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Climate Change Adaptation and Farm Profitability among Smallholder Farmers in Sub-Saharan Africa

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Abstract
In Sub-Saharan Africa, smallholder farmers who rely heavily on external inputs and rainfall for their production systems, climate change represents a serious risk to agricultural sustainability, rural livelihoods and food security. Due to greater climate variability and environmental stress, some adaptive measures have been implemented by farmers in the region, such as crop diversification, planting improved seeds, mulching, intercropping, water harvesting, conservation agriculture, and changes in planting schedules, in recent years. How effective these adaptation actions are for improving farm profitability is a question that needs to be answered when assessing their sustainability. This study brings together the latest literature on climate change adaptation and farm profitability for sub-saharan africa smallholder farmers. The evidence suggests that several climate-smart agricultural practices offer good economic returns and reinforce resilience, but are limited in their adoption by high initial costs, labour requirements, lack of access to credit and insecure land tenure, poor extension service and weak market integration. The review also demonstrates that the profitability of adaptation is highly context-specific, depending on ecological zones, farming systems and types of crops. The study finds that enabling policies and institutional support, coupled with specific investments, can facilitate climate adaptation among smallholder farmers to improve their resilience and livelihoods. Enhancing these conditions is crucial for the development of sustainable and profitable smallholder agriculture in Sub-Saharan Africa in the face of climate change.

Keywords: Climate change adaptation, farm profitability, smallholder farmers and Sub-Saharan Africa.

1. Introduction

Climate change has become one of the most pressing challenges to agricultural development, food security, and rural livelihoods in sub-Saharan Africa, where millions of smallholder farmers rely heavily on external inputs and natural ecosystems, as well as rainfall, for agricultural production (Descheemaeker et al., 2025; FAO, 2025). Warm conditions, variable rainfall, extended dry periods, flooding and the heightened risk of extreme events are already impacting crop and animal production, jeopardizing some regions for agricultural production and creating uncertainty for farmers from one season to the next across the region (Descheemaeker et al., 2025; FAO, 2025). As smallholder farming is the mainstay of rural livelihoods in many African countries, the implications of these climate pressures go beyond the farm gate, impacting on household livelihoods, food availability, food market stability and national development goals (World Bank, n.d.; FAO, 2025).

Smallholder farmers in Sub-Saharan Africa are particularly vulnerable due to their generally small farms, insufficient capital, poor access to information, credit, and irrigation, and rain-fed farming practices (FAO 2025; Jellason et al. 2022). Many farmers are already producing at the limits of viability, so that small climate events can result in lower productivity, loss of crops, loss of assets, and loss of incomes (Descheemaeker et al., 2025). These vulnerabilities are exacerbated by broader structural issues, including insecure land tenure, inadequate infrastructure, weak input and output markets and limited extension services, which limit farmers' capacity to respond to climate change (FAO, 2025; World Bank, n.d.). This makes climate change a development and poverty problem as well as biophysical problem, directly affecting the profitability of rural activities.

Adaptation is thus a key focus for the sustainability of smallholder farming in the area. Climate change adaptation can be defined as measures that reduce vulnerability, minimise adverse effects, or capitalise on potential climate change benefits. (Descheemaeker et al., 2025) Smallholder farmers responding to climate change can be seen in practice, through changes in planting dates, use of drought tolerant varieties, crop diversification, intercropping, mulching, water harvesting, terracing, and soil fertility management (Mba et al, 2023; Jellason et al, 2022). They are strategies farmers have used to sustain production in the face of uncertainty, and they do not only show one

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aspect of adaptation, but also an important fact: adaptation is not one strategy and not one process. Rather, rather than employing a single strategy, farmers use a mixture of strategies depending on their ecological zone, resource base, access to knowledge, and livelihood objectives (Mensah et al., 2025).

There is emerging evidence that the smallholder farmers in Sub-Saharan Africa are already implementing many adaptation measures - both on and off farm (Mensah et al., 2025). On Farm strategies would involve agricultural intensification, agricultural extensification and off farm strategies would comprise livelihood diversification and migration (Mensah et al., 2025). Farmers also combine local ecological knowledge with information from scientific and institutional sources to fill information gaps and enhance the effectiveness of adaptation responses in drylands (Jellason et al., 2022). The need for this combination of knowledge is important because climate change is driving a change in the familiar nature of weather at an unprecedented rate beyond what may be possible to rely on past experience alone for managing risk (Jellason et al., 2022). Adaptation is thus no longer perceived as a mere climate stress reaction but as an ongoing learning process, adaptation and innovation.

