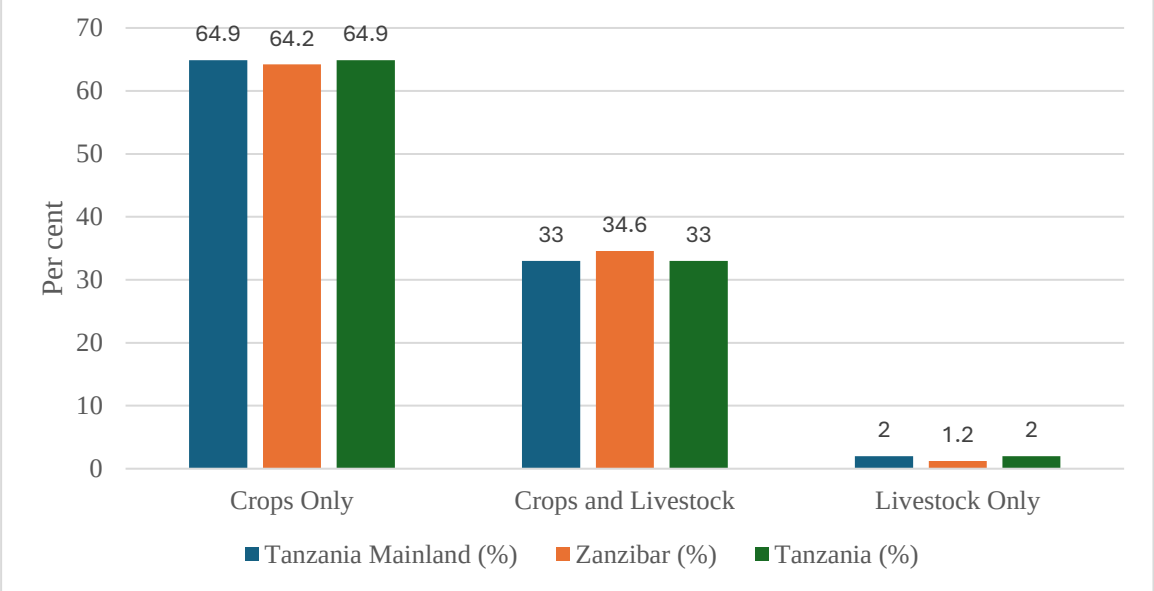

Figure 1: Farmers' characteristics (Source: NBS,2021)

Tanzania is estimated to have a total land area of 94.5 million hectares, of which 47% (44 million hectares) is classified as arable land (United Republic of Tanzania (URT), 2015).

Nonetheless, only about 34% of the total arable land is currently under production. This leaves a significant potential for expansion given that over 65% of the arable is unutilised. Moreover, even the cultivated land is underutilised due to low productivity and limited irrigation infrastructure to produce throughout a year (Mpogole et al., 2020). Despite the availability of land, access to productive land among smallholder farmers remains a challenge. Land tenure dynamics are increasingly marginalising smallholder farmers from productive land. According to Mpogole (2019), smallholder farmers are deprived of productive land for many reasons, including land acquisitions by investors for large-scale commercial production or speculation purposes, competing interests with natural resources and wildlife, conflicts with pastoralists, degradation and expropriation. Increasingly, land is being commoditised, which is characterised by coercion, non-adherence to procedures, collusion, corruption, and other unfair practices (Isinika et al., 2019). Also, anecdotal evidence has shown that there has been a wave of urban dwellers going back to their homes or other villages to acquire land for production or for speculative purposes. As a result, most of the acquired land remains unutilized (Mpogole, 2029). Yet, the one-time off payment that smallholder farmers received in compensation for the land transfer is insufficient for them to survive in the long run, leaving them resource poor and exacerbating poverty levels (Isinika et al., 2019; Sulle, 2017). However, since smallholder farmers are responsible for national food security, displacing them from their productive land may threaten future availability and affordability of food and the overall wellbeing of the rural population.

