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Trade-offs and synergies of climate change adaptation strategies among smallholder farmers in sub-Saharan Africa: A systematic review

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ABSTRACT

Climate change adaptation strategies provide a cushion for smallholder farmers, especially in sub-Saharan Africa against the risks posed by climate hazards such as droughts and floods. However, the decision-making process in climate adaptation is complex. To better understand the dynamics of the process, we strive to answer this question: what are the potential trade-offs and synergies related to decision-making and implementation of climate adaptation strategies among smallholder farmers in sub-Saharan Africa region? A systematic literature review methodology was used through the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement with the four-stage inclusion/exclusion criteria to identify the literature from selected databases (Scopus and Google Scholar). The climate adaptation strategies are organized into five broad categories (crop management, risk management, soil/land management, water management, and livestock management strategies). Evidence suggests that potential trade-offs may arise concerning added costs, additional labor requirements, and competition among objectives or available resources. The synergies, on the other hand, arise from implementing two or more adaptation strategies concurrently in respect of increased productivity, resilience, yield stability, sustainability, and environmental protection. Trade-offs and synergies may also differ among the various adaptation strategies with minimum/zero tillage, comparatively, presenting more trade-offs. The development and promotion of low-cost adaptation strategies and complementary climate adaptation options that minimize the trade-offs and maximize the synergies are suggested. Skills and knowledge on proper implementation of climate change adaptation strategies are encouraged, especially at the local farm level.

1. Introduction

Climate change is causing distortions in human, agricultural, and ecological systems. Sub-Saharan Africa (SSA) is classified as one of the most vulnerable regions to increased temperature and unpredictable rainfall (Field et al., 2014). This is mainly due to the lower capacity of the populations and systems to quickly adapt to the climate change and the higher dependence on rain-fed agriculture in most countries (Kiboi et al., 2017). Furthermore, the Central and Eastern Africa regions are the most sensitive due to the increased

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frequencies of El Nino episodes (Williams et al., 2018). Climate change and variability are occurring faster than vulnerable populations can cope with. Resource-poor farmers who are less resilient may not be able to respond quickly enough and improve their resilience to the risks posed by climate change (Zougmoré, 2018).

Adaptation refers to long-term measures that provide vulnerable populations with the potential to deal with the risks and shocks posed by climate change (Ng'ang'a et al., 2016). Climate change adaptation is crucial for households and communities to secure their livelihoods and build their resilience to hazards such as floods and droughts. According to the IPCC, adaptation is a process of adjusting to the actual or expected climate and its effects with the intent to lessen the negative impacts and/or exploit the valuable opportunities (Field et al., 2014).

Food and Agriculture Organization of the United Nations (FAO) explains three types of adaptation that could occur at different scales: autonomous or incremental adaptation, planned or systematic adaptation, and transformational adaptation. FAO defines autonomous adaptation as the changes in management that farmers undertake within their existing systems. For example, changes in planting dates, reallocation of land, and other resources among different crops and livestock systems, or reallocation of time and labor requirements among farm and non-farm activities (FAO et al., 2018). Other examples of autonomous adaptation innovations as presented by Ciscar et al. (2010) include: switching to drought-tolerant crops, adopting salinity-tolerant crops, changing farming methods, and altering crop-livestock rotations among others.

On the other hand, planned or systematic adaptation mainly focuses on increased spending on research and development of new varieties, diversification strategies such as intercropping or rotational cropping systems, and risk management options such as index-based insurance (Ciscar et al., 2010; FAO et al., 2018). Transformational adaptation strategies are those options that require substantial changes in the production systems in terms of institutional arrangements, priorities for investments, and changes in norms and behaviors (FAO et al., 2018). Despite emphasis being placed on the importance of the adaptation strategies in increasing productivity (Rigolot et al., 2015), building resilience (Keenan, 2015), and reducing vulnerability (Descheemaeker et al., 2018) in the face of climate change, the uptake and up-scaling are still low. These examples considered in the study fall under planned adaptation options as opposed to autonomous or transformational adaptation strategies, which include introduction of new crop varieties, crop rotation, intercropping, index-based insurance, minimum/zero tillage, mulching, agroforestry, *Zaï* pits (a kind of planting pit, about 20–40 cm in diameter and 10–15 cm in depth) and half-moons (a kind of planting pit, about 2 m in diameter), stone/soil/vegetation bunds, use of mineral fertilizers and/or manure, water storage or water harvesting, irrigation, and livestock management practices.

