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Political Economy of Climate-Resilient Agriculture Policy Failures in Sub-Saharan Africa: Unpacking the Governance Gap

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Abstract

Sub-Saharan Africa (SSA) faces existential threats from climate change, with its agriculture sector, the backbone of most economies and livelihoods, disproportionately vulnerable. Despite widespread recognition of the need for climate-resilient agriculture (CRA) policies and numerous initiatives, implementation failures remain pervasive. This paper argues that these failures are fundamentally rooted in the complex political economy of the region. Utilising a political economy framework, it analyses how power dynamics, institutional weaknesses, competing interests, rent-seeking, colonial legacies, and donor influence systematically undermine the formulation and execution of effective CRA policies. The analysis highlights the misalignment between formal policy objectives and the incentives and capacities of key actors, including political elites, bureaucracies, smallholders, traditional authorities, and international donors. The findings illustrate common pitfalls. The paper concludes that addressing CRA policy failures requires confronting these deep-seated political economy constraints through context-specific governance reforms, enhanced accountability mechanisms, and more politically informed donor engagement.

Keywords: political economy, climate, resilience, policy, governance, institution, agriculture policy, Sub-Saharan Africa

1. Introduction

Globally, there is a consensus that the fundamental principle of public policy should be to expand the social opportunities open to people (Ribot, 2002; Whitfield, 2010). In this framework, state-sponsored public policies can be classified as market-complementary and market-excluding. Policies towards the agricultural sector have been for a long time, thus reducing opportunities for the rural population to develop and expand their capabilities (Tanner & Allouche, 2011). At the same time, many countries have often failed to "go beyond the market" and provide the essential supportive services that could prevent rural stagnation, decline, and poverty - rural infrastructure, education, health care and sanitation, child nutrition programmes, agricultural research and extension (Ribot, 2002; Whitfield, 2010). In South Asia and several sub-Saharan African countries, generally, these activities are largely left to private initiative, with indifferent results, whereas in the East Asian countries, there is strong public action with a payoff in higher economic growth and poverty reduction (Tanner & Allouche, 2011).

Generally, population growth will occur in areas where poverty and food insecurity are widespread. Food, as such, is a relatively inelastic commodity. This means that demand for food does not depend on the market price, but instead on the size of the population. Thus, one pivotal question arises: how can an increasing number of people be fed with declining agriculture? One possible means is to improve agricultural production to increase food production. However, this strategy is limited by external circumstances since resources such as water and arable land are not only limited in quantity in Africa, but also geographically unequally distributed. Also, a very large part of food production is used to feed livestock and to produce biofuel. The agricultural food production improvement will not solve the problem of raising food demand if it is not accompanied by other policies and strategies. In this regard, agricultural development is

crucial in the attainment of socio-economic transformation, wealth creation, and poverty reduction in all developing countries (Acemoglu & Robinson, 2012).

Thus, as the world population increases, so does the demand for food, whereas natural resources are declining. Most of this population growth is expected in the emerging economies such as India or China, and developing countries mainly situated in sub-Saharan Africa. Growing urbanization has also created slums in the cities of these countries, where unemployment and low incomes appear to be the main constraints to increased calorie consumption (Acemoglu & Robinson, 2012). This state of affairs keeps worsening with the years, and the nutritional status of these city immigrants keeps deteriorating each year. This has been further compounded by the rapid urbanisation that also increased the demand for imported food, which in turn has helped to change the consumption patterns of urban dwellers from traditional staples to rice and wheat products. Financial access to food is determined by a combination of income levels, its distribution, and the purchasing power of the incomes earned (Ribot, 2002; Whitfield, 2010). High malnutrition is often recorded, and low incomes appear to be the main constraint to increased calorie consumption. Adequate access to foods like meat and fish is restricted to relatively high-income groups and households (Patel, 2013). This means that a small elite class is overfed at the same time that many others go hungry.