One of the main challenges in this discussion is to assess the advantages of adaptation, beyond resilience, also in terms of farm profitability. Smallholders might want to do a practice for ecological reasons, but if it does not lead to income generation, losses cannot be reduced, or an economic return is expected in time, it will be unsustainable (Ng'ang'a et al., 2023; World Bank, n.d.). Profitability is important since farmers are generally operating under serious constraints on cash, competing labour requirements, and limited planning horizons. While an adaptation strategy may be effective, without financing support, it can be difficult to get it adopted, even if it has a long payback period or high initial cost (Ng'ang'a et al., 2023). That's why climate adaptation and profitability should be explored together, instead of separately.

Some of the climate-smart agriculture practices are increasingly found to increase both profitability and resilience. For instance, in northeast Nigeria, a cost benefit analysis of a sample of climate-smart agriculture (CSA) practices revealed that all of the practices studied exhibited positive net present values and relatively low risk and short payback periods for smallholder farmers (Ng'ang'a et al., 2023). The study additionally found that while some practices were profitable, they also needed to be supported either institutionally or with policies to facilitate adoption at scale (Ng'ang'a et al., 2023). This is relevant to the broader sub-Saharan African context as it points to the fact that, in addition to the technology itself, the enabling context is crucial for economic viability.

Likewise, there is evidence at the policy level that diversification, in the presence of the right market and institutional environments, can enhance resilience and enable steady income. World Bank, n.d. World Bank review of productive diversification in African agriculture, 'On-farm diversification can boost dietary diversity and enhance resilience, but may be less effective at boosting farm income than optimal'. The same evidence indicates that diversified production systems may also lower input needs, and result in savings, that could boost farm profitability in the long run (World Bank, n.d.). But diversification potential is dependent on markets that function, secure land and water rights, agricultural research and advisories (World Bank n.d.). This helps to illustrate the importance of farm management and policy level conditions on profitability.

Although there is growing focus on adaptation to climate change, there are still significant research gaps. The adoption of adaptation strategies has been the theme of many studies, while fewer studies have focused on the long-term economic consequences of adaptation strategies, particularly on profitability, household income, and livelihood transformation (Mensah et al., 2025; Jellason et al., 2022). Evidence of the effectiveness of adaptation interventions are also limited at the ecological zone, gender group and farming system levels (Mensah et al., 2025). Specifically, recent reviews highlight the need of more integrated analyses that look at the synergic effects of climatic stress with institutions, markets and livelihood capitals on vulnerability and adaptive capacity (Mensah et al., 2025). This is important because what works in one place does not necessarily work in another.

Outside of the literature, it is also clear that barriers to adaptation are not always technical, but more often economic and institutional. Access to land, capital and labour are also limited and insecure for farmers, hindering their ability to invest in adaptation (FAO, 2025). However, weak extension systems, poor access to irrigation and other production assets, and inadequate information flows continue to decrease adaptive capacity (FAO, 2025; Jellason et al., 2022). Concurrently, smallholders tend to be risk averse as farming is risky, and this risk aversion can impede adoption of innovations that may be beneficial to them (FAO, 2025). In the case of adaptation investment that is large, like water resources management and/or upgrading technologies, supportive policies and financing are necessary (Ng'ang'a et al., 2023).

Understanding the link between adaptation to climate change and farm profitability is essential for building an economically sustainable and climate resilient intervention. Even though farmers benefit from adaptation by increasing their yields, if the increased costs of production are also too high, this can cause a decline in income. Even if adaptation reduces risk, but offers only small returns without access to the market, this can also be a problem for farmers to make money. However, adaptation can act as a catalyst for increased productivity and resilience, as well as more secure

incomes, when combined with better institutions, market development, and tenure security (World Bank, n.d.; Ng'ang'a et al., 2023). This is the reason why climate-resilient development pathways are increasingly gaining the attention of policymakers, and not just technical solutions.

Finally, adaptation to climate change by smallholder farmers in Sub-Saharan Africa is a critical concern that has to be linked to the agriculture and livelihood and rural development issues. The impacts of a changing climate are already being felt by the smallholders and their adaptation is influenced by the ecological, economic and institutional set up of the region (Descheemaeker et al., 2025; Mensah et al., 2025). Many adaptation practices can increase farm resilience and reduce vulnerability, but their effect on farm profitability will depend on costs, markets, policy support and overall enabling conditions (Ng'ang'a et al., 2023; World Bank, n.d.). This relationship needs to be understood to ensure that adaptation strategies are not just climate-smart, but also profitable, scalable and sustainable for smallholder farmers across.