In terms of irrigation, Tanzania has 29.4 million hectares suitable for irrigation. However, only about 2.5% of the total planted area is irrigated, lower than the sub-Saharan Africa average of 4 to 6% or the global average of 20% (NBS, 2021; Wanyama et al., 2024). Moreover, only 411,108 households (5.2%) out of the 7.8 million agricultural households practiced irrigation (NBS, 2021). Despite the low irrigation rate, the total area under irrigation has increased by about 3% from 280,597 hectares in 2007/08 to 289,386 hectares in 2019/20. However, the increment of 3% in ten years is marginal and signals a slow implementation of irrigation initiatives (NBS, 2021). The overreliance on rainfall makes the agricultural sector vulnerable to climate variability. As a result, the Government of Tanzania (GoT) has taken considerable steps to enhance irrigation systems, particularly by increasing budget allocation (URT, 2024). For example, the irrigation budget increased significantly from TZS 46.5 billion in the 2020/21 to TZS 332 billion in the 2024/25 financial year (Juma, 2024; URT, 2024). These efforts are made to ensure the expansion of irrigation infrastructure, rehabilitation, and construction of new irrigation schemes, which are crucial for agricultural transformation, food security, and adaptation to climate variability.

Regarding commercialisation, agriculture in Tanzania is characterised by a mix of traditional and modern practices (de Bont et al., 2019). Although subsistence farmers dominate agricultural production, there is a gradual shift trend towards commercialisation (Mpogole et al., 2023). This shift is driven partly by the increasing demand for food and exports and GoT initiatives. Notable GoT initiatives include the Agricultural Growth Corridor of Tanzania, which aims to boost commercial farming by linking smallholder farmers with commercial farms and industries, and the Building Better Tomorrow - Youth Initiatives for Agribusiness (BBT – YIA) (URT, 2024; World Bank, 2016). The BBT-YIA aims to promote active engagement of youth and women in agribusiness, fostering sustainable food systems and enhancing livelihoods (URT, 2024). The increasing potential for agro-processing, particularly fruits and vegetables, is likely to increase the commercial orientation of smallholder farmers, value addition, and reduced post-harvest losses.

Other agricultural characteristics include mechanization, use of purchased inputs, and extension services (NBS, 2021). Despite efforts, mechanization is still limited with a majority of farmers relying on traditional tools and manual labour (Mpogole et al., 2023). The 2019/20 National Sample Census of Agriculture indicate that only 25.7% of the total cultivated area used tractors. Tractors and other modern farming equipment are not widely adopted, particularly among smallholder farmers. Additionally, adoption of improved seeds and chemical fertilizers is low. The NBS (2021) shows that 76% of about 14 million hectares of cultivated area is planted with local seeds while 20% is planted with improved seeds and the rest is a mixture of local and improved seeds. On the other hand, fertilizer application was only

about 20% of the total planted area. The low application of chemical fertilizers and improved seeds is particularly due to associated costs, limited availability, the presence of counterfeits which deter production, and weak extension services. For example, the 2019/20 National Sample Census of Agriculture shows that access to crop extension services stands at 7%, while access to livestock extension services is about 9% (NBS, 2021).

The significance of the agricultural sector in Tanzania cannot be overemphasized. Although there is a growing emphasis on improving productivity, promoting sustainable practices, and enhancing market access to bolster the sector's contribution to economic development, notable challenges persist. Smallholder farmers rely on rain-fed agriculture with limited application of improved technologies, leading to low yield and vulnerability to climate change and future food security. This shows the reasons why smallholders are poor and why they have remained in poverty (Brockington, 2021; Kabote, 2022). Since agriculture and rural development are inseparable in Tanzania and elsewhere in sub-Saharan Africa (SSA) (Mpogole et al., 2020), there is a dire need to transform agriculture to ensure sustainable food production and to enhance resilience to climate variability.