The decision-making process in climate change adaptation management is complex and involves trade-offs and synergies which vary depending on the specific objectives that need to be achieved. Trade-offs assessed by Wiréhn et al. (2020) involve the balance between factors that cannot be attained at the same time or in combination, often referred to as opportunity costs. Zhao et al. (2018) also referred to trade-offs as situations that involve foregoing an aspect or a quality of one alternative to gain another. Synergies, on the other hand, occur when the aggregate effect of combining two or more adaptation strategies is greater than the sum of each if they were implemented separately (Locatelli et al., 2015; Zhao et al., 2018). Trade-offs can occur in the allocation of resources between activities, knowledge, or interest in participating in one activity and less attention given to another (Wiréhn et al., 2020). Given the limited financial and natural resources base, especially in SSA, an effective management process requires that these trade-offs and synergies are explicitly evaluated to enable informed and rational decisions.

Morrison-Saunders and Pope (2013) discussed two categories of trade-offs: process trade-offs and substantive trade-offs. The former refers to the trade-offs of decisions made by individuals or firms during daily operations and activities. The latter occurs when the positive and negative effects of a decision to implement a strategy are weighed against each other. It is important to address trade-offs and synergies at the initial stages, because the greater the number and significance of trade-offs, the more challenging the decision-making process.

A series of interdependent adaptation options are adopted together, resulting in synergistic benefits. However, some may not be compatible presenting substantial trade-offs. Taking the Water-Energy-Food (WEF) nexus as an example, the cultivation of biofuels may be useful in increasing income and enhancing energy security under a changing climate. However, it may not be suitable for adaptations that aim at improving water and food security, especially for resource-scarce regions. Because the cultivation of biofuels requires a lot of water, it also takes up much of arable land that could otherwise be used for agricultural food production. Mulching is another example. Iheoma (2015) considered mulching as a traditional adaptation measure to climate change, which shields food crops from excessive heat thus providing crop-based food security. For instance, the combination of mulching and manure increases the content of soil organic matter and helps to recycle plant nutrients during decomposition (Kiboi et al., 2017). However, the practice is labor-intensive presenting trade-offs with labor resources allocation (Idrisa et al., 2012). The main research question that this study seeks to answer is: what are the potential trade-offs and synergies that related to decision-making in climate change adaptation strategies among smallholder farmers in SSA? Climate change adaptation strategies may require huge initial investments that deter their adoption. The decision-making process is complex and it is therefore pivotal that all potential trade-offs and synergies associated with each climate adaptation alternative should be evaluated at the initial stages before implementation. This study aims to provide this information for smallholder farmers and stakeholders to make informed decisions. Building a knowledge foundation is key to ensure sustainable development and contribute to climate-resilient agricultural and ecological systems. Most literature emphasized a single broad category of climate adaptation management strategy (Reed et al., 2013; Iheoma, 2015; Nigussie et al., 2017). This paper provides a summary of potential trade-offs and synergies in five broad categories, including crop management, risk management, soil/land management, water management, and livestock management strategies.

Policymakers require realistic approaches to understand trade-offs and synergies depending on the objectives to be achieved (DeFries et al., 2016). The significance of this study is to identify the potential trade-offs and synergies that arise from decision-making in climate change adaptation. From a policy perspective, based on the available financial, natural, and human resources, this study will enable smallholder farmers to effectively and efficiently allocate scarce resources among the competing uses.

2. Methodology

2.1. Systematic literature review

This study focused on the potential trade-offs and synergies of implementing climate adaptation strategies, especially at the smallholder farmer level. A Systematic Literature Review (SLR) method was used in the study. SLR is a methodology applied to review studies, which is commonly used to evaluate the state of knowledge related to a particular topic under consideration (Williams et al., 2018). It follows the criteria for selecting and examining scientific articles and documents systematically in selected databases. This methodology has gained much popularity in recent years and is being applied to agricultural and environmental disciplines including climate change studies. It is considered more rigorous and structured in its assessment of published science and knowledge. It also provides detailed information and identifies gaps in the literature related to the topic being researched (Williams et al., 2018).

In this study, the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement was also used to systematically select and examine documents found in selected databases (i.e., Scopus and Google Scholar) (Fig. 1). This approach helps to assess the quality of the data and information from literature sources (Moher et al., 2009). Further, we used key search terms and phrases and chosen inclusion/exclusion criteria for identification and selection.

The assessment criteria for the article selection in this study include the study area, the key search terms, the climate adaptation strategies, and the methodology or framework. Only articles focused on SSA regions are considered in this study. The use of key search terms is crucial; articles without at least one of the terms in the title or in the abstract were excluded in final assessment. The adaptation strategies mentioned in the articles are also important. This is helpful to classify the strategies into appropriate categories, i.e., crop management, risk management, soil/land management, water management, and livestock management strategies. All these were categorized under planned strategies since they have a longer life cycle and require an initial assessment of all possible costs and benefits. The assessment also requires the evaluation of potential trade-offs and synergies for each strategy. However, there is a paucity of this information in most researches, thus verifying the significance of this study.