Arguably, agriculture is the backbone of many economies in SSA, contributing significantly to GDP, employment, and food security. Agricultural development is crucial in attaining socio-economic transformation, wealth creation, and poverty reduction in all developing countries (Ribot, 2002; Whitfield, 2010). It also promotes economic growth, poverty reduction, and food security (Acemoglu & Robinson, 2012). Sub-Saharan Africa is one of the most vulnerable regions to climate change due to its dependence on agriculture, which employs over 60% of the population and contributes significantly to GDP (FAO, 2013). It is one of the most vulnerable regions to the impacts of climate change, with agriculture being the most affected sector. The region faces increasing challenges such as erratic rainfall, prolonged droughts, soil degradation, and rising temperatures, which threaten agricultural productivity and livelihoods. Climate-resilient agriculture (CRA) has emerged as a critical approach to mitigate these challenges and ensure sustainable agricultural transformation. In Sub-Saharan Africa (SSA), climate change significantly threatens agricultural productivity for livelihoods. Climate-resilient agriculture (CRA) emerged as a critical strategy to mitigate the impacts of climate change, enhance food security, and promote sustainable development. However, despite the proliferation of CRA policies across SSA, their implementation has been fraught with challenges, leading to limited success. Climate change poses a significant threat to agricultural productivity and food security in Sub-Saharan Africa (SSA), where the majority of the population depends on rain-fed agriculture (IPCC, 2022). Climate change poses a severe and escalating threat to agricultural systems and food security in Sub-Saharan Africa (SSA). Rising temperatures, erratic rainfall, increased frequency of extreme weather events, and shifting agro-ecological zones directly undermine crop yields, livestock productivity, and rural livelihoods (IPCC, 2022; Niang et al., 2014). Climate-Resilient Agriculture (CRA), defined as integrated approaches that sustainably increase productivity, enhance resilience (adaptation), and reduce greenhouse gas emissions (mitigation) where possible, is thus critical for the region's sustainable development (Patel, 2013; Lipper et al., 2014).

Many governments in SSA and some international organisations have promoted climate-resilient agriculture (CRA) policies to enhance adaptive capacity and mitigate climate risk in the region. Many of the CRA policies have failed to achieve their objectives, leading to persistent vulnerabilities among smallholder farmers (Ribot, 2002; Whitfield, 2010). That is, despite decades of policy pronouncements, national adaptation plans, and significant international investment, the effective implementation of CRA policies across SSA remains largely elusive (Carty et al., 2020). While technical and financial constraints are often cited, a growing body of evidence points to the political economy as the primary driver of these failures (Newell et al., 2021). Political economy analysis examines how political forces, economic interests, and institutional arrangements shape policy choices, resource allocation, and implementation outcomes (Ribot, 2002; Whitfield, 2010). In the context of SSA's CRA policies, this lens reveals how power structures, vested interests, weak institutions, and historical legacies consistently undermine the translation of technical solutions into effective, equitable, and sustained action. This paper, therefore, explores the political economy of CRA policy failures in SSA, focusing on the interplay of governance, institutional, stakeholder interests, and socio-economic factors that hinder effective policy implementation. That is, it seeks to synthesize existing literature and analyses to provide a detailed examination of the political economy factors driving CRA policy failures in SSA. The paper argues that understanding and addressing these underlying political and institutional constraints is paramount for designing and implementing policies that can genuinely build resilience for Sub-Saharan Africa's vulnerable agricultural populations. The rest of the paper is structured into the following sections. The next section is the literature review, and this is followed by the analytical framework, methodology, findings and discussion, conclusion and policy recommendations, and references.

2. Literature Review

The concept of climate-resilient agriculture encompasses practices and technologies that enhance the adaptive capacity of farming systems while reducing greenhouse gas emissions (Ribot, 2002; Whitfield, 2010). In SSA, the adoption of CRA practices such as conservation agriculture, agroforestry, and drought-resistant crops has been limited due to socioeconomic and institutional barriers (Carty, Kowalzig & Zagema, 2020). Studies have also highlighted the role of gender inequality, as women farmers often face restricted access to resources and decision-making processes (Carty et al., 2020). Furthermore, inadequate funding and weak extension services hinder the scaling up of CRA initiatives (Collier, 2010).