3.2. Drivers of Agricultural Transformation

Agricultural transformation is defined as how agricultural production transforms over time, particularly from subsistence and farm-centred to commercial, productive and market-centred, and adopting innovative practices and technologies, including climate-smart farming (Jayne et al., 2019; Mayaya et al., 2022). This transformation involves the use of improved technologies and sustainable practices to make farming more productive and profitable, which is crucial for food security and rural development as it increases incomes and improves rural livelihoods. Nevertheless, there are debates in the body of literature about what exactly is to be transformed between the farm and the farmer (Mayaya et al., 2022). In deciding what to focus on in the transformation process, either the farm itself or the farmer's mind-set, there is compelling evidence that both the farm and the farmer should be transformed. Studies such as those of Boettiger et al. (2017) and Bakker et al. (2022) show that agricultural transformation should start with the farmer's mind-set. This entails helping farmers to be open to new ideas and innovation, particularly the use of digital technologies or adopting eco-friendly methods, which then leads to changes in how the farm operates. When farmers are willing to try new things, they are likely to adopt improved technologies, which improve efficiency and sustainability. Appropriate support is needed to help to change farmers' mind-set (Boettiger et al., 2017). A farmer's mind-set is influenced by household economics, balancing profit, risk, and cash flow. Thus, transformation plans should consider this analysis for income growth. This approach ensures that changes in the farmer's mind-set are not superficial but are deeply rooted, leading to long-term sustainability (Bakker et al., 2022).

Another issue regarding transforming the farmer's mind-set is attracting the new generation in agriculture. This involves changing the mind-set of youth for future agriculture by altering the perceptions of farming as 'dirty work' and tiresome, with high stigmatization from peers and communities. According to Kayodi (2017), attracting and keeping youth in food production involves supplying modern and affordable farm technology to help them do the farm work well and efficiently. Access to land, affordable sources of finance, skills development, and improved farm technologies, particularly mechanization are likely to attract youth into the agricultural sector. Additionally, education programmes, including agribusiness incubation and market linkages initiatives can attract youth to agriculture. However, this is subject to willingness to change, which may require incentives, exposure, or showing a viable path forward, with commitment from the government as in the BBT-YIA initiative. This underscores the significance of mindset change in overcoming barriers to agricultural transformation.

While the farmer's mindset is crucial, transforming farm practices is equally significant for operational efficiency, economic viability, and environmental sustainability. Regarding operational efficiency, transforming farm practices, particularly through technology and sustainable methods like Climate Smart Agriculture (CSA) is crucial. CSA, including conservation tillage, agroforestry, and water-efficient irrigation improves productivity and resilience. Although these changes enhance

farm operations, they require farmers to first embrace new ways of thinking or practices. Furthermore, changes in farm practices can lead to increased economic outcomes. For example, Boettiger et al. (2017) show Morocco's success in growing high-value crops like tomatoes and olives on irrigated land, increasing smallholder income by 30% and average land productivity, which demonstrates how farm practices can bolster profitability. Additionally, sustainable farm practices are critical in addressing global challenges, including climate change and loss of biodiversity. Sustainable practices like regenerative agriculture can mitigate the impact of agricultural expansion as a major driver of deforestation and ecological destruction.

The foregoing discussion shows that there is an interconnection between mindset and farm practices. Transformation of farm practices and the farmer's mind-set are not isolated from one another but rather they influence each other in a bidirectional relationship (Bakker et al., 2022). A shift in mind-set can lead to changes in farm practices, while new practices can also shape how farmers think. For example, adopting CSA requires farmers to learn new skills, which in turn influences their mind-set. Table 1 illustrates the conceptualization of the relationship between the farmer's mindset and farm practices, emphasizing that while farm practices are the tangible outcome, the farmer's mindset is often the gateway to making changes happen.