The study also provides a summary of the main methodologies that were employed in the previous researches. This is essential since

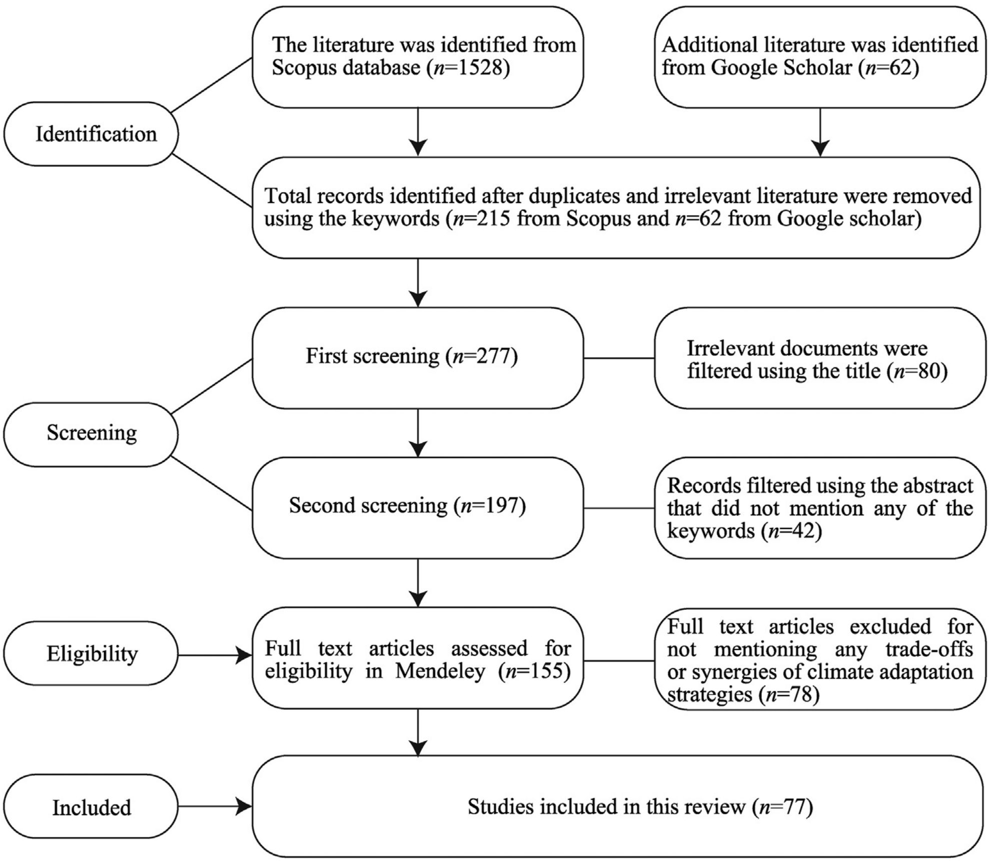

Fig. 1. Flow diagram of the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) in this study. *n* represents the number of articles.

Table 1
Characteristics of adaptation strategies in reviewed literature.