Studies on climate-resilient agriculture highlight the importance of integrating climate adaptation strategies into agricultural policies (Whitfield, 2010). However, studies have also identified numerous challenges, including inadequate funding, weak institutional capacity, and poor stakeholder engagement (Carty et al, 2020). In SSA, these challenges are exacerbated by political instability, corruption, and competing development priorities (Crook, 2003). Studies have emphasised the role of political economy in shaping policy outcomes. For example, Collier (2010) argues that elite capture and rent-seeking behavior often undermine the effectiveness of CRA policies. Similarly, institutional fragmentation and lack of coordination among government agencies have been identified as major barriers to policy implementation (Eriksen et al, 2021). Some research also suggests that SSA is particularly vulnerable to climate change due to its reliance on rain-fed agriculture, limited adaptive capacity, and high levels of poverty. Studies have shown that climate change is expected to reduce agricultural yields by 10-25% by 2050, with some regions experiencing even greater losses (Newell et al., 2021). Key impacts include reduced water availability, increased pest and disease outbreaks, and loss of arable land.

Climate-resilient agriculture refers to practices and systems that enhance the capacity of agricultural systems to withstand and recover from climate-related shocks and stresses. This includes the adoption of sustainable land management practices, diversification of crops, improved water management, and the use of climate-smart technologies. The literature emphasizes the importance of integrating traditional knowledge with modern innovations to build resilience. Several policy frameworks have been proposed to support CRA in SSA. These include the Comprehensive Africa Agriculture Development Programme (CAADP), the African Union’s Agenda 2063, and the United Nations Sustainable Development Goals (SDGs). However, the implementation of these policies has been hindered by factors such as inadequate funding, weak institutional capacity, and a lack of coordination among stakeholders. Climate change poses an existential threat to Sub-Saharan Africa's (SSA) agricultural systems, upon which 60-70% of livelihoods directly depend (IPCC, 2022; Niang et al., 2014). Climate-Resilient Agriculture (CRA), integrating sustainable productivity increases, adaptation, and mitigation, is widely advocated as the solution (FAO, 2013; Eriksen et al, 2021).

However, despite decades of policy frameworks, international funding, and technical interventions, the implementation and effectiveness of CRA policies across SSA remain profoundly disappointing (Carty et al., 2020). While resource constraints and technical barriers are real, a growing consensus identifies the political economy, the interplay of power, institutions, and interests, as the primary driver of these failures (Newell et al., 2021). Also, chronic underfunding, fragmentation, and limited technical skills within agricultural ministries and extension services hinder the complex coordination required for integrated CRA across water, environment, and finance sectors (Andrews et al., 2017). Many states in the SSA countries have engaged in isomorphic mimicry, adopting the forms of CRA policies without building functional implementation capability (Andrews et al., 2017; Carty et al., 2020). Public resources for CRA inputs (seeds, fertilizer), infrastructure, or contracts are vulnerable to diversion through patronage networks and corruption. Elite actors capture benefits, distorting program targeting and reducing effectiveness (Ribot, 2002; Crook, 2003; Khan, 2010; Andrews et al., 2017). As Khan (2010) argues, rent-seeking is endemic in contexts with weak property rights and contract enforcement. While decentralisation is often promoted, local governments frequently lack fiscal autonomy, technical capacity, and genuine authority to tailor and implement CRA strategies. Power often remains centralised or captured by local elites, undermining responsiveness (Ribot, 2002; Crook, 2003).

In a nutshell, despite the growing body of literature on CRA, there is still a need for more research on the effectiveness of specific policy interventions in different contexts within SSA. Additionally, there is limited evidence on the role of gender and social inclusion in climate-resilient agricultural practices. The analysis revealed several key challenges to achieving climate-resilient agriculture in SSA, including smallholder farmers often lacking access to improved seeds, irrigation systems, and weather forecasting tools (Tanner & Allouche, 2011). Poor road networks and storage facilities exacerbate post-harvest losses and limit market access (Crook, 2003), fragmented policies and insufficient coordination among stakeholders hinder the effective implementation of CRA initiatives (Peters, 2004; Tanner & Allouche, 2011), and poverty, gender inequality, and low levels of education restrict farmers' ability to adopt CRA practices (Lipper et al, 2014; Acemoglu & Robinson, 2012).

3. Theoretical Framework of Analysis

This paper employs a political economy framework lens to analyse CRA policy failures, drawing on theories of governance, institutional analysis, and resource allocation (North, 1990; Acemoglu & Robinson, 2012). Political economy emphasises the role of power dynamics, incentives, and institutional structures in shaping policy outcomes. In the context of SSA, these factors are critical in understanding why well-intentioned CRA policies often fail to achieve their objectives (North, 1990; Acemoglu & Robinson, 2012). The framework draws on the concepts of power, interests, and institutions to explain how governance structures and stakeholder dynamics influence policy outcomes (North, 1990; Acemoglu & Robinson, 2012). Specifically, the analysis focuses on three key dimensions:

i. The role of state institutions, decentralisation, and accountability mechanisms in shaping policy implementation.

ii. The impact of weak regulatory frameworks, bureaucratic inefficiencies, and resource limitations on policy effectiveness.

iii. The influence of elite capture, rent-seeking behaviour, and competing priorities on policy design and execution.