Table 1: Illustration of the interconnection between mind-set and farm practices

SN	Aspect	Farmer's mind-set	Farm practices
1	Primary Role	Catalyst for change, enabling adoption of new methods.	A change in mind-set by adopting new improved methods can translate to operational efficiency, economic viability, environmental sustainability.
2	Examples	Willingness to use improved technologies, openness to sustainability, and youth perception shifts.	Climate-smart agriculture, digital technologies, high-value crop adoption.
3	Challenges	Resistance to change, negative perceptions, lack of awareness.	High costs, technical barriers, environmental constraints.
4	External Support	Education, incentives, change agents.	Policy reforms, financial aid, technological infrastructure.

As shown in Table 1, while both the farm and the farmer's mind-set need to be transformed for successful agricultural transformation, the evidence leans toward prioritizing the farmer's mind-set as the starting point. A mind-set, which is open to innovation, sustainability, and long-term planning enables farmers to adopt new practices and improved technologies, leading to transformed farms. Nevertheless, this process is facilitated by external factors such as policy support, education, and economic incentives, particularly access to affordable credit (Boettiger et al., 2017; Kayodi, 2017). This implies that agricultural transformation should focus on a holistic approach that cultivates an open mind-set for change while supporting the operational shifts needed on the farm.

In addition to changing the farmer and the farm, drivers of agricultural transformation are also multidimensional, interrelated, and change over time. Boettiger et al. (2017) highlight three key categories of drivers of agricultural transformation, including institutional framework, national agricultural plans, and agricultural service delivery mechanisms. Improvement in the institutional framework, particularly governing mechanisms and political will, can significantly influence agricultural transformation. Also, the quality of agricultural plans or strategies, such as the Agricultural Sector Development Plans I and II (ASDP I and II) and District Agricultural Development Plans (DADPs) is pivotal. Moreover, agricultural service delivery mechanisms, particularly extension services, improved inputs, and transport

infrastructure are crucial in translating the agricultural plans into on the ground impact.

Other drivers of agricultural transformation include urbanization and changing demand and preferences; population growth, which increases demand for food thereby incentivizing intensification and market-oriented farming; advancement in agricultural technologies; global market integration in which export crops like horticulture encourage farmers to adopt modern practices to meet international standards as in the case of avocado production; climate adaptation needs where droughts and floods drive adoption of CSA and sustainable farming practices; land tenure dynamics, particularly land commoditization fosters commercial agriculture but challenges smallholder land access; and, policy reforms and investments like BBT-YIA and Agricultural Growth Corridor of Tanzania promote infrastructure development, extension services, and market access. Additionally, the involvement of the private sector and public-private partnerships is critical in driving innovation to improve productivity, food security, and rural livelihoods.

3.3. Food Security Dynamics

Despite Tanzania's ability to provide 128% of the country's food production needs, the resource-poor and most marginalized households, particularly in rural areas, struggle to meet their basic food and nutrition requirements on a regular basis (NBS, 2019; WFP, 2016). Food insecurity is both transitory and chronic in nature. Transitory food insecurity arises from the instability of food production, food prices, or household income commonly experienced in rural and other marginal areas of the central and northern regions, including Dodoma, Singida, Shinyanga, Tabora, some parts of Tanga, Arusha, Kilimanjaro, and Manyara (Mushi, 2012; Roothaert et al., 2021). This phenomenon is also contributed to by the fact that some farm households sell their surplus product immediately after harvest. As a result, six to nine months later, many do not have their crop or the cash to purchase food from the market. The situation is particularly critical during the rainy season when calorie needs are high due to agricultural work and market prices are high due to a shortage in supply (Randell et al., 2022a; URT, 2006). This situation also triggers food insecurity in urban areas through price fluctuations.