2. Literature Review

Climate change adaptation and farm profitability for smallholder farmers in Sub-Saharan Africa (SSA) has become a prominent research issue given the high climate vulnerability and the key role of agriculture in rural livelihoods and food security for the region's smallholder farmers (Descheemaeker et al., 2025; FAO, 2025). It was observed from the literature that smallholders are not only victims of climate change, but they also adapt their farming practices to deal with the various climate change challenges including rainfall variability, drought, heat stress, flooding and new pest and disease attack (Mba et al., 2023; Mensah et al., 2025). But whether farmers adapt or not is only a part of the story; whether they adapt in ways that increase their profitability, resilience, and long-term livelihood security is the more pertinent question (Ng'ang'a et al., 2023; Worou et al., 2025).

2.1 Climate change and smallholder vulnerability

Smallholder farmers in Sub-Saharan Africa are consistently seen in the literature as highly vulnerable to climate change due to their reliance on rain-fed agriculture, small parcel sizes, and lack of access to capital and formal insurance systems (Descheemaeker et al., 2025; FAO, 2025). In many areas of the region, growing season temperatures, irregular precipitation patterns, droughts and floods have already had an impact on productivity of crop and animalbased livelihood activities and will likely increase (FAO, 2025; Descheemaeker et al., 2025). Consequently, climate change is broadly considered a threat to the production of food and family incomes for smallholders. Vulnerability is also shaped by structural and institutional constraints. Farmers' limited access to credit, insecure land tenure, and weak rural infrastructure, lack of extension services, and weak climate information systems, all hinder their ability to respond effectively to climate stress (FAO, 2025; Jellason et al., 2022). Many farmers are unable to afford or undertake adaptation strategies at scale because of these constraints, even if they have a choice of such interventions (Ng'ang'a et al., 2023). Hence, the literature focuses on the social, economic, and institutional dimensions of climate vulnerability in Sub-Saharan Africa, not just the environmental (Descheemaeker et al., 2025; Jellason et al., 2022).

2.2 Adaptation strategies

The role of adaptation strategies used by smallholders to climate change has been a topic of numerous studies. The most commonly cited adaptation strategies by the smallholder farmers in Sub-Saharan Africa identified through a systematic review involve planting different (new) plant varieties or seeds, adjusting the use of fertilizers and manure, reducing runoff and erosion, adjusting crop sequences, planting trees, mulching, crop rotation, changing planting or harvesting dates, crop diversification, water harvesting, intercropping, and terracing (Mba et al., 2023). These strategies can be used together with others, and often farmers use a mix of strategies to lower risk and create more stable production from one season to the next (Mba et al., 2023; Jellason et al., 2022).

Adaptation is also strongly related to knowledge integration in dryland regions. Jellason et al. (2022) find that local and scientific knowledge are used together if farmers find gaps in their knowledge of climate threats and solutions. Additionally, their review emphasizes enabling conditions like stakeholder engagement, continuous learning, access to extension, market access, property rights, and institutional support (Jellason et al., 2022). This implies adaptation is not just a technical matter, it is social and institutional too. Access to knowledge, support networks, and incentives that make adaptation possible are more conducive to adaptation by farmers (Jellason et al., 2022; FAO, 2025).

Recent studies have broadened the scope of consideration for climate-smart agriculture as a more general adaptation option. The empirical literature is emerging, but limited to a small number of countries in Africa and tends to focus mainly on binary adoption and not on more detailed indicators of adoption intensity, persistence or livelihood outcomes (Rurii & Muasya, 2025). The review also indicates that crop-based practices are the predominant subject of the literature, whereas ecological diversity, livestock systems and gender are under-represented; ecological diversity is not discussed at all (Rurii & Muasya, 2025). There is a significant regional, farming systems and household difference in adaptation needs of smallholders which is a major gap (Rurii & Muasya, 2025; Mensah et al., 2025).

2.3 Adaptation and farm profitability

The literature has now begun to question whether it is profitable to adapt, rather than resilient. It is vital

because the farmer will be constrained by cash, labour and high uncertainty and certain adaptation practices may not be technically useful if they do not give a good economic return to the farmer (Ng'ang'a et al., 2023; Worou et al., 2025). Profitability is thus a key element in assessing the sustainability of adaptation over time (Ng'ang'a et al., 2023).