In short, the paper employs a political economy framework lens to analyse CRA policy failures, drawing on theories of governance, institutional analysis, and resource allocation. Political economy emphasizes the role of power dynamics, incentives, and institutional structures in shaping policy outcomes. In the context of SSA, these factors are critical in understanding why well-intentioned CRA policies often fail to achieve their objectives.

4. Design, Method, and Data Sources

We employed an exploratory case study design. The focus of this design is to explore the field for more detailed views of study participants in this study in their natural environment. A case study method, which is one of the qualitative approaches of social research, was employed. Case study research is a qualitative approach in which the investigator explores a real-life, contemporary bounded system over time. Given the fact that processes of interpretation and sense-making, as well as the particularities of context, are central to this analysis, the choice of exploratory case design seemed to be the most appropriate one. This is because the study fits into the exploratory case study, often designed to bring out details from the viewpoint of the participants (Creswell, 2014). An exploratory case study design is therefore considered an appropriate design, and central to providing answers to the conceptual and empirical questions the study interrogated.

The paper was designed to explore to collect primary and secondary data on the politics and economics of agricultural development in SSA. Data collection in case study research, according to Creswell (2014), is typically extensive, drawing on multiple sources of information, such as observation, interviews, and documents. For the primary data, key informants were purposively selected in Ghana based on their knowledge of the issue of interest for the discussion and interviewed. The study also collected data from focus group discussions. Accordingly, it begins with the selection of key informants assumed to have an in-depth knowledge of politics and agricultural economics. The primary data from the interviews and focus group discussions was complemented by a review of academic journal papers, published books, policy reports, and other relevant documents on policies and interventions in agricultural development. Thus, the secondary data for analysis was obtained from government reports, policy documents, and academic literature. It involves a systematic review of peer-reviewed literature, policy documents, and case studies from SSA. Data were collected from academic databases such as Scopus and Web of Science, focusing on publications from 2010 to 2023. The former entailed the administration of semi-structured questionnaires and in-depth interviews with the purposively selected sample participants. The interviews were conducted in English and the local dialect, and the sample group consisted of participants selected from three broad categories of persons who are directly connected to food systems. All these categories were selected using purposive sampling**.** This is because, according to Crewell (2007), where it is known that certain individual units, by their very characteristics, will provide more and better information on a particular subject than randomly selected units, then such units are purposefully picked for the study. It simply involves picking units based on their known characteristics. Therefore, in this paper, data were collected through data gathering methods such as observation, interviews, and documents. The in-depth interviews were conducted using an interview guide for detailed information in four (4) selected towns in Ghana and these were Tamale in the northern region, Damango in the Savannah region, Wa in the Upper West region, and Techiman in the Bono East region. Thus, drawing on a wide range of empirical evidence from the key informant interviews in these regions and documents, relevant information was gathered for the analysis and discussion in this paper**.** Thematic analysis was used to identify recurring challenges and policy gaps.

5. Findings and Discussion

The study revealed that CRA policies and resources are frequently diverted to benefit politically connected elites or regions, rather than vulnerable smallholders in climate-vulnerable zones across SSA. Policy design and project location often reflect patronage rather than vulnerability or need of the people. A study participant indicated that "…the

drought-resistant seeds? We heard they arrived at the district office. But only those known to the District Chief Executive and party executives, or who support the [ruling party] in Ghana, got them. Our village, where the river dried up first? Nothing. It's always for the 'big men' who are close to the politicians, not us in the villages and have no connections…" (Participant interview, Tamale 2024). Also, a local non-governmental worker in Damango in Ghana said, "… the government launched a big Planting for Food and Jobs Programme in 2017, but to our surprise, the project was just owned by politicians, not in the communities documented as most at risk from erratic rains…the maps showing vulnerability were ignored; the political map decided…" (Participant interview, Damango 2024).