The food security in Tanzania does not only relate to availability or shortage but is a multidimensional challenge encompassing accessibility, utilisation, and stability (Lukiko & Sokoni, 2023). According to FAO (2023), food availability refers to the supply side determined by the level of production, stock, and net food trade. Accessibility is the ability of households to acquire adequate amounts of appropriate food for a nutritious diet. While utilisation refers to the food storage, preparation, and feeding practices, and stability refers to the reliability in food availability, access and utilisation. Even in areas with high food production, including the southern Highlands of Tanzania, food insecurity is manifested in different forms such as malnutrition and low dietary diversity. For example, URT (2019) shows that 32% of under five children (24.7% in urban areas and 37.8% in rural areas) suffer from stunting and over 40% of women of reproductive age are anaemic, indicating severe nutritional deficiencies. WFP (2016) notes that 59% of families cannot afford a nutritious diet, contributing to high rates of stunting, obesity, and micronutrient deficiencies. Also, there are regional disparities characterised by agro-ecological zones and food trade where some areas are worse off than others and moving food from areas with surplus to areas with deficit is another challenge. This challenge is due to infrastructure development and market access issues facing smallholder farmers. Thus, food insecurity in Tanzania can be summarised as shown in Table 2.

Table 2: Characterization of Food Insecurity in Tanzania

SN	Type	Severity	Causes	Mitigation Strategies
1	Insufficient Production	Approximately 379,000 people (5% of 7.1 million in 21 districts) experienced some form of food insecurity (May-Oct 2024) (IPC, 2014).	Subsistence farming, poverty, climate change (droughts, floods), insufficient access to resources (water, land).	Promote commercialization, Sensitise the use of farm inputs, strengthen pest and disease surveillance, and promote horticultural production.
2	Postharvest Losses	Up to 40% (Mpogole et al., 2020).	Inadequate storage facilities, inadequate processing techniques, transportation issues, and gaps in policy action on postharvest loss management.	Implement a Postharvest Loss Management Strategy, improve storage and processing facilities, and educate farmers on better practices.
3	Transportation Challenges	Severity could not be established but likely contributes to food insecurity in deficit areas.	Scattered production in small, fragmented plots, infrastructure, and limited transportation networks.	Enhance land consolidation for medium and large-scale production, improve road networks, develop transportation infrastructure, and establish market linkages.
4	Malnutrition	Over 32% of children under five are stunted; over 40% of women of reproductive age are anaemic; 59% of families cannot afford a nutritious diet (URT, 2019; WFP, 2016).	Insufficient access to nutritious food, poverty, and lack of education on nutrition.	Nutrition education, school feeding programs, fortification of foods, and improve access to diverse foods.
5	Dietary Diversity	Low dietary diversity and overreliance on staple foods, particularly carbohydrates (Roothaert et al., 2021).	Poverty, limited access to markets, and limited production of diverse crops.	Promote production of diverse crops, improve market access, and nutrition education.

The causes of insufficient production include poverty, which limits access to agricultural inputs; traditional or subsistence farming, where farming is considered a normal routine activity rather than a serious business; and climate change, which manifests itself in the form of droughts and floods that disrupt crop and livestock production. Resource poor smallholder farmers are unable to purchase improved seeds or fertilisers that can increase yield (Mpogole et al., 2023; NBS, 2021). Additionally, climate variability, which manifests in the form of floods or drought affects smallholder food production. Drought is further exacerbated by limited access to irrigation infrastructure, particularly for smallholder farmers who dominate the agricultural sector. Promoting commercialization and use of improved farm inputs would increase both production and productivity per unit of land. Moreover, encouraging off-season production of grains and horticulture is crucial for increasing food production and availability. Moreover, encouraging a shift in food preferences to, for example, sorghum, potato, cassava, pumpkin, yam, and horticulture would reduce overreliance on maize and rice (Mpogole et al., 2012; Roothaert et al., 2021).