Research in Nigeria demonstrates that adaptation of climate-smart agriculture can be profitable. All nine practices measured by Ng'ang'a et al. (2023) in the three States (Adamawa, Borno and Yobe) yielded positive NPVs and seven practices had low risk and short payback period. The study found that certain CSA practices are more costly and might need policy or institutional support to be rolled out successfully, while they can, at the same time, improve the resilience and profitability of rural households (Ng'ang'a et al., 2023). This is significant because it indicates that profitability is not always achievable and relies on circumstances over which the farm has little control (Ng'ang'a et al., 2023).

The same is true for Senegal, where a significant number of children were identified with the same symptoms. Worou et al. (2025) assessed profitability of cowpea, millet, and groundnut growers and indicated that climate-smart agriculture boosted the yield, with cowpea being the most profitable crop in the long term, followed by groundnut, while the profitability of millet depended on the situation. The same study revealed that the main challenges to adoption were high initial cost, labour requirement and low adoption of some specific practices like micro-dosing fertilizers (Worou et al., 2025). The results evidence that adaptation can be financially rewarding, however, that is dependent on the local appropriateness of the practices adopted and the farmers' capacity to overcome the upfront costs of adoption (Worou et al., 2025; Ng'ang'a et al., 2023).

2.4 Role of diversification

One of the most discussed in the literature adaptation strategies is crop diversification, which may reduce risk, income uncertainty, and ecological vulnerability. Productive diversification in African agriculture suggests that on-farm diversification can enhance dietary diversification and resilience, and diversified production systems can lower dependence on purchased inputs like fertilizers and pesticides (World Bank, n.d.). At the same time, the same source reports that income gains can decrease with further diversification and so more diversification is not necessarily better for profitability (World Bank, n.d.).

This nuance is significant to comprehend the adaptation-profitability link. While diversification can help buffer farmers from the shocks of climate change by decreasing reliance on one crop, it can also reduce economies of scale and/or make it more difficult to participate in markets if not managed in a carefully planned manner (World Bank, n.d.). The literature thus proposes that diversification should be considered a strategic decision for the economy and not just an environmental reaction (World Bank, n.d.; Mba et al., 2023). In the landscape level, diversification of actors and products is also linked to more stable income, and increased food system resilience (World Bank, n.d.).

2.5 Enabling and constraining factors

Enabling conditions play a crucial role in adoption of and profitability of adaptation strategies. Extension services, market information, credit, secure land tenure, labour and climate information have been repeatedly cited as key factors influencing uptake in the literature (Jellason et al., 2022; FAO, 2025). An assessment of the adoption of climate-smart agriculture in 2024 synthesis showed that extension services played an important role in enhancing the adoption, while secure land tenure supported investments for longer duration. The same evidence also revealed that the high initial cost led to low adoption rate among the poor farmers. This implies that decisions to adapt are more about costs and institutional capacities than awareness (Ng'ang'a et al., 2023).

The literature also demonstrates that policy has an impact. To create diversification and resilience, governments need to restructure input support policies, develop market institutions, invest in research and advisory systems, and enhance access to land and water resources, according to the World Bank (World Bank, n.d.). The recommendations are consistent with the overall evidence that profitable adaptation is far from a standalone action, and institutions, markets and public investment are required to make adaptation a reality (FAO, 2025; World Bank, n.d.). Thus, the economic opportunity for smallholder farmers to benefit from adaptation depends on the quality of the surrounding enabling environment (Jellason et al., 2022; Ng'ang'a et al., 2023).

2.6 Research gaps

While literature on adaptation has grown rapidly, there are key gaps. First, many studies continue to focus on the adoption process instead of economic outcome, so Limited evidence exists on whether adaptation enhances long-term profitability, income stability or household welfare (Rurii & Muasya, 2025; Mensah et al., 2025). Second, research is not evenly distributed among countries and farming systems, and research is stronger in some countries than others (Rurii & Muasya, 2025). Third, although gender dynamics and intra-household decision-making may influence both adoption and returns, this is not fully explored in this study (Rurii & Muasya, 2025; Mensah et al., 2025).