Broad category	Specific adaptation strategy	Study area	Source
Crop management	Introduction of new crop varieties	Burkina Faso, Ethiopia, Tanzania, Ghana, Benin, and SSA	Lasco et al. (2006); Webber et al. (2014); Segnon et al. (2015); Sanou et al. (2016); Lankoski et al. (2018); Williams et al. (2018); Hansen et al. (2019); Loboguerrero et al. (2019); Maredia et al. (2019); Brocke et al. (2020)
	Crop rotation	Ethiopia, Ghana, Benin, Kenya, Malawi, Togo, Nigeria, and SSA	Rosenzweig and Tubiello (2007); Segnon et al. (2015); Debaeke et al. (2017); Njeru (2018); Agula et al. (2019); Asmare et al. (2019); Hansen et al. (2019)
	Intercropping	Ghana, Burkina Faso, Benin, and Kenya	Segnon et al. (2015); Sanou et al. (2016); Agula et al. (2019); Nassary et al. (2020)
Risk management	Index-based insurance	Burkina Faso, Togo, Ethiopia, Kenya, Nigeria, and Tanzania	Agula et al. (2018); Fonta et al. (2018); Asmare et al. (2019); Hansen et al. (2019); Loboguerrero et al. (2019); Teklewold et al. (2019); Ali et al. (2020); Brocke et al. (2020); Wiréhn et al. (2020)
Soil/land management	Minimum/zero tillage	Kenya, Ghana, Malawi, and Tanzania	Rosenzweig and Tubiello (2007); Beddington et al. (2012); Vermeulen et al. (2012); Rhodes et al. (2014); Ward et al. (2016); Kiboi et al. (2017); Agula et al. (2018); Fonta et al. (2018); Lankoski et al. (2018); Peter (2018); Totin et al. (2018)
	Mulching	Ghana, Kenya, Zimbabwe, West Africa, Ethiopia, Malawi, and Burkina Faso	Beddington et al. (2012); Homann-Kee Tui et al. (2015); Wainaina et al. (2016); Ward et al. (2016); Debaeke et al. (2017); Kiboi et al. (2017); Agula et al. (2018); Peter (2018); Zougmoré et al. (2018)
	Agroforestry	Malawi, Nigeria, Kenya, and Benin	Franzel et al. (2004); Beedy et al. (2014); Homann-Kee Tui et al. (2015); Teklewold et al. (2017); Toth et al. (2017); Loboguerrero et al. (2019); Rhodes and Atewamba (2019)
	Half-moons and *Zaï* pits	West Africa and Kenya	Zougmoré (2018)
	Stone/soil/vegetation bunds	Kenya, Ghana, West Africa, and Ethiopia	Wainaina et al. (2016); Asrat and Simane (2017); Lankoski et al. (2018); Tarfasa et al. (2018); Wolka et al. (2018); Zougmoré (2018); Ahiale et al. (2019)
	Mineral fertilizer and/or manure	Kenya, Ethiopia, Zimbabwe, and Malawi	Franzel et al. (2004); Homann-Kee Tui et al. (2015); Wainaina et al. (2016); Olubode et al. (2018); Tongwane and Moeletsi (2018); Teklewold et al. (2019), Cedrez et al. (2020); Kurgat et al. (2020)
Water management	Water storage or water harvesting	Kenya and SSA	Recha et al. (2016); Hölscher et al. (2017); Lankoski et al. (2018); Oremo et al. (2021)
	Irrigation	Nigeria, Kenya, Togo, Ethiopia, and SSA	Suckall et al. (2015); Gadédjisso-Tossou et al. (2018); Mabhaudhi et al. (2018); Njoroge et al. (2018); Olubode et al. (2018); Tarfa et al. (2019); Kurgat et al. (2020)
Livestock management	Breeding of climate-tolerant species, matching stocking rates to pasture production and pasture rotation, changing animal feeds, livestock insurance, uptake of animal health services, and improvement of animal husbandry	Malawi, Zimbabwe, Kenya, Nigeria, West Africa, and SSA	Descheemaeker et al. (2016); Wainaina et al. (2016); Bjornlund et al. (2017); Lankoski et al. (2018); Loboguerrero et al. (2019); Wiréhn et al. (2020)

Note: SSA refers to sub-Saharan Africa; West Africa countries include Ghana, Nigeria, Togo, Mali, Burkina Faso, and Ivory Coast.

it adds to the knowledge base on the most frequently used methodologies and frameworks relevant to climate change adaptation decisions. The implementation of adaptation strategies aims at achieving three objectives, i.e., increasing productivity, building resilience, and mitigating climate change. At the initial stages of the decision-making process, the potential trade-offs and synergies should be identified.

In this review, an adaptation strategy or practice may fall into more than one category depending on the specific benefits or synergies from their implementation. For instance, crop management strategies include shifting planting dates, crop rotation, multi-cropping, introduction of new crop varieties, and intercropping. Crop rotation can also be considered as a risk management strategy, a soil/land management strategy, or a pest and weed management strategy. Other risk management strategies are crop insurance and livestock insurance. Mulching, multi-cropping, and mixed cropping belong to pest and weed management strategy and soil/land management strategy. Minimum/zero tillage, tied ridging tillage, agroforestry and reforestation, stone/soil/vegetation bunds, and Half-moons and *Zaï* pits are all soil/land management practices. The use of organic and inorganic fertilizers belongs to the crop management and soil/land management practices, while water harvesting through the construction of storage tanks and irrigation are considered as a water management strategy. Livestock management strategies include, but are not limited to, breeding of climate-tolerant species, matching stocking rates to pasture production and pasture rotation, changing animal feeds, livestock insurance, uptake of animal health services, and improvement of animal husbandry.

2.2. Data selection process

Two databases were used in this study: Scopus and Google Scholar. The Scopus database is purposively selected since it provides easy access to articles with complex search terms; it also offers extensive coverage both in terms of discipline and quality of publication (Totin et al., 2018). The search of the literature in Scopus database was conducted in English language using a Boolean search function. The search terms and phrases were separated using the Boolean operator (i.e., OR). That is "trade-offs" OR "synergies" OR "adaptation" OR "agriculture" OR "climate change" OR "climate-smart" OR "sub-Saharan Africa" OR "cost-benefit" OR "cost-effectiveness" OR "willingness to pay" OR "willingness to accept" OR "strategies" OR "innovations" OR "practices". The search was conducted in the advanced document search field in Scopus (https://www.scopus.com). The search in Google Scholar was also conducted using the keywords and phrases. The articles that had at least one of the keywords in the title were selected. We limited the search in the following ways to further refine the results: (1) all literature is open access; (2) some literature comes from the research in Scopus in the last five years (2016–2020), and other comes from Google Scholar in the last ten years (2011–2020); (3) subjects are agricultural, biological sciences and environmental sciences; (4) the document type is article; (5) the publication stage is the final stage; (6) the study area is only conducted in SSA region; (7) the source type is journal; and (8) the language of the article is English. The literature search in both Scopus and Google Scholar was conducted during June–July, 2020.

