Climate Change Adaptation Strategies among Smallholder Farmers in Sub-Saharan Africa: A Systematic Review

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Abstract

Climate change remains a global challenge, threatening food security and livelihoods, especially among smallholder farmers in sub-Saharan Africa (SSA). Recent estimates reveal that smallholder farmers account for 75% of the total agricultural output and 70% of marketed agricultural produce in Kenya. However, it is projected that climate change and variability will reduce agricultural production by 10–20% by 2050. Climate change adaptation strategies among smallholder farmers are thus critical to ensure the resilience of people's livelihoods and the survival of agriculture. This systematic review examined climate change adaptation strategies among smallholder farmers in sub-Saharan Africa. The synthesis included ten studies that met the criteria, including three quantitative and seven mixed-methods studies. The quantitative studies identified significant climate adaptation strategies included such as: adopting different seed/ plant varieties, changes in fertilizer and manure use patterns, reducing runoff and erosion, and changes in crop sequences. In contrast, the mixed methods studies revealed different significant climate adaptation strategies such as planting trees, mulching, crop rotation, varying planting and harvesting dates, crop diversification, water harvesting, use of farmland manure, intercropping, and terracing. Key factors influencing the uptake of climate change adaptation strategies among smallholder farmers included increasingly challenging climate conditions, educational attainment, and farming in higher potential agroecological environments. The review identifies evidence gaps in optimizing the benefits from a unified approach to adaptation rather than separate treatment of adaptation or mitigation. Besides, despite adaptation strategies being skewed towards integrated drought-related effects of climate change, the review did not identify any gender-sensitive climate adaptation strategies reducing farmers' vulnerability to climate change impacts. There is a need for impact evaluations on the effects of climate adaptation strategies, and further research on the effectiveness of climate change adaptation strategies to examine both the extent to which these climate change adaptation strategies interventions are transferrable to sub-Saharan countries.

Keywords: Climate change, smallholder farmer, Adaptation strategies,Agricultural, Variability

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1. Introduction and Background

Numerous papers suggest the growing recognition of the role of climate change adaptation among smallholder farmers in African rain-fed agriculture(Ombogoh, Tanui, McMullin, Muriuki, & Mowo, 2016).This recognition includes rigorous scientific and political debates regarding farmers'ability to adapt to changing climatic conditions(Autio, Johansson, Motaroki, Minoia, & Pellikka, 2021), the limited understanding of the link between small-scale farmland management practices and climate greenhouse gas emissions(Mairura, et al., 2022)and the possibilities tomitigate climate change without threatening their livelihoods(Autio, Johansson, Motaroki, Minoia, & Pellikka, 2021). In addition, as with climate change adaptation and variability(Opiyo, et al., 2015), adoption of appropriate technologies in small-scale farming(Kalungu & Filho, 2016), perceptions of climate change(Opiyo, et al., 2015), crop diversification(Ochieng, et al., 2020), collective action among smallholder farmers (Ombogoh, Tanui, McMullin, Muriuki, & Mowo, 2016), and building buffer capacity(Speranza, 2013) have emerged to receive considerable attention.

Although managerial and policy focus on climate change has increased of late (Opiyo et al., 2015; Ombogoh, Tanui, McMullin, Muriuki, & Mowo, 2016; Autio, Johansson, Motaroki, Minoia, & Pellikka, 2021;Mairura et al., 2022), a review of the literature reveals relatively little theoretical work in the area of uptake of climate change adaptation strategies, and especially among smallholder farmers in Kenya. Early climate change action focused on building resilience to climate change in agriculturalproduction(Speranza, 2013), challenges facing farmers(Autio, Johansson, Motaroki, Minoia, & Pellikka, 2021), ensuring the functioning of agricultural-based livelihoods (Speranza, 2013; Ochieng et al., 2020) and reducing farmers' their vulnerability toclimate change impacts (Speranza, 2013; Opiyo et al., 2015; Ochieng et al., 2020). Additional research includes integrated drought-related effects of climate change (McCord, Waldman, Baldwin, Dell'Angelo, & Evans, 2018)and other environmental, social and political pressures (Opiyo et al., 2015; Autio, Johansson, Motaroki, Minoia, & Pellikka, 2021).

Despite this work, little is known about the specifics of climate change adaptation strategiesto ensure the resilience of people's livelihoods and the survival of agriculture, freshwater supply and other naturalresources.Similarly, Climatic conditions play a significant role in food security insemi-arid environments where livelihood is dependent on agriculture.The focus on smallholder farmers is essential given the farmers' role in the productive economy. For instance, Kalungu and Filho (2016)note that smallholder farmers account for 75% of the total agricultural output and 70% of marketed agricultural produce in Kenya. In addition, Kalungu and Filho (2016) posit thatsmallholder farming createsopportunities for women, who provide 60–80% of labourin the agriculture sector.