The other is that there is a lack of evidence from a longitudinal perspective or from multi-scale. Most of the studies are cross-sectional, and thus are not able to fully reflect the evolution of adaptation choices or their impact on profitability over time (Rurii & Muasya, 2025). Furthermore, there is a need for further research on the interaction among climatic and non-climatic stressors particularly in crop-livestock systems and in

agroecologically-diverse areas (Mensah et al., 2025). There is therefore a need to explore what adaptations are most profitable, to whom, under what conditions and with what trade-offs if any, rather than whether farmers adapt, in the future. (Ng'ang'a et al., 2023; Worou et al., 2025)

2.7 Summary of the Literature

In general, the literature indicates that there is a need for adaptation to climate change to safeguard the livelihoods of smallholders in Sub-Saharan Africa, but that adaptation is only profitable if it is applied in the right context, over the right scale and with the right support system (FAO, 2025; Descheemaeker et al., 2025). Currently, farmers employ a variety of strategies to adapt to climate stress, but the economic benefits of these strategies are highly variable (Mba et al., 2023; Worou et al., 2025). Financing, extension, secure tenures, market access and locally appropriate technologies are the strongest evidence of adaptation becoming more profitable (Ng'ang'a et al., 2023; World Bank, n.d.). This not only creates a resilience challenge but also a development and a profitability challenge for smallholder agriculture in Sub-Saharan Africa (Jellason et al., 2022; Rurii & Muasya, 2025).

3. Research Methodology

The chapter discusses the research design and data sources, data analysis methods and analytical procedures used to explore the issues of adaptation to climate change and profitability of smallholder farmers in Sub-Saharan Africa. The approach is based on the findings by Ng'ang'a et al. (2023) and Rurii and Muasya (2025) that integrated the scoping review, cost benefit analysis and farm level profitability assessment. The mixed evidence approach is used to organize and interpret literature since the topic covers adoption behaviour, economic returns and resilience outcomes.

3.1 Research design

The study uses a literature review design and structured thematic synthesis method. The method is appropriate for the researcher to identify, compare, and interpret patterns from previous research on climate adaptation, profitability, and smallholder farming systems (Rurii & Muasya, 2025). Also, it assists in the synthesis of empirical evidence from various countries, crops and adaptation strategies into an integrated analytical chapter (Mba et al., 2023; Worou et al., 2025). The literature-based design is useful with this topic because evidence from the different fields of research is scattered across agronomy, economics, climate adaptation, and rural development studies (Descheemaeker et al., 2025; FAO, 2025).

3.2 Scope of the review

The review is specific to smallholder farmers in Sub-Saharan Africa, and it highlights studies that take into consideration the impact of climate adaptation measures on farm profitability, productivity, resilience or income stability (Mba et al., 2023; Ng'ang'a et al., 2023). Recent studies published from 2022 to 2025 are highlighted since they offer the most up-to-date research evidence regarding the climate-smart agriculture initiatives in the region, adaptation economics and resilience building (Rurii & Muasya, 2025; Worou et al., 2025). Contextually diverse evidence from Nigeria, Senegal, Ghana, Uganda, Malawi, Zambia, Kenya, Ethiopia and Sub-Saharan Africa in general are included in the studies considered due to the diversity of the context.

An emphasis on smallholders is relevant as their share of production is high in the region, and they are highly vulnerable to climate risk because of their limited assets, poor market access and low level of adaptive capacity (FAO, 2025; Descheemaeker et al., 2025). The review therefore does not cover large-scale commercial agriculture unless the study has specifically included smallholder data or whether the study have segregated smallholders from other farm categories (Rurii & Muasya, 2025). This ensures the analysis is aligned with the central concern of the study; how adaptation can enhance the economic viability of smallholder farming systems (Ng'ang'a et al., 2023; Worou et al., 2025).

3.3 Search strategy

A literature review focused on concepts of climate change adaptation, smallholder farmers, profitability and Sub-Saharan Africa was used as a basis for guiding the search strategy. Search phrases were used in combination for example, climate change adaptation and climate-smart agriculture, smallholder farmers and farm profitability, income and resilience, cost-benefit analysis and sub-Saharan Africa (Rurii & Muasya, 2025; Ng'ang'a et al., 2023). The following terms were used to search for peer reviewed articles, systematic reviews, scoping reviews and applied economic studies related to the subject (Mba et al., 2023).

The evidence base consisted of recent research that covers adaptation pathways, livelihood resilience, and the economics of climate-smart agriculture in various farming systems (Descheemaeker et al., 2025; World Bank, n.d.). Studies that explicitly present data on profitability indicators like NPV, B/C ratio, IRR, payback period, yield improvement or farm income effects were prioritized (Ng'ang'a et al., 2023). This focus is essential as the subject is not simply about describing adaptation; it is about whether or not adaptation generates economic returns for farmers (Worou et al., 2025).