The search produced 1528 documents after filtering using the criteria discussed in Scopus. An additional 62 relevant documents from Google Scholar were added, giving a total of 1590 documents considered for screening (Fig. 1). The articles were then exported in a Comma Separated Values (CSV) excel file with the main elements, including authors' names, article title, source title, abstract, and keywords. Using the exclusion/inclusion criteria described in the PRISMA flow diagram (Fig. 1), the articles were screened to remove all duplicates and any irrelevant literature in the CSV excel file. This was followed by the screening of the title so that all publications that did not mention any of the keywords were excluded. The abstract and full-text screening was the final step. Full articles that were deemed relevant for the study were downloaded and then exported to the Mendeley citation application for full-text review. This review only includes information that focuses on the trade-offs and synergies of climate change adaptation strategies in SSA. The total number of articles considered for inclusion is 77.

3. Results and discussion

3.1. Characteristics of the reviewed literature

The assessment criteria include the study area, the specific adaptation strategies, the methodology used, and the identification of the potential trade-offs and synergies of the strategies as those assessed in the previous literature (Table 1). According to the methodology used, about 33% of the literature are review articles, and 13% incorporated various frameworks in the assessment, for example, the Integrated Adaptation and Mitigation Framework (Jarvis et al., 2011) and the Integrated Assessment Modelling Framework (Recha et al., 2016). Approximately 9% of the articles used the choice experiment modeling and 9% utilized the Multivariate Probit and Simulation or scenario analysis. Other methodologies used included regression analysis, correlation analysis, Logistic model, contingent valuation, on-farm trials, cost-benefit analysis, and the Trade-Off Analysis of Multi-Dimension Impact Assessment.

In considering the study area, this review includes literature that mentioned the specific country(s) or region(s) in SSA. For example, literature related with Ethiopia occupies 15% of the total, Kenya 12%, Ghana 7%, Burkina Faso 8%, and Malawi 7%; Benin, Tanzania, Togo, Zambia, and Zimbabwe respectively account for 1%. There are 45% of articles that focused on SSA or regions such as West Africa or Southern Africa. However, these articles did not specify the focus country and were therefore categorized under SSA. This is applicable, especially in the review articles.

The main climate adaptation strategies in this review include the introduction of new crop varieties, crop rotation, intercropping, use of index-based insurance, minimum/zero tillage, mulching, agroforestry, half-moons and *Zaï* pits, stone/soil/vegetation bunds, use of mineral fertilizers and/or manure, water storage or water harvesting, irrigation, and livestock management. The most frequently mentioned strategy is the introduction of new crop varieties while the least mentioned strategy is the half-moons and *Zaï* pits.

3.2. A review of the trade-offs and synergies of climate adaptation strategies

Results from the review indicated that implementation of different climate adaptation strategies can not only produce substantial benefits alone, but also produce significant benefits when integrate with other strategies. However, each strategy also presents trade-offs, which are often assessed as opportunity costs. These may be in the forms of the added costs, increased labor requirements, competition with other systems, objectives to be achieved, or competition with the available resources. Since climate change is negatively affecting agricultural production in SSA, the most obvious trade-off is whether to implement an adaptation strategy. Morrison-Saunders and Pope (2013) believed that this is a process trade-off, because it reflects the realities of decision-making in an imperfect world with limited resources.

Consequently, climate change adaptation strategies are rife with substantive trade-offs because the decision-making process involves selection among competing uses. Although the present study only considered planned adaptation strategies, substantive trade-offs did involve substitution in time, place, or in-kind (Morrison-Saunders and Pope, 2013). For instance, deforestation for commercial agricultural production may aim at improving the socio-economic aspects in terms of improved food security and job creation. However, this is at the expense of environmental protection and the destruction of traditional land used for hunting and foraging. Adaptation strategies such as agroforestry could help counter such trade-offs.

3.3. Crop management strategies

Crop management strategies are measures or innovations that are aimed at improving crop production under climate change. These include introduction of new crop varieties, crop rotation, and intercropping (Table 1).