Another finding was that despite rhetorical commitment, CRA initiatives are severely underfunded. Scarce resources are often siphoned off for politically expedient short-term projects (e.g., input handouts) or consumed by administrative overhead, rather than long-term resilience building (e.g., fertilizer, soil fertility, water infrastructure). This was supported by a participant observation, who pointed out that:

> "……Our Climate-Smart Agriculture Action Plan sits on the shelf. The fertilizer subsidy promised was not honoured. Meanwhile, millions appear overnight for fertilizer subsidies just before elections on 7 December 2024; it's visible, quick, and wins votes. Building terraces or water harvesting? That takes years, ministers don't see the political return…." (Participant interview, Damango 2024).

Yet, a participant from the Upper West region said:

> "… We were promised a conservation agriculture programme during the 2016 and 2020 election campaigns by President Akuffo Addo, but this from the government never materialised…and the concept of agriculture support for farmers in Ghana has become a political game; everything is in the hands of politicians and those connected to them. There is a priority for people who dearly need the support. My observation is that agricultural sustainability is impossible without genuine national budget commitment, not just donor dependence…"(Participant interview, Wa 2024).

In Ghana and many of the sub-Saharan African countries, weak technical and administrative capacity at the implementation level is always a limitation to Government-sponsored policies in the country**.** This long-held view was supported by the study findings. Local government agencies tasked with implementing CRA policies often lack the specialised technical skills (agro-meteorology, soil science, climate modeling), staffing, equipment, and logistical capacity to effectively deliver complex resilience programmes in the country. A participant in Wa said:

> "… the government sends us these complex climate-resilient packages, like new seeds, specific planting calendars based on forecasts, and water management techniques. But we have one extension officer for over 1000 farmers in my community, no vehicle, no reliable weather station data here, and minimal training on these new methods. How are we supposed to implement this properly ..." and that the officers come, tell us about new drought-tolerant varieties, but then disappear. No follow-up, no support when the seeds don't perform as expected in *our* specific soil, no help accessing markets. It feels like a box-ticking exercise for them, not real help for us…"(Participant interview, Wa 2024).

It was also established that responsibility for CRA is often scattered across multiple ministries (Agriculture, Environment, Water, Finance, Planning) with weak coordination mechanisms. This leads to conflicting mandates, duplication, gaps, and a lack of coherent strategy. A senior policy advisor, a regional Agricultural Department in Techiman in Ghana, said:

> "…in Ghana, the Ministry of Agriculture promotes irrigation expansion for resilience, while Water Resources restricts borehole drilling due to aquifer depletion, and the Environment is worried about watershed degradation. No one is talking to each other…. farmers get contradictory messages and are permitted to stall indefinitely…"(Participant interview, Techiman 2024). Also, a climate change agriculture worker supported this and emphasized that "…. our study found 7 different government programmes and 12 NGO projects all claiming to do 'climate-smart agriculture' in one Techiman district. None share data, some use competing approaches, and farmers are utterly confused. It's a classic case of siloed governance failing the people…." (Participant interview, Techiman 2024).

Further, study findings show that there is always a top-down design and marginalisation of local government initiatives in Ghana and in many sub-Saharan African countries. Government policies on agriculture are frequently designed centrally or driven by international templates, with minimal meaningful consultation or incorporation of indigenous knowledge and the specific needs/contexts of local communities. This leads to inappropriate technologies and low adoption. This phenomenon was revealed during the study. For instance, a focus group discussion with the study participants revealed that:

> "… as they said, government and some NGOs brought some machines for minimum tillage, telling us it's 'climate-smart'. But they don't work in our rocky soils, and we know how to use our traditional pits and half-moons [water harvesting techniques], which work better here. Why don't they ask us first? They come with their solutions,

> not listening to ours…. they also said the national policy talks about 'participatory approaches', but in reality, consultations are rushed, tokenistic. Decisions are made in Accra on what donors want or what looks good in reports, not on the realities we face daily in our changing climate. Our voice is absent in the plans meant for us…"(Focused group discussion, Tamale and Damango, 2024).

The study found that weak institutional capacity is a major barrier to effective CRA policy implementation. Many SSA countries lack the technical expertise, financial resources, and infrastructure needed to implement complex CRA initiatives. For example, in Malawi, the National Climate Change Policy has struggled to achieve its objectives due to limited coordination among government agencies and inadequate monitoring and evaluation systems.