3.4 Inclusion criteria

Studies were only considered if they fulfilled four major criteria. First, they had to be related to climate change adaptation, climate smart agriculture, resilience building or farming for resilience in Sub-Saharan Africa (Mba et al., 2023). Second, they needed to involve smallholder farmers or to be clear that the farming system was/should be smallholder based (FAO, 2025; Descheemaeker et al., 2025). Third, the effects of economic outcomes on profitability, productivity or livelihoods in some way were

addressed (Ng'ang'a et al., 2023; Worou et al., 2025) Fourth, they needed to be current or very topical to the current discussion on adaptation and farm viability (Rurii & Muasya, 2025).

Studies that only highlighted impacts of climate change, without considering adaptation, and those that only discussed agriculture without considering smallholder systems, were excluded (FAO, 2025). Theoretical papers were also not included unless they offered a conceptual framework directly related to adaptation and profitability (Descheemaeker et al., 2025). This facilitates the creation of a chapter that is based on studies that directly relate to the link between adaptation practices and economic performance (Ng'ang'a et al., 2023).

3.5 Data extraction

The following data was collected for each selected study: author(s) and year of publication, location of the study, farming system, adaptation strategy, type of analyses, main results on the profitability/resilience and major constraints to adaptation (Mba et al., 2023). When available quantitative indicators like NPV, B/C ratio, IRR, yield change or payback period were documented (Ng'ang'a et al., 2023; Worou et al., 2025). Active themes, patterns, and policy implications were identified and categorized into themes for qualitative and/or review-based studies (Rurii & Muasya, 2025).

As noted by Jellason et al. (2022) and World Bank (n.d.), this extraction process allows for a comparison of findings, rather than considering each paper as individual evidence. It also allows for the identification of common adaptation strategies like the use of improved seed, conservation agriculture, intercropping, early sowing, fertilizer management, mulching, and crop diversification (Mba et al., 2023). The information retrieved was then aggregated into thematic categories, which included vulnerability, adaptation strategies, profitability outcomes, enabling conditions and research gaps (Descheemaeker et al., 2025; Rurii & Muasya, 2025).

3.6 Analytical approach

Thematic synthesis was used as an analysis approach. Studies were first categorised based on their primary contribution, either adaptation patterns, profitability evidence, enabling conditions or resilience outcomes (Mba et al., 2023). Second, the results were analysed across country contexts for similarities and differences in the impact of adaptation on farm income and economic sustainability. Third, the findings of the synthesized evidence were analysed in the context of development issues including: food security, livelihood security, resource constraints, and policy support (FAO, 2025; World Bank, n.d.).

This analytical approach is in line with the evaluation of climate-smart agriculture that has been recently carried out in various studies. For instance, in SSA, adaptation interventions were ranked and assessed for economic feasibility through a Cost and Benefit framework, and in Uganda and Senegal, farm level studies estimated profitability by applying a Benefit Cost ratio and Net returns approach. Evidence of resilience and of climate-smart technologies also demonstrates a need for considering the evidence in institutional and equity contexts, not merely in terms of technical performance, as highlighted in scoping reviews (Rurii & Muasya, 2025). Themes are therefore analysed in the present chapter to address the economic and the structural aspects of adaptation.

3.7 Conceptual framework

A conceptual framework was used to guide the study where climate stress affects the farm output and income of climate vulnerable households, adaptation practices mitigate these effects and climate stress and adaptation are themselves interlinked (Descheemaeker et al., 2025; FAO, 2025). In this context, adaptation measures like using better seed, early planting, conservation farming, diversification and water management are expected to lessen losses, maintain yields and boost profit. (Ng'ang'a et al., 2023; Worou et al., 2025). The impact of this effect, however, will be influenced by the enabling factors like access to credit, extension, land tenure, labour and markets (Jellason et al., 2022; World Bank, n.d.).

The framework also takes into account that adaptation and profitability are not always synonymous. There are practices which will yield benefits to improve resilience, but they will involve investments of substantial capital or labour, and can result in some loss of short-term profitability for resource poor farmers. Some can be making a profit in one area or at a particular time but not in another due to the fluctuations of rain, soil conditions or market prices. Profitability cannot therefore be viewed as a generic term, but rather as case-specific (Ng'ang'a et al., 2023) (Rurii & Muasya, 2025).

3.8 Ethical consideration

This chapter is based on published work which did not involve direct interview or survey of any human subjects, and thus no primary ethical approval was necessary (Rurii & Muasya, 2025). All sources were cited correctly and paraphrased (wherever possible) instead of being copied verbatim (Mba et al., 2023). Throughout the document, APA style of citation was adhered to for transparency and credibility (Ng'ang'a et al., 2023; Worou et al., 2025).