As a critical sector with direct impacts on development linked to solutions that cope with climate change, farmers' adaptation in the agricultural sector remains integral to food security and sustained livelihoodchange (McCord, Waldman, Baldwin, Dell'Angelo, & Evans, 2018). As a result, policymakers within the U.N. Framework Convention on Climate Change (UNFCCC or Convention) have increasingly invested in lobbying, advocacy activities, and other programmatic interventions toward agriculture. The policy goal has been geared towards optimizing the benefits from a unified approach rather than separate treatment in UNFCCC negotiating streams, such as adaptation, mitigation, finance, technology, capacity building, or reducing emissions from deforestation(Meridian Institute, 2011).

It is increasingly evident that climate change has severely affected households, especially smallholder farmers. For instance, Ombogoh, Tanui, McMullin, Muriuki, and Mowo (2016)project that climate change and variability will reduce agriculturalproduction by 10–20% by 2050. Ombogoh, Tanui, McMullin, Muriuki, and Mowo (2016)further contend that theprojected reduction will mainly result fromthe changing climate patterns, which overall increasethe prevalence of crop pests and diseases. This perspective is also supported by Kalungu and Filho (2016) who posit that 'investment aimed at reducing the impactsof climate change and variability on small-scale farmers is critical in attaining the objective of global poverty reduction and food security.'Similarly, McCord, Waldman, Baldwin, Dell'Angelo, and Evans (2018)and Kalungu and Filho (2016) explain that climatic conditions play a significant role in food security, especially in semi-arid environments where livelihood depends on agriculture.

Smallholder farmer's vulnerability to increasing climate change is further compounded by other socioeconomic, political and ecological factors, including inadequate sources of capital and income(Thinda, Ogundeji, Belle, & Ojo, 2020), limited livestock marketing opportunities, political marginalization, changing land tenure, unclear property rights regimes, and breakdown of traditional social and resource governance institutions(Opiyo, et al., 2015), inadequate public infrastructure,such as roads, long-term weather forecasts and extension support(Thinda, Ogundeji, Belle, & Ojo, 2020). Furthermore, Nyang'au, Mohamed, Mango, & Makate(2021) identify social isolation from local markets and lack of institutionalsupport as other obstacles facing smallholder farmers.

Various authors recognize the significant role of food security in sub-Saharan Africa countries, especially given that livelihoods depend greatly on smallholder farmers (Opiyo et al., 2015; Kalungu and Filho, 2016; Ombogoh, Tanui, McMullin, Muriuki, &Mowo; 2016; McCord, Waldman, Baldwin, Dell'Angelo, & Evans, 2018; Ochieng et al. 2020; Autio, Johansson, Motaroki, Minoia, &Pellikka, 2021). Besides, it is argued that climate variability and change may overwhelm the resilience of smallholder farmers if local adaptation strategies are not strengthened (Opiyo et al., 2015; Kalungu & Filho, 2016; Autio, Johansson, Motaroki, Minoia, &Pellikka, 2021). Faced with such climate adversities,Ochieng et al.(2020) note that small-scale farmers generally adopt various mitigationstrategies.Kalungu and Filho (2016) summarize this point more articulately by arguing that the effects of climate change and variability on the world's 500 million smallholder farmers cannot be overlooked. However, detailed research questions do not guide the study byKalungu and Filho (2016).Therefore, it is critical to understand factors that influence the uptake of climate change adaptation strategies(choice) among smallholder farmers in sub-Saharan Africa contexts who are particularly vulnerable (Ochieng, et al., 2020) to respond appropriately to climate variability and change(McCord, Waldman, Baldwin, Dell'Angelo, & Evans, 2018) and mitigate the negative impacts(Thinda, Ogundeji, Belle, & Ojo, 2020). Recognizing that climate change remains a global challenge, Nyang'au, Mohamed, Mango, and Makate(2021) note that smallholder farmers in developingcountries are more vulnerable as theylack adequate adaptive capacity. In addition,Nyang'au, Mohamed, Mango, and Makate(2021) suggest that smallholder farmers' high dependence on rain-fed agriculture,reliance on natural resources(Speranza, 2013), elevated poverty levels, and defective infrastructural and technological developmentmakes them vulnerable to the profound impacts of climate change.