Regarding harvest and post-harvest losses, available statistics show that up to 40% of food is lost either during harvest due to the use of poor harvesting tools, particularly in rice and maize, or on transit from farm to storage facilities or market centres due to inefficient transportation and use of dilapidated materials (Mpogole et al., 2020). Yet, harvest and post-harvest losses happen when production costs have already been incurred. This does not only reduce food available for consumption or sale but also it increases poverty levels among smallholder farmers. Addressing harvest and post-harvest losses can increase food availability without unnecessarily increasing production areas or levels, which is critical for environmental conservation.

According to Roothaert et al. (2021), dietary diversity is not only affected by affordability and availability of diverse foods but also influenced by attitudes, traditions, and cultural practices that determine food preference dynamics. As Roothaert et al. (2021) show, communities in northern Tanzania did not prefer to take vegetables as they associated them with poverty. Furthermore, despite remarkable quantities of calories in other carbohydrates, communities continue to rely on maize and rice as their staple food. A shortage of maize and rice is synonymous with food insecurity even when other food crops, including wheat, sorghum, millet, potatoes, cassava, and yams are available (Mpogole et al., 2012). Roots and tubers such as potatoes, cassava and yams, which are readily available, easy to prepare, and have adequate calories comparable to cereals, could be used to reduce the pressure on maize and rice. However, this points to the need to address cultural dietary patterns and potential resistance to dietary diversification to promote nutrient-dense foods and reduce hunger.

3.4 Climate Change and its Impact on Agriculture and Food Security

Climate change poses a significant threat not only to food security but also to rural development in Tanzania due to reliance on rain-fed agriculture, livestock, and natural resources for their livelihoods (World Bank, 2024b). Rising temperatures, prolonged droughts, erratic rainfall patterns (Figure 2), and intense rain events disrupt crop production. Seasonal rainfall variability leads to unreliable planting and harvesting schedules, reducing yields of staple crops like maize and rice (Rowhani et al., 2011). These extreme weather events are the primary threats to agricultural productivity, with direct impacts on rural livelihoods. The World Bank (2024) projects that, if not addressed, climate change could reduce Tanzania's economic growth by up to 4% by 2050. If this happens, it will push an additional 2.6 million people into poverty.

Food security is further compromised as climate variability affects crop production and access to food. According to Randell et al. (2022), climate change disrupts food production, availability, and nutrition, particularly in semi-arid regions like Dodoma and Singida. The reliance on rain-fed agriculture makes rural households vulnerable, with smallholder farmers facing challenges due to limited access to technology and resources. Studies in Mvomero and Rungwe districts demonstrate that variable climatic conditions reduce agricultural output, threatening household food security (Kane, 2010). However, the literature lacks field-based experimental data to quantify impacts on specific crops.