Elite capture is a pervasive issue in SSA, where powerful actors often divert resources intended for CRA initiatives to serve their interests. In Nigeria, for instance, subsidies for climate-smart agricultural technologies have been disproportionately allocated to large-scale farmers with political connections, leaving smallholder farmers marginalised. Misaligned incentives among policymakers and implementers further exacerbate the problem, as short-term political gains often take precedence over long-term sustainability goals.

Despite the high costs associated with CRA, financing remains insufficient in most SSA countries. The study found that governments often prioritize other sectors over agriculture, and donor funding is frequently fragmented and short-term. In Kenya, for example, the reliance on external funding for CRA initiatives has led to project discontinuation once donor support ends. In Ghana, the government launched a comprehensive agricultural policy program called Planting for Food and Jobs in 2017. It was an externally funded agricultural development progamme with a Canadian grant which did not yield its intended results.

External actors, including international organizations and donor agencies, play a significant role in shaping CRA policies in SSA. However, their interventions often lack alignment with local priorities and contexts. The study highlights cases where externally driven CRA projects failed to consider indigenous knowledge and practices, leading to low adoption rates among farmers. For example, in Nigeria, the National Agricultural Resilience Framework (NARF) has been criticized for its top-down approach and lack of stakeholder engagement, resulting in low adoption rates among smallholder farmers. Analysis identifies several key factors contributing to CRA policy failures in SSA, and these are fragmented institutional frameworks and a lack of coordination among government agencies hinder effective policy implementation; limited financial resources, inadequate technical capacity, and weak regulatory frameworks undermine policy effectiveness, and elite capture and rent-seeking behaviour often divert resources away from intended beneficiaries, leading to inequitable outcomes.

6. Conclusion and Policy Recommendations

The persistent failures of climate-resilient agriculture policies in Sub-Saharan Africa are not primarily a result of technical ignorance or insufficient finance, though these are significant challenges. They are fundamentally rooted in the region's complex political economy. Power imbalances, institutional weaknesses, elite capture, marginalisation of key stakeholders, insecure land tenure, donor fragmentation, and historical legacies systematically distort policy agendas, misallocate resources, and cripple implementation capacity.

Addressing climate vulnerability in SSA agriculture requires confronting these political realities head-on. Technical solutions must be embedded within strategies that explicitly target governance reforms: strengthening domestic accountability, fostering inclusive participation, securing land rights, building capable local institutions, and ensuring donor support is politically savvy and long-term. Ignoring the political economy ensures that well-intentioned CRA policies will continue to fall short, leaving millions of smallholder farmers dangerously exposed to the escalating impacts of climate change. Governments in SSA should not implement the following policy measures:

First, empowering parliaments, audit institutions, civil society organizations (CSOs), farmer-based organizations (FOs), and media to scrutinise CRA policies and expenditures. Supporting social audits and participatory monitoring.

Second, create genuine spaces for smallholders, women, pastoralists, and marginalised groups in CRA policy design, implementation, and evaluation, as well as integrating traditional knowledge with scientific approaches.

Third, build the genuine capacity and financial autonomy of local governments and support effective, accountable community-based organizations for managing natural resources and CRA initiatives.

Fourth, implement clear, secure, and equitable land rights, particularly for women and vulnerable groups, recognizing customary systems where appropriate.

Fifth, the need for donors to align behind nationally owned CRA strategies, providing long-term, predictable funding through country systems where possible, and using their influence to support domestic accountability actors and processes rather than imposing external blueprints is very necessary.

Sixth, promote transparency in public spending (e.g., open contracting), strengthen anti-corruption agencies, and foster

competitive political environments in Ghana, where elites will face consequences for misappropriation.

Finally, encourage experimentation and learning at multiple levels (local, national, regional), allowing for adaptation based on context and evidence, rather than rigid top-down models as currently practiced in Ghana, and for that matter, sub-Saharan Africa.

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Authors' contributions

Musah Ibrahim Mordzeh-Ekpampo and Alhassan Iddrisu were responsible for study design and revision. All the authors were responsible for data collection. Gbensuglo Alidu Bukari drafted the manuscript and also revised it. All authors read and approved the final manuscript. In this paper, all authors contributed equally to the study.

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