3.3.1. Introduction of new crop varieties

Climate change is affecting cropping systems in SSA with different intensities. New crop varieties with stronger resistance to heat shocks are recommended, especially in the areas with high temperature and scarce water resources (Debaeke et al., 2017). Different choices include the use of early maturing crops, the cultivation of flood-tolerant and/or drought-tolerant crops, and the plantation of disease-resistant and pest-resistant crops (Webber et al., 2014). New crop varieties combined with soil management practices (such as mulching or use of fertilizers) can provide a buffer to effectively cope with climate change risks (Sanou et al., 2016), increase crop yield (Loboguerrero et al., 2019), and improve income (Lasco et al., 2006). The additional income earned from the selling of products can also be used to purchase food for the households, thus contributing further to food and nutrition security (Brocke et al., 2020) and dietary diversity (Lasco et al., 2006; Loboguerrero et al., 2019). Crop varieties with shorter planting cycle have a positive effect on household's food security than those with longer planting cycle (Brocke et al., 2020). Diversifying the cultivars could increase production outputs and reduce yield variations (Hansen et al., 2019). The high yields, in turn, result in high biomass for farmers to use as mulch or livestock feed (Sanou et al., 2016). The mulch further provides mitigation benefits as it can help to increase the soil carbon storage (Lankoski et al., 2018) and enhance the ecosystem services (Suckall et al., 2018).

The decision to adopt new varieties may present opportunity costs or trade-offs within the production system. For instance, farmers may incur additional transaction costs of acquiring reliable information about new varieties and even face moral hazardous behavior of selling poor quality seeds. Suppliers could also face added costs of information search on farmers' preferences and may face the risks of unsold stocks (Maredia et al., 2019). Timely and accurate information and technical advisory services are therefore crucial for making informed investment decisions (Williams et al., 2018).

New crop varieties are often cultivated in intense systems with heavy reliance on agrochemical inputs such as fertilizers and pesticides. These have led to environmental degradation, biodiversity loss, soil erosion and water pollution from leaching or surface run-off, and increased greenhouse gas emission (Segnon et al., 2015). They may also be bred for specific characteristics that make them unable to cope with seasonal or site-to-site fluctuations (Njeru, 2018). Furthermore, the breeding process takes a longer period before it can be distributed to farmers and realize the benefits from adoption (Rosenzweig and Tubiello, 2007). The breeding is also knowledge-intensive and requires careful selection since it may differ in their ability to utilize and fix nitrogen from the atmosphere and to improve soil fertility (Nassary et al., 2020). Cultivation of new varieties is a long-term adaptation strategy and may cause significant changes in the socio-technical system like the development of cooperatives or farmer groups, seed companies, and consultants with possible lock-ins in the adoption of innovations (Debaeke et al., 2017).

3.3.2. Crop rotation

Asmare et al. (2019) defined crop rotation as a practice of growing and managing more than one crop variety across space or time; crop rotation takes advantage of the benefits from the interactions of different crops. The system allows for the variations in the crop choice from every season or year (Agula et al., 2019). Most farmers choose leguminous crops in the rotations, which can make better use of organic fertilizers, reduce N_2O emissions, and enhance nitrogen fixation in soil (Debaeke et al., 2017). This, in turn, improves soil fertility (Segnon et al., 2015), increases soil organic matter content, enhances water holding capacity (Asmare et al., 2019), and eventually improves yield (Rosenzweig and Tubiello, 2007; Hansen et al., 2019).

The use of different crop types in the rotations provides room for the cultivation of high biomass crops (Peter, 2018). These further provide mitigation benefits, such as improving the carbon sequestration and nutrient cycling, reducing soil degradation (Debaeke et al., 2017), enhancing the resilience of ecosystems (Njeru, 2018), and helping to meet the varied requirements of financial and natural resources in different seasons (Asmare et al., 2019).

3.3.3. Intercropping

Intercropping involves the cultivation of two or more crops at the same time during the same cropping season or year on the same piece of land (Nassary et al., 2020). Like crop rotation, intercropping is often done with leguminous crops, such as beans, cowpeas, and soybeans. The leguminous crops could fix nitrogen from the atmosphere through a synergistic relationship with *Rhizobium* spp. (Agula et al., 2019). This process is helpful to restore the fertility of degraded soil and provide residual nutrients for the subsequent cereal crops (Sanou et al., 2016).

Intercropping of the cereal crops and leguminous crops can increase the utilization efficiency of limited resources (Nassary et al., 2020). For example, the cereal crops improve the availability of iron by legume crops, while the legume crops increase the intake of nitrogen and phosphorus by the cereal crops. Smallholder farmers who implement intercropping in their farming systems can get more than one output from the same piece of land (Sanou et al., 2016). This is an excellent food security strategy (Segnon et al., 2015), since households can diversify their diet requirement, sell more than they would have in monoculture systems, and utilize the extra income in their other investments. Further, the more the output, the more the biomass; this thus can provide more forage for livestock feed or as mulch in improving soil fertility and soil water infiltration capacity.