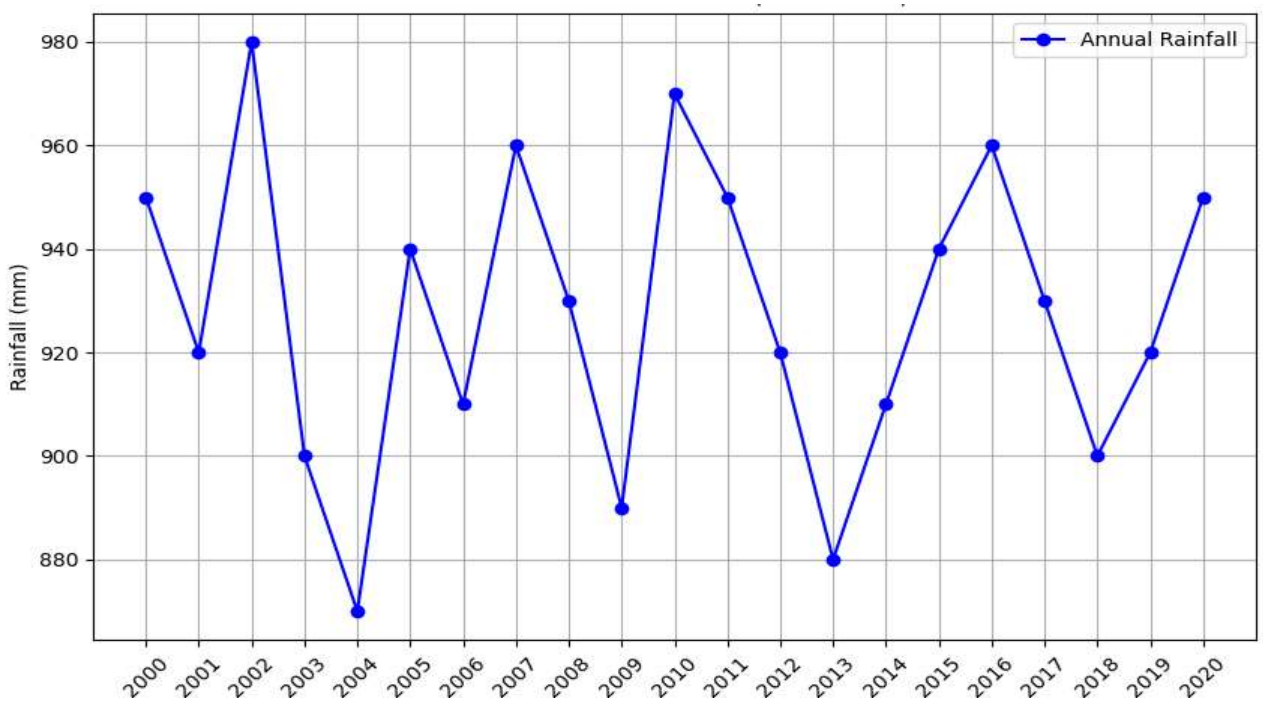

Figure 2: Tanzania annual rainfall variations (2000–2020)
Source: Climate Hazards group InfraRed Precipitation with Stations (CHIRPS) v2.0 dataset

Apart from agriculture, climate change affects livestock. Pastoral communities, particularly the Maasai in northern Tanzania, face acute challenges due to climate change (Kimaro et al., 2018). Prolonged droughts and unpredictable rainfall have reduced pasture availability and water sources, leading to livestock losses and diminished livelihoods. In Longido district, for example, climate change has adversely affected livestock productivity, forcing pastoralists to sell animals to buy food during drought seasons (Bubeck et al., 2013). Additionally, rural-urban migration among young Maasai men has increased as they seek alternative livelihoods, disrupting traditional socio-economic structures. Yet, traditional adaptation strategies, such as herd mobility, are constrained by land-use policies prioritizing sedentary livestock systems (Cho et al., 2025; Homewood et al., 2009; Ripkey et al., 2021). Land-use policies are increasingly forcing pastoralists to switch to sedentary livestock systems, which restricts their traditional practice of herd mobility. These policies, combined with land tenure reforms, have a direct effect on pastoral production systems. Pastoral communities face vulnerabilities due to their sensitivity to extreme weather and limited ability to adapt their livelihoods to the impacts of climate change. As a result, the transition to sedentary systems challenges traditional practices and may necessitate new strategies to promote sustainable livestock farming (Cho et al., 2025).

Climate change exacerbates socio-economic vulnerabilities in rural areas, particularly among marginalised groups. Yet, marginalised groups, particularly female-headed households are less likely to adopt adaptation strategies due to limited access to resources, education, and land ownership (Garcia-Herrero et al., 2017). Moreover, non-climatic stressors, such as inadequate extension services and low household assets, amplify vulnerabilities. For example, villages in the western highlands, with a high vulnerability index (0.61), face compounded risks, resulting into low agricultural yields and reduced income (Swai et al., 2012). Rapid population growth and rural-urban disparities further exacerbate vulnerabilities, as noted in the World Bank's Country Climate and Development Report (World Bank, 2024b).