The main purpose of this study is to examine climate change adaptation strategies among smallholders and to assess factors that influence the uptake of climate change adaptation strategies. Specifically, this study sought to (i) describe the diversity of published evidence

on climate change adaptation strategies among smallholder farmers in SSA, (ii) synthesize evidence on climate change adaptation strategies among smallholder farmers in SSA, and (iii) examine factors influencing uptake of climate change adaptation strategies among smallholder farmers in SSA.The findings of this paper will inform ongoing debates around climate change issues as part of the development discourse. This paper also recognizes that climatic change harms people's livelihoods and that agriculture is crucial for human survival (Thinda, Ogundeji, Belle, & Ojo, 2020).This study views livelihood as the benefits such as food, income, insurance and poverty reduction(Speranza, 2013). In that regard, a livelihood is resilient if it can maintain its key functions (e.g. food, income, insurance, etc.) and absorb theimpacts of disturbances without undergoing major declines in production and well-being(Speranza, 2013). Furthermore, thispaper recognizes that manysub-Saharan African countries experience the negative impacts of climate change, especially in the decline of agricultural productivityleading to decreased national and household food security(Nyang'au, Mohamed, Mango, & Makate, 2021).

2. Methods

2.1 Eligibility criteria

A preliminary scoping exercise conducted by the authors and reviews in this area suggested a scarcity of relevant research literature. Therefore, studies were required to meet several eligibility criteria to be included in the review. First, studies must have evaluated the nexus between climate change and smallholder farming. Such studies took the form of articles published in peer-reviewed journals. Second, studies must have investigated aspects of adoptingclimate change adaptation strategies among smallholder farming. Third, the study setting must have been an African country. Fourth, studies must have utilized an empirical research approach based on observing and measuringvariables of interest. In that regard, the studies must have followed one of the following: (a) Structured and semi-structured surveys, (b) key informant interviews, and (b) focused-group discussions. Fifth, the studies must have quantitative, mixed methods, or qualitative design. Sixth, studies must have reported at least one quantitative climate change action-related outcome variable. Finally, the study's date of publication or reporting must have been 1 January 2013 to 27 July 2022.

2.2 Study designs in the review

As the literature was expected to be scarce, eligibility was extended to (a) Rapid Appraisals methods that form a holistic view ofclimate change adaptation strategiesand technologies, (b) cross-sectional survey designs where studiesexamine the phenomena among the study participants at the same time, (c) longitudinal survey designs, (d) Descriptive research, and (e) Inferential research. There were no language restrictions.

2.3 Search methods for identification of studies

Electronic searches on journals using keyword searches were conducted using JSTOR, Wiley Online Library, EBSCO Host Research Databases, and Google Scholar to follow up on potentially relevant papers that came to light during the review.In that regard, the author searched using the following keywords: Adaptation, Climate policy,Agriculture, Smallholder, Climate-smart, Appropriate technology, Small-scale farms, Conservation agriculture, Climate-smart agriculture, Climate variability and change, and Climate change adaptation strategies. In addition, the information provided by publishers about journal focus and content suggested that these were the most relevant for the search.

2.4 Method of study synthesis

The method of synthesis used in this review reflects the nature of the included studies. Statistical meta-analysis was neither feasible nor appropriate. As shown in the next chapter, the reviewed body of literature is broad regarding population and intervention characteristics. In addition, most studies used a repeated measures design and presented data in the form of proportions or frequencies. On balance, it was felt that a narrative approach to data synthesis was the most appropriate method for this review. Narrative synthesis involvedarranging studies into relatively homogenous groups according to a standard format, with similarities and differences across studies.

2.5 Search results

Initially, 22,915 citations were identified by electronically searching the major bibliographic databases. After removing 2,426 duplicates, the remaining 20,489 items were electronically screened against the eligibility criteria on title and abstract. This excluded 10,217 studies, leaving 10272 references that had the potential for review. Searches of additional sources yielded a further 132 potentially relevant studies, and these were added to the 347 studies from the main electronic search. Upon careful examination of the selection criteria, 9434 study reports reviewed at this stage did not meet the eligibility requirements, leaving 838. This study mostly excluded studies that were not located in sub-Saharan Africa. Studies published conducted before 2013 were also excluded. Fourteen studies (reported in ten papers) met all requirements and were selected for analysis. Figure 1 details the search and study selection process.