3.9 Chapter summary

To summarise, the approach taken in this study was a structured literature review and thematic synthesis of recent evidence on the impact of climate change adaptation on farm profitability of smallholder farmers in Sub-Saharan Africa (Rurii & Muasya, 2025). Given the shared focus on adaptation and its effect on the economic viability of smallholder farming (Ng'ang'a et al., 2023; Worou et al., 2025) and the diversity in methods used to study adaptation, the approach is

appropriate. The chapter brings together vulnerability, adaptation, profitability and enabling factors, thus offering a solid foundation for the subsequent discussion (Descheemaeker et al., 2025; FAO, 2025).

4. Results and Discussion

The chapter summarizes the primary results on adaptation, sustainability, and farm profitability of smallholder farmers in Sub-Saharan Africa and discusses their implications for livelihoods, resilience and policy. The evidence indicates that smallholders respond to climate stress in a variety of ways, and profits from those practices are very context dependent, financially constrained and institutionally dependent. It also demonstrates that while a number of adaptation options are viable and economically viable, other options can prove to be maladaptive or poorly rewarded if they are undertaken without the necessary support.

4.1 Patterns of adaptation

Based on the literature reviewed, the use of multiple adaptation strategies, rather than one or the other, is identified as occurring in smallholder farming in Sub-Saharan Africa. Crop diversification, planting date shifts, adoption of drought-tolerant varieties, intercropping, mulching, water harvesting, soil management and manure and fertilizer management are the most common practices. These results align with recent review evidence that smallholders respond to make production less vulnerable to climate risk and more resilient to rainfall variability and temperature stress.

Literature also reveals that adaptation is becoming more and more knowledge based than technology based. Farmers in drylands apply knowledge and scientific information to enhance their decision making and build resilience. The scoping evidence confirms that there is a large volume of literature discussing the climate-smart agricultural technologies, but they are not being adopted evenly, and location, farm resources and access to services all influence the uptake of these technologies. This indicates that in addition to being aware of adaptation, it should also be possible, affordable and readily available for institutional support.

4.2 Profitability outcomes

Among the most significant findings in the literature is that under the right conditions, adaptation to the climate can enhance profitability. A cost benefit analysis of the various climate-smart agriculture practices conducted in north-east Nigeria revealed that all the practices considered in the analysis had positive NPV with short payback periods and relatively low risks to the farmers. This means that adaptation can be not only environmentally, but also economically desirable. A study of the same type in Uganda showed that chosen climate-smart technologies had positive effects on yield and benefit-cost ratios in drought-prone maize-bean systems.

This trend also holds true in Senegal. Climate Smart Agriculture had positive effect on yields of cowpea, millet and groundnut farmers, while cowpea is the most profitable crop in the long run. Profitability, however, was different for each crop and context, and thus there was no single optimal adaptation package. It is important to note that these findings highlight the potential of climate adaptation to play a role in enhancing both resilience and income, while returns are strongly context specific.

4.3 Sustainable and maladaptive responses

People also distinguish between sustainable adaptation and maladaptation in the literature. Sustainable strategies are ones that result in long-term environmental, social, and economic benefits and decrease vulnerability. These can include agroforestry, cover cropping, pit planting, crop diversification and soil conservation to enhance soil moisture, soil health, and long-term productivity. The practices are widely considered to be beneficial as they create co-benefits for livelihoods and ecosystems.

In contrast, maladaptive responses are coping strategies that can temporarily alleviate stress, but weaken resilience in the long run. The recent review evidence suggests that maladaptation can be represented as excessive use of chemical fertilizers, distress sale of productive assets, other environmentally damaging and/or economically harmful practices. These responses frequently occur in situations of high financial, information and institutional constraints. That is, if a household does not receive assistance, then it can engage in activities that resolve the immediate issue but introduce new or increased risks in the future.

4.4 Barriers to adaptation

The results indicate that some challenges still prevent the smallholder farmers from successful adaptation. The most enduring challenges are inadequate investment, limited access to climate information, inadequately timed weather information, weak extension services, and the initial costs of technology adoption. The barriers are challenging farmers to invest in adaptation even when they realize the benefits. This has led many farmers to stick with the low cost or reactive approach that may not generate high long-term returns.

This is a place where institutional support is very important. Extension services, secure land tenure and access to finance are associated with high adoption rates and promote long-term investment in climate smart practices, according to reviews. In the absence of these factors, farmers are less inclined to transition from coping to continuous adaptation. This is why the profitability benefits from adaptation vary across regions and farm types.

4.5 Discussion of findings

The findings lend weight to the argument that adaptation to climate change is a resilience measure and an economic choice for smallholder farmers.