Climate change threatens rural development in Tanzania, undermining agriculture, food security, and pastoral livelihoods while exacerbating vulnerabilities. Adaptation strategies offer resilience but are constrained by socio-economic and policy barriers. Additionally, private sector involvement is crucial in mobilising finance for climate-smart technologies, but rural areas remain underserved (World Bank, 2024b). Nonetheless, there is a need to strengthen efforts to promote CSA practices, enhance adoption of drought-resistant crop varieties, and provide farmer training on climate change adaptation to mitigate the impact of climate variability on food production. Also, there is a need for a structured strategy for promoting alternative staples, including market incentives, nutritional education, and policy support for diversified cropping systems. Market incentives involve creating demand and improving market access for alternative staples to encourage farmers to diversify crops and ensure economic viability. This goal can be achieved through market linkages and promotion of local food systems that encourage local procurement policies for alternative staples in public programmes, including school feeding, to create consistent demand and incentivise production. Raising awareness about the nutritional benefits of alternative staples is crucial to shift consumer preferences and dietary habits, particularly in rural areas. This nutritional education can be achieved through community campaigns that engage women who often influence household diets, and youth, who can adopt new practices. Policy support can be achieved through the creation of an enabling environment for smallholder farmers to adopt alternative staples and for markets to support their uptake through research and development, extension services, the development of infrastructure, particularly irrigation systems, and other incentives.

4. Conclusion and Recommendations

The nexus between agricultural transformation, food security, and climate change is critical, as it shapes the future of food systems and rural livelihoods. Agricultural transformation involves modernizing farming practices, diversifying crop production, and improving market access, which are crucial for enhancing food security. However, climate change poses significant challenges, including increased frequency of droughts and floods, which can devastate traditional farming systems reliant on rainfall and a narrow range of crops, typical among smallholder farmers. Smallholder agriculture, while central to food security and economic growth, faces persistent

low productivity, socio-economic barriers, and climate vulnerabilities. As a result, the ability to adapt to these climatic changes while transforming agriculture becomes essential for ensuring sustainable food production and improving rural livelihoods. Thus, rural development hinges on addressing the interconnected challenges of agricultural transformation, food security, and climate change.

The impacts of climate change are evident, leading to reduced agricultural productivity and threatening food security. Food insecurity, driven by production shortfalls, post-harvest losses, and nutritional deficiencies, is worsened by climate shocks, threatening rural livelihoods and national development. The reliance on traditional staples like maize and rice exacerbates vulnerability, as these crops are sensitive to changing weather patterns. Agricultural transformation efforts should focus on promoting resilient and climate-smart practices. Besides climate change, cultural context is crucial in understanding food security in Tanzania. Traditional beliefs and cultural practices significantly influence food choices and dietary habits. In rural communities, certain foods, especially vegetables and alternative staples, may be stigmatized or associated with lower social status, leading to a preference for more culturally valued staples like maize and rice. This perception can hinder efforts to diversify diets and improve nutrition.

To address these cultural barriers, it is critical to incorporate community engagement and education into strategies for promoting food security. Efforts should focus on reshaping perceptions through campaigns that celebrate the nutritional and economic benefits of diverse foods, leading to increased resilience to climate variability; cultivation of diverse and alternative crops, which reduce pressure on maize and rice; increased farmer incomes through diversified markets and value-added products; and improved dietary diversity and nutritional outcomes in rural households. Highlighting traditional recipes that include a variety of crops can help in changing attitudes and encouraging acceptance of alternative staples. Such efforts can foster an inclusive approach that improves nutrition and supports sustainable agricultural practices.

Additionally, the paper recommends holistic strategies integrating commercialization, irrigation, CSA, and women and youth engagement in agriculture, which are essential for sustainable rural development. Moreover, fostering innovation, policy coherence, and private sector involvement is crucial in building resilient food systems and achieving inclusive growth. Future research may prioritize field experiments, underexplored regions, social capital, indigenous knowledge integration, and policy reforms to support sustainable rural development.

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