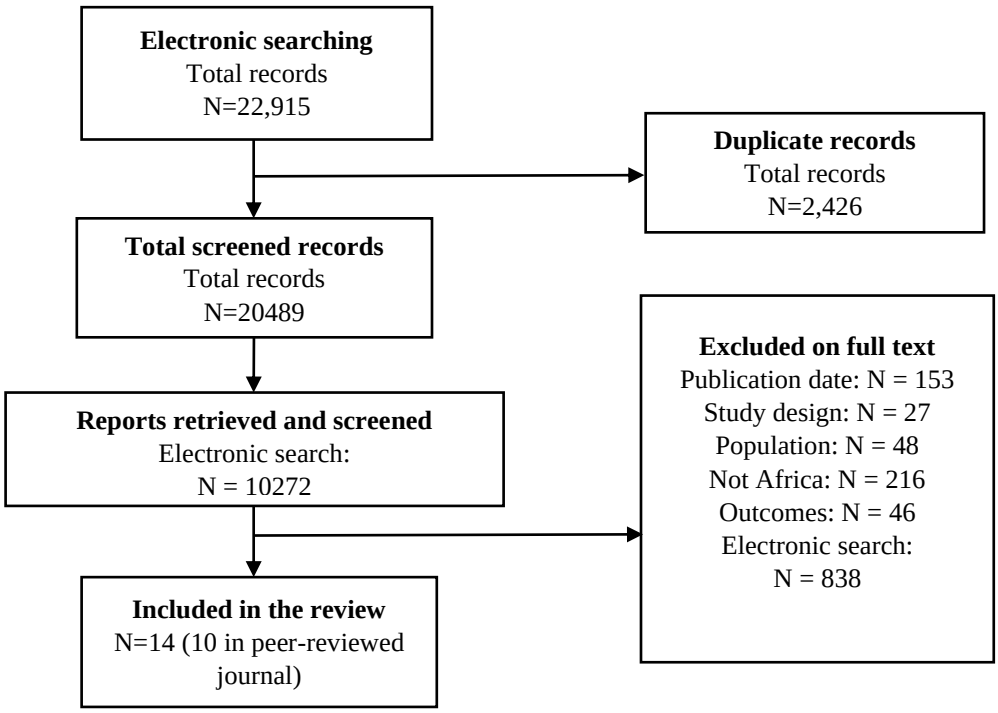

Figure 1: Flow of literature through the Review Source: Authors (2022)

2.6 Limitations from papers reviewed

Autio, Johansson, Motaroki, Minoia, and Pellikka (2021)note their study on 'constraints for adopting climate-smart agricultural practices amongsmallholder farmers in Southeast Kenya' was limited by generalizability and representativeness due to smaller sample sizes

and the subjectivity of perceived applicability andimpacts of CSA practices. Furthermore, Autio, Johansson, Motaroki, Minoia, and Pellikka (2021)posit that the descriptiveness made detecting significant drivers ofagricultural knowledge and technology uptake more difficult.

3. Results and Discussions

3.1 Descriptive findings

Ten studies met the criteria for inclusion in the synthesis. The ten studies in the synthesis includedthree quantitative and seven mixed methods studies. The mix of quantitative and mixed-methods studies methodologies was moderately variable to policy on climate change adaptation strategies. To fully explore the data, the author conducted several types of analyses. This chapter describes the profile of the included studies.

3.2 Study characteristics

This section presents key features of the included research. Tables 1, 2 and 3 summarize the substantive and methodological characteristics of the ten included journal articles.

Table 1: General characteristicsof included studies

Publication dates*	**k**	**Study funding***	**k**
2013	1	International Fund for Agricultural Development (IFAD)	1
2015	1	Academy of Finland	1
2016	1	U.S. National Science Foundation	1
2018	2	Federal Ministry for Economic Cooperation and Development, Germany (BMZ)	2
2020	2	African Climate Change Fellowship Program (ACCFP)/START, Red Cross/Red Crescent Climate Centre/START, UNISDR under Climate and Development Knowledge Network & TWAS small grant.	1
2021	2	USAID/Kenya	1
2022	1	Not stated	2
Form of publication*		World Bank	1
Journal article	10		

*Response mutually exclusive

3.2.1. Geographical distribution

The studies were conducted in various regions for Kenya (eight journal article), South Africa (one journal article), and one journal article in both Kenya and Uganda which is treated as one study.

3.2.2. Quantitative sample

There was variation in sample sizes.Two studies had a sample size greater than 500 participants.Kalungu and Filho (2016) sampled 722 respondents, while Ochieng et al. (2020) adopted a balanced panel of 1243 farm households surveyed in four years. Seven studies had a sample size ranging between 200 and 500 participants (Ombogoh, Tanui, McMullin, Muriuki, & Mowo; 2016; Autio, Johansson, Motaroki, Minoia, & Pellikka, 2021; Mairura et al., 2022; McCord, Waldman, Baldwin, Dell'Angelo, and Evans, 2018; Opiyo et al., 2015. For example, Speranza, 2013 sampled 41 respondents, Nyang'au, Mohamed, Mango, & Makate (2021) sampled 196 smallholder respondents, and Thinda, Ogundeji, Belle, & Ojo, 2020sampled 183 respondents.