Farmers practice those which assist them in managing rainfall variability, drought, declining soil fertility and pest attack, depending on the rainfall climate, labour demand and risk exposure. Therefore, adaptation policies need to be assessed not only technically, but also in terms of their impacts on livelihoods.

The results also indicate that there is a close relationship between the concepts of sustainability and profitability, but they are not synonymous. Some of the sustainable practices can generate better long-term income and reduce dependence on inputs and stabilize yields, while some profitable practices can have hidden social or environmental costs if not managed properly. Hence the trend in the literature for package support which is a combination of finance, extension, weather services and training, instead of separating technology promotion from the other support aspects.

In summary, the evidence presented here indicates that adaptation can enhance the profitability of smallholder farmers in Sub-Saharan Africa, if it is done in a context-specific, institutionally supported and economically viable way. This conclusion is supported by the recent literature, and is a good foundation for the policy recommendations in the final chapter.

5. Conclusion and Recommendations

5.1 Conclusion

In this study, the authors found that a successful climate change adaptation for smallholder farmers in Sub-Saharan Africa must be context-specific, affordable and institutionally supported in order to be economically meaningful to their livelihoods and profits. The evidence examined in Nigeria, Senegal, Ghana, Uganda, dryland sub-Saharan Africa and on a broader African farming systems basis suggests that smallholders have a variety of strategies in place to mitigate climate risk, such as crop diversification, better seed, soil and water conservation, changing planting dates, water harvests, and nutrient management. These practices can enhance farmers' resilience and, in some instances, yields and profitability, particularly when farmers are able to access extension support, finance and operating markets. Meanwhile the literature has made it abundantly clear that adaptation is not necessarily profitable. Benefits of some practices depend on expensive, initial investments, more labor, more information, or secure land tenure. Other approaches might mitigate short-term losses, but would be less effective in enhancing incomes when output prices are low and/or market access is poor. Therefore the success of adaptation should be assessed by success in adoption and also with regard to its contribution to long-term farm viability, income stability, and household welfare.

Another finding from the literature is the need to differentiate between sustainable adaptation and maladaptive coping. Sustainable actions like agroforestry, diversification, mulching, and conservation agriculture build resilience and productivity, whereas maladaptive actions can lock households into survival measures that jeopardize their future productivity and food security. The review thus confirms the opinion that adaptation policy in Sub-Saharan Africa needs to focus on practices that have both economic and environmental co-benefits. This is particularly relevant since climate change is likely to increase the risk level over rain-fed agricultural systems and production may decline if this continues to happen.

5.2 Recommendations

Based on the findings, several policy and practice recommendations are made. Government and development partners should increase funding for climate-smart agricultural practices that have been proven to be profitable and resilient, particularly better crop seeds, water management, soil fertility management, intercropping and crop diversification. Promote these technologies via farmer training, demonstration plots, extension systems that clearly communicate benefits and operation requirements to smallholders. Practical support is particularly crucial for the poorest households which may know about adaptation measures but not have the means to adopt them without support.

Second, financial resources in agriculture should be enhanced by making credit, savings arrangements and risk-sharing mechanisms, including insurance and input support packages, more accessible. The literature reveals that credit can be used to adopt technologies that demand cash flow requirements, and insurance and other financial instruments can help farmers respond to uncertainty arising from climate change. However, they need to be created with caution not to be excluding for farmers who have limited resources and not to make them more indebted in the face of climate stress.

Thirdly, policy should make conditions more favorable for conducting business, including secure land rights, access to extension, climate information services and effective input and output markets. Secure land rights incentivize farmers to invest more in practices like soil and water conservation, agroforestry and other longer-term investments. There is also a need for improved market systems to enable farmers to reap a better income from increased productivity, and not just from increased output at low farm-gate prices.

Fourth, sustainability should be considered as a lens for adaptation programs. Fourth, sustainability must be a lens in designing adaptation programs. Policymakers should “do no harm” by encouraging short-term coping while making farmers more vulnerable over time. Rather, they should promote practices that enhance soil health, water management, diversification, and minimize reliance on expensive external resources. This can increase the likelihood of achieving long-term profitability and resilience under varying climate conditions.

Lastly, future studies will need to pay more attention to

the long-term profitability of adaptation, differentiated by gender, farm size, crop type and agroecological zone. There is a need for more longitudinal and comparative studies to better understand which adaptation packages will be most economically viable under specific circumstances and why some practices scale up and others scale down. This kind of research can guide policy makers to a more targeted and evidence-based approach to promote climate-smart agriculture to improve farm incomes and adaptation.

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