Although the cultivation of intercrops may utilize environmental resources synergistically, intercropping, especially interrow cropping, is a labor-intensive farming method (Sanou et al., 2016). Labor is the mostly required element for operation in the field such as sowing, weeding, and spraying to suppress pests, weeds, and diseases due to mechanization is impossible. This presents a trade-off in the reallocation of available labor among the existing systems. Intercropping also provides a canopy cover which results in a micro-climate with higher relative humidity. This micro-climate may catalyze the occurrence of pests and diseases (Nassary et al., 2020). As a result, farmers may be forced to invest in alternative methods to deal with the pests and diseases, presenting a trade-off in terms of added costs.

3.4. Risk management strategies: index-based insurance

Risk management strategies have the potential to effectively stabilize farm production and income, mitigate extreme events, and overcome any adoption barriers (Hansen et al., 2019). Most literature defined index-based insurance as a climate adaptation strategy or innovation that stimulates pay-outs based on a weather index that correlates with agricultural losses (Asmare et al., 2019; vom Brocke et al., 2020) (Table 1), for example, rainfall, area average yield, vegetation remote sensing, or modeled water stress. Insurance is based on an indicator that helps farmers to overcome moral hazardous behavior or hidden action, adverse selection or hidden information, and the high costs of verifying losses (Agula et al., 2019; Asmare et al., 2019; Tarfa et al., 2019). The uptake of insurance also protects farmers' assets against the adverse effects of climate hazard events (Hansen et al., 2019), promotes access to credit, and stimulates the adoption of improved farm technologies and practices (Loboguerrero et al., 2019). Index-based insurance makes faster pay-outs to farmers which enables them to make further investments in agricultural inputs, leading to higher outputs and income (Fonta et al., 2018). The fast pay-outs also help smallholder farmers to maintain their productive capacity by minimizing the need to liquidate assets in case of any shocks (Teklewold et al., 2020), and to strengthen their resilience by assisting them to get out of the vicious circle of poverty (Fonta et al., 2018).

The insurance industry in Africa accounts for only 0.5% of the world's insurance industry (Fonta et al., 2018). This could be attributed to the high premiums that prevent farmers from taking up insurance (Ali et al., 2020). Insurance also involves direct costs to the farmers, which directly affects the farm economy (Wiréhn et al., 2020). This presents a trade-off with financial resource allocation among different household uses. It also has rigid enrolment criteria and requires a coherent stakeholder involvement in analyzing insurance products and policies (Fonta et al., 2018), implying that smallholder farmers with little or no knowledge of the available insurance products are unlikely to take-up insurance. Provision of education and information, especially through farmer groups or cooperatives, therefore, is a viable policy option to increase the uptake of insurance products.

3.5. Soil/land management strategies

Soil/land management strategies are innovations and strategies that focus on improving or enhancing soil health (Agrawala et al., 2011) (Table 1).

3.5.1. Minimum/zero tillage

Minimum/zero tillage is one of the principles of conservation agriculture, which advocates minimizing soil disturbance to prevent any adverse impacts on the soil's structural properties (Peter, 2018). It helps to maintain and restore soil fertility (Vermeulen et al., 2012; Fonta et al., 2018; Totin et al., 2018), prevent soil erosion (Beddington et al., 2012), increase soil water holding capacity (Lankoski et al., 2018), and enhance soil carbon storage, ultimately improving the agricultural soil structure and fertility (Agula et al., 2018). According to Rosenzweig and Tubiello (2007), minimum/zero tillage practice can help to store about 8 Gt of carbon in agricultural soil, thus providing mitigation benefits and reducing field operations and input requirements.

However, there are various trade-offs associated with the minimum/zero tillage practice. For instance, there are fixed costs associated with the practice, and it takes a relatively long time (three years or more) before any perceived benefits can be observed (Ward et al., 2016). It increases the incidences of pests and diseases and soil waterlogging (Lankoski et al., 2018). The trade-off in terms of weed management may result in the shifts of labor use from other farm operations such as land clearing to weed management (Rhodes et al., 2014). Minimum/zero tillage could also lead to lower yields especially if it is solely adopted.

3.5.2. Mulching

Agula et al. (2019) defined mulch as a layer of materials, most often leaves that are applied to the soil surface to conserve soil moisture, reduce the growth of weeds, and improve soil fertility. The mulch impedes the evaporation of water from the soil surface by protecting it from direct solar radiation (Kiboi et al., 2017), which further improves the efficiency of water use, increases water infiltration, and aggregates soil stability (Wainaina et al., 2016).

The mulch provides sufficient moisture, temperature, and organic materials to create a conducive environment for microbial activities (Peter, 2018). These microbial activities improve the soil structure and soil nutrient cycling, and enhance soil carbon sequestration (Debaeke et al., 2017). The increased content of soil organic matter from additional mulch significantly prevents soil erosion from wind and water (Peter, 2018). When combined with the use of organic or inorganic fertilizers, the mulch could increase the relative yields by 229.5% (Homann-Kee Tui et al., 2015). Furthermore, if mulch is combined with contour stone bunds or soil bunds, it could improve yield significantly and reduce runoff of fine sediments (Zougmoré, 2018).