Table 2: Sample characteristics

Publication dates*	k	Study participants	k
1-200	3	Smallholder farmer households	10
200-500	5		
More than 500 2	2		

*Response mutually exclusive

3.2.3. Evaluation design

Cross-sectional approach

The studies employed different approaches in measuring the study participants' outcomes and exposures. Eight studies used a *cross-sectional design*(Kalungu and Filho, 2016; Ombogoh, Tanui, McMullin, Muriuki, & Mowo; 2016; Autio, Johansson, Motaroki, Minoia, & Pellikka, 2021; Mairura, et al., 2022; Opiyo, et al., 2015; Speranza, 2013; Nyang'au, Mohamed, Mango, & Makate, 2021;and Thinda, Ogundeji, Belle, & Ojo, 2020). Of the eight studies that employed a *cross-sectional design*, seven applied a mixed methods approach (Kalungu and Filho, 2016; Ombogoh, Tanui, McMullin, Muriuki, & Mowo; 2016; Autio, Johansson, Motaroki, Minoia, & Pellikka, 2021; Opiyo et al., 2015; Speranza, 2013; Nyang'au, Mohamed, Mango, & Makate, 2021;and Thinda, Ogundeji, Belle, & Ojo, 2020).

Table 3: Methodological characteristics

Study approach	k	Study design	k
Cross-sectional	8	Quantitative	3
Longitudinal	2	Mixed methods	7
		Data collection approach*	
		Structured/semi-structure surveys	7
		FGD	5
		Key informant interview	4
		Transect walks 1	1

*Response not mutually exclusive

Longitudinal study approach

Two studies adopted a *longitudinal study approach* (McCord, Waldman, Baldwin, Dell'Angelo, and Evans, 2018; Ochieng et al., 2020), as depicted in table 3. Two separate data collection efforts conducted in 2013 and 2014 provided McCord, Waldman, Baldwin, Dell'Angelo, and Evans(2018) with the household-levelinformation used in our analysis, one conducted in 2013 and a secondconducted in 2014.Ochieng et al. (2020) used panel data (accounting for unobserved factors that may affect the uptake of climate change adaptation strategies) collected from Kenya's Agroecological zones as follows: lowlands (coastal and inner lowlands); midlands (lower midland, lower highland/upper midland, and upper midland); and highlands (lower highland, upper highland/lower highland, and upper highland).

3.2.4. Study variables

Social economic variables

All included studies measured aspects of uptake of climate change adaptation strategies and their nexus to food security among smallholder farmers and reported frequential statistics. Ten studies examined one or more primary socioeconomic characteristics of farmers: gender (nine studies); income (nine studies); age (seven studies), education (seven studies), land size (six studies); and distance to market (three studies). Other socioeconomic variables of interest included farming experience (five studies), training in

agriculture (four studies), access to services and information (five studies), and access to credit for farming (six studies). Timing of variable measurement varied between studies.

Dependent variables

The ten included studies covered adaptation strategies among smallholder farmers as summarized in table 4.

Table 4: Variable characteristics

Dependent variables	k	Independent variables*	k
Climate change adaptation strategies/ processes	9	Functioning of collective action among smallholder farmer groups	2
Resilience of smallholder agriculture to climate change.	1	Access to climate-smart technologies	1
		Awareness of climate-smart agricultural (CSA) practices	2
		Households' perception of climate change	3
		Temporal characteristics of land-use sequences	1
		Climatic variability and change	1
		Buffer capacity	1

*Response not mutually exclusive

Nine of the ten studies investigated other factors on various forms of climate change adaptation processes among smallholder farmers as their dependent variable (Ombogoh, Tanui, McMullin, Muriuki, & Mowo; 2016; Autio, Johansson, Motaroki, Minoia, & Pellikka, 2021; Mairura, et al., 2022;Kalungu and Filho, 2016; McCord, Waldman, Baldwin, Dell'Angelo, and Evans, 2018; Ochieng et al., 2020;Nyang'au, Mohamed, Mango, & Makate, 2021; Thinda, Ogundeji, Belle, & Ojo, 2020). One study investigated buffer capacity's effect on smallholder agriculture's resilience to climate change(Speranza, 2013).

Independent variables

All ten studies included examined various factors that have a causal link to adaptation strategies among smallholder farmers. Threestudies looked at how smallholder farmer households' perception of climate change might influence adaptation strategies (Ombogoh, Tanui, McMullin, Muriuki, and Mowo, 2016;Opiyo, et al., 2015; Nyang'au, Mohamed, Mango, & Makate , 2021; Thinda, Ogundeji, Belle, & Ojo, 2020).Two studies assessed the awareness of climate-smart agricultural (CSA) practices (Autio, Johansson, Motaroki, Minoia, & Pellikka, 2021;Nyang'au, Mohamed, Mango, & Makate, 2021.Two studies evaluated the functioning of collective action among smallholder farmer groups(Ombogoh, Tanui, McMullin, Muriuki, &Mowo, 2016;McCord, Waldman, Baldwin, Dell'Angelo, & Evans, 2018). A study by Mairura et al. (2022)assessed temporal characteristics of land-use sequencesunder small-scale farms in Tharaka-Nithi County.Ochieng et al.(2020)examined the interplay of climaticvariability and change. Astudy by Autio, Johansson, Motaroki, Minoia and Pellikka (2021)identified the key dimensions thatcharacterize buffer capacity through conservationagriculture, including soil protection, adapted crops,intensification/irrigation, mechanization and livelihooddiversification.

Synthesis of Results

3.3.1. Quantitative findings

This synthesis identified and presented three eligible studies with unique designs (Mairura et al., 2022; McCord, Waldman, Baldwin, Dell'Angelo, and Evans, 2018; Speranza, 2013).The three quantitative studies were conducted in different locations in Kenya. Three quantitative studies examining ten climate change adaptation strategiesaddressed this question (see Table 5). The review identified ten climate change adaptation strategies adopted by the smallholder farmers, from adopting different seed/ plant varieties to conservation agriculture, as shown in table 5.Statistical meta-analysis was neither feasible nor appropriate. Table 3 depicts that evidence in the studies is heterogeneous, with the reviewed body of literature broad in terms of population and intervention characteristics. A narrative approach was therefore taken for data synthesis.

Table 5: Quantitative Study/ dependent variable outcome

Climate change adaptation strategies/ processes*	k
Adoption of a different seed/ plant variety	3
Changes in fertilizer and manure use patterns	2
Changes in land-use patterns	1
Changes in crop sequences	2
Soil protection (Maintaining soil moisture, Reducing evaporation, Agroforestry)	1
Growing adapted crops (Growing drought-tolerant crops,Growing early-maturing crops)	1
Intensification/Irrigation (Irrigation, On-farm water harvesting,	2
Mechanization	1
Livelihood diversification	1
Conservation agriculture (Continuousminimum mechanical soil disturbance; Permanent organic soil cover; Diversification of crop speciesgrown in sequences and/or associations', residue management,crop rotations, zero tillage, conservation tillage, directplanting/seeding and in some cases, organic farming)	1

*Response not mutually exclusive

Significant dependent variables/ factors

Adoption of a different seed/ plant variety: Three studies found that smallholder farmers adopt different seeds/ plant varieties as part of the climate change adaptation strategies(Mairura et al., 2022; McCord, Waldman, Baldwin, Dell'Angelo, and Evans, 2018; Speranza, 2013).

Changes in fertilizer and manure use patterns: Two studies found that smallholder farmers use soil fertility enhancements to increase yields (Speranza, 2013; Mairura et al., 2022). Interestingly, both studies were conducted in Tharaka Nithi County, Kenya.

Reducing runoff and erosion: Two studies in the quantitative category found that farmers have adopted ways of reducing runoff and erosion(Mairura et al., 2022; McCord, Waldman, Baldwin, Dell'Angelo, and Evans, 2018; Speranza, 2013).

Changes in crop sequences:Two studies found that diversification of crop species grown in sequences and/or associations can contribute to sustainable agriculture by increasing food productivity without adversely affecting environmental goods and services (Mairura et al., 2022; Speranza, 2013).

Insignificant dependent variables/ factors

Other climate change adaptation strategies:Speranza(2013)identified other climate change adaptation strategies of smallholder farmers,including Soil protection (Maintaining soil moisture, Reducing evaporation, Agroforestry); Growing adapted crops(Growing drought-tolerant crops,Growing early-maturing crops); Intensification/Irrigation (Irrigation, On-farm water harvesting); Mechanization; and Livelihood diversification. Mairura et al. (2022) found that land-use change patterns were key climate change adaptation strategies of smallholder farmers.

Table 6: Quantitative Study/ independent variable outcome

Factors influencing climate change adaptation strategies/processes	**k**
Increasingly challenging climate conditions	2
Higher educational attainments	2
Higher potential agroecological areas	1
Economic farm production (cash crops)	1
Gender of household head (Mairura,	1
Access to credit for agricultural purposes	1
Farmer household income	1
Increased population pressure	1
Farming experience	1
Land tenure	1
Increasing slope	1
Soil fertility	1

*Response not mutually exclusive

Significant independent variables/ factors

Increasingly challenging climate conditions: Two studies address this variable (see table 6). McCord, Waldman, Baldwin, Dell'Angelo, and Evans (2018) found evidence that farmers' decisions toexperiment with shorter maturity maize varieties areadaptation strategies to cope with challenging climatic conditions.Speranza(2013)also found that to address various climate challenges, farmers mitigate the negative effects of climate change through planting trees, adopting CA, constructing boreholes, dams and water pans, conserving water and practising irrigation.

Educational attainment of farmers: Two studies linking the uptake of climate change adaptation strategies toeducational attainment of farmers found a positive correlation between educational attainment and adaptive action to climate change (McCord, Waldman, Baldwin, Dell'Angelo, & Evans, 2018, Mairura, et al., 2022).

Higher potential agroecological areas: Two studiesfound that farmers in higher potential ago-ecological zones (receiving higher rainfall levels) were more likely to adjust their crop sequences than farmers in lower potential agroecological zones(Speranza, 2013, Mairura, et al., 2022).

Insignificantindependent variables/ factors

Other insignificant independent variables included gender of household head,Access to credit for agricultural purposes, Farmer household income, Increased population pressure(Mairura, et al., 2022).

3.3.2. Mixed Methods Findings

This synthesis identified and presented seven eligible studies with mixed methods designs (Ombogoh, Tanui, McMullin, Muriuki, & Mowo; 2016; Autio, Johansson, Motaroki, Minoia, & Pellikka, 2021;Kalungu and Filho, 2016;Opiyo et al., 2015; Ochieng et al., 2020; Nyang'au, Mohamed, Mango, & Makate, 2021; Thinda, Ogundeji, Belle, & Ojo, 2020). Seven quantitative studies examining over twenty-six climate change adaptation strategies addressed this question (see Table 7). The smallholder farmers adopted various climate change adaptation strategies, ranging from using different seed crop varieties to insurance.Therefore, statistical meta-analysis was neither feasible nor appropriate. Table 3 shows that the evidence base is heterogeneous, with the reviewed body of literature broad concerning population and intervention characteristics.Therefore, this study adopted narrative approach for data synthesis.

Table 7: Mixed-methods study/ dependent variable outcome

Climate change adaptation strategies/ processes*	k
Using different crop varieties	1
Planting trees	3
Mulching/Soil and water conservation	5
Crop rotation /Different crops in different seasons	3
Early planting/Vary planting and harvesting dates	4
Shorten the length of the growing period	1
Crop diversification	4
Water harvesting	3
Composting	1
Contour ploughing	1
Fallowing	1
Farmland manure	3
Green manure	2
Intercropping	2
Irrigation	1
Organic agriculture	1
Ridges	1
Terracing	2
Zai pits	1
Zero tillage	2
Seed priming	1
Pest and disease control	1
Chemical fertilizer	1
Use of improved planning material	1
Migration	2
Insurance	1

*Response not mutually exclusive

Significant dependent variables/ factors

Planting trees: Three studies in the mixed-methods category found that farmers plant trees as a form of climate change adaptation strategy (Ombogoh, Tanui, McMullin, Muriuki, & Mowo; 2016; Autio, Johansson, Motaroki, Minoia, & Pellikka, 2021;Thinda, Ogundeji, Belle, & Ojo, 2020).

Mulching/Soil and water conservation: Of the seven mixed methods studies, five studies found that farmers adopted mulching/soil and water conservation as a climate change adaptation strategy (Ombogoh, Tanui, McMullin, Muriuki, & Mowo; 2016; Autio,

Johansson, Motaroki, Minoia, & Pellikka, 2021;Kalungu and Filho, 2016;Nyang'au, Mohamed, Mango, & Makate, 2021; Thinda, Ogundeji, Belle, & Ojo, 2020).

Other significant dependent variables included: *Crop rotation /Different crops at different seasons*(Ombogoh, Tanui, McMullin, Muriuki, & Mowo; 2016; Autio, Johansson, Motaroki, Minoia, & Pellikka, 2021; Kalungu and Filho, 2016);*Early planting/varying planting and harvesting dates*(Ombogoh, Tanui, McMullin, Muriuki, & Mowo; 2016; Autio, Johansson, Motaroki, Minoia, & Pellikka, 2021; Nyang'au, Mohamed, Mango, & Makate, 2021; Thinda, Ogundeji, Belle, & Ojo, 2020); *Crop diversification* (Ombogoh, Tanui, McMullin, Muriuki, & Mowo; 2016; Opiyo et al., 2015; Ochieng et al., 2020; Nyang'au, Mohamed, Mango, & Makate, 2021); *Water harvesting* (Ombogoh, Tanui, McMullin, Muriuki, & Mowo; 2016; Autio, Johansson, Motaroki, Minoia, & Pellikka, 2021; Kalungu and Filho, 2016); *Farmland manure*(Autio, Johansson, Motaroki, Minoia, & Pellikka, 2021; Kalungu and Filho, 2016;Nyang'au, Mohamed, Mango, & Makate, 2021); *Intercropping:* (Autio, Johansson, Motaroki, Minoia, &Pellikka, 2021; Nyang'au, Mohamed, Mango, & Makate, 2021); *Terracing* (Autio, Johansson, Motaroki, Minoia, & Pellikka, 2021; Kalungu and Filho, 2016); and *Migration* (Opiyo et al., 2015; Thinda, Ogundeji, Belle, & Ojo, 2020).

Insignificant dependent variables/ factors

Insignificant dependent variables found in the review included; Using different crop varieties, Shorten the length of the growing period (Ombogoh, Tanui, McMullin, Muriuki, & Mowo, 2016); Composting, Contour ploughing, Fallowing, Irrigation, Organic agriculture, Ridges, Zai pits (Autio, Johansson, Motaroki, Minoia, & Pellikka, 2024); Seed priming, Pest and disease control, Chemical fertilizer (Kalungu and Filho, 2016); Use of improved planning material, and Insurance(Thinda, Ogundeji, Belle, & Ojo, 2020)

4. Conclusions

Recognizing that climate change remains a global challenge, especially among smallholder farmers in sub-Saharan Africa, makes this study important in an attempt to solve the food crisis.As a critical sector with direct impacts on development linked to climate change mitigation measures, farmers' adaptation in the agricultural sector remains integral to food security and sustained livelihood change. Therefore, the ten studies reviewed examinedthe current evidence on climate change adaptation strategies among smallholders and determined how these actions are linked to food security, improved livelihoods and sustainable development in sub-Saharan Africa.The studies included in this systematic review covered various strategies, geographical locations and evaluation designs. This allowed us to draw on a broader range of evidence.Unfortunately, research in this area has received very little attention. Despite an extensive search, onlyone study identified ten eligible empirical and peer-reviewed journal articles published across the ten years(2013-2022).

While over recent decades, there have been ongoing policy debates around climate change issues as part of the development discourse, with policymakers now focusing on optimizing the benefits from a unified approach rather than separate treatment of adaptation, mitigation, or reducing emissions from deforestation. This is not reflected in the review. First, the climate change adaptation strategies primarily focus on building resilience to climate change in agriculturalproduction, mitigating farmers' challenges, and ensuring the functioning of agricultural-based livelihoods. Secondly, the review did not identify any gender-sensitive climate adaptation strategy reducing farmers' vulnerability toclimate change impacts. Furthermore, adaptation strategies are skewed towards integrated drought-related effects of climate change and other environmental and social pressures.

The first objective was to identify, assess systematically, and synthesize the evidence on climate change adaptation strategies among smallholder farmers in sub-Saharan Africa. The assessment of quantitative evidence shows that the significant climate adaptation strategies among smallholder farmers in sub-Saharan Africa include adopting a different seed/ plant variety, changes in fertilizer and manure use patterns, reducing runoff and erosion, and changes in crop sequences. Interestingly, findings on climate change adaptation strategies among smallholder farmers from quantitative study vary from those of mixed methods studies. Mixed methods evidence revealed significant climate adaptation strategies include; planting trees, mulching/Soil and water conservation, crop rotation /different crops at different seasons, early planting/varying planting and harvesting dates, crop diversification, water harvesting, use of farmland manure, intercropping, and terracing.

A further objective was to explain the uptake of climate change adaptation strategies by examining the factors influencing the uptake of climate change adaptation strategies/processes among smallholder farmers in the included studies. The review aimed to discuss the influence of a factor within a specific target geographic location, gender, type and severity of climate change. However, the review identified only a limited number of studies addressing the question of interest. However, we found that increasingly challenging climate conditions, educational attainment of farmers, and farming in higher potential agroecological areas emerge as significant factors that influencethe uptake of climate change adaptation strategies/processes among smallholder farmers in the quantitative studies. Other insignificant factors influencingthe uptake of climate change adaptation strategies/processes among smallholder farmers in the quantitative studies included; gender of household head, access to credit for agricultural purposes, farmer household income, and increased population pressure.

5. Recommendations

This systematic review aimed to provide an evidence base for policy development, especially on factors that influence the uptake of appropriate climate change adaptation strategies. However, the available evidence is limited to providing fodder for meaningful policy discourse sincethe evidence comes from few studies implemented in near similar settings over a relatively short period. Besides, most studies are conducted at a small scale and have not cited the degree of bias. Firstly, we note that there is a need for impact evaluations on the effects of climate adaptation strategies among smallholder farmers in sub-Saharan Africa. Secondly, there is also a need to researchclimate-smart agriculture legislations and policies and a spectrum of climate change adaptation strategies appropriate to different social, economic, cultural and geographic contexts in sub-Saharan Africa. Thirdly, there is a need for studies to review the effectiveness of climate change adaptation strategies available and feasible for sub-Saharan countries, and more analytical work is needed to examine both the extent to which these climate change adaptation strategies interventions are transferrable to sub-Saharan countries and the characteristics of the that determine the differences. Finally, there is a need to develop climate change adaptation scales to measure the effectiveness of appropriate strategies for sub-Saharan countries.

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