In considering trade-offs, there are opportunity costs of retaining the mulch from crop residues (Ward et al., 2016). For example, the use of mulch as feed for livestock may reduce the volume available to be used in the cropping system and *vice versa* (Beddington et al., 2012; Rigolot et al., 2015). Mulching may have great repercussions on milk production, mortality, and calving rates, especially during the dry season (Homann-Kee Tui et al., 2015). It is also labor-intensive, and its uptake depends on farm labor availability (Wainaina et al., 2016). The additional labor is especially required for weed control and transporting the mulch to feed the animals (Debaeke et al., 2017). Mulching may not be applicable in areas with high rainfall since it may result in water logging, thus exerting negative impacts on yield and productivity (Ward et al., 2016).

3.5.3. Agroforestry

Agroforestry entails the cultivation of multi-purpose fodder trees on farmlands (Toth et al., 2017). Beedy et al. (2014) explained agroforestry as a set of land-use practices that combines trees, shrubs, palm trees, or bamboos with crops or animals. Example of agroforestry systems being promoted in SSA includes: improved fallow,[1] intercropping of main crops with tree species, rotational woodlots, and agro-pastoral parkland (Beedy et al., 2014).

Agroforestry system contributes to a significant reduction in greenhouse gas emissions from agricultural production activities (Loboguerrero et al., 2019). This is achieved through an increased rate of soil carbon sequestration (Homann-Kee Tui et al., 2015; Teklewold et al., 2020). The system also provides multiple income sources for smallholder farmers, for example, timber and wood fuel production from rotational woodlots (Rhodes et al., 2014; Toth et al., 2017). In the long run, agroforestry system positively impacts the food and nutrition security of smallholder farmers (Partey et al., 2017).

Agroforestry, when combined with crop management strategies, such as intercropping or crop rotation, can maximize the use of soil resources, e.g., water and nitrogen (Debaeke et al., 2017). This is based on the fact that trees recycle crop nutrients from below the crop root zone back to the upper soil layers, thus improving soil fertility (Kurgat et al., 2020). Different tree species provide habitat for biodiversity, change micro-climate to reduce high-temperature extremes, contribute to environmental protection, and suppress the occurrence of pests and weeds (Segnon et al., 2015). Short-term tree species in agroforestry system may increase crop yields by 200%; this leads to an increase in biomass, and crop residues may further be incorporated in the soil as mulch or utilized as feed for animals (Beedy et al., 2014). However, smaller crops are likely to lose production due to the competition with trees for water, sunlight, and soil nutrients (Lankoski et al., 2018). This competition for resources can also be realized through allelopathy.[2] In a mixed system with livestock production, it is necessary to protect the area of land allocated for the tree seedlings to prevent the animals from being damaged during grazing (Kurgat et al., 2020). Combining livestock and agroforestry systems present trade-offs between increasing tree cover and improving livestock productivity.

3.5.4. Half-moons and Zaï pits

A *Zaï* is a small pit dug manually, especially during the dry season, and each pit is provided with a handful of animal manure or compost. A half-moon is a basin with 2 m in diameter, which is dug manually with a hoe, and each half-moon is provided with a barrowful of animal manure or compost. They are applicable in dry areas or on extremely degraded soil and help in improving the soil productivity. The incorporation of animal manure and compost provides the benefits of increasing agricultural productivity, vegetative cover, and carbon sequestration. Half-moons and *Zaï* pits also catalyze the regrowth or regeneration of local species. The major trade-off associated with the half-moons and *Zaï* pits is that they are labor-intensive and their adoption depends on labor availability (Zougmoré, 2018).

3.5.5. Stone/soil/vegetation bunds

Soil bunds are embankments made by ridging soils on the lower side of a ditch along a sloped contour (Wainaina et al., 2016). They act as barriers to prevent runoffs, reduce soil erosion, and further increase soil water holding capacity (Ahiale et al., 2019). Stone bunds are erosion control structures that are built using quarry rocks or stones placed in a series of two or three at a height of 20–30 cm from the ground and spaced 20–50 m apart depending on the topography (Zougmoré, 2018). In areas with high rainfall, the bunds can be planted with grasses for livestock feed or with trees for fruit or fuel (Asrat and Simane, 2017). Tree cover can reduce soil temperature

[1] It is an agroforestry technology consisting of planting mainly legume tree/shrub species in rotation with cultivated crops.

[2] Allelopathy refers to the chemical inhibition of one plant or organism by another due to the release of substances into the environment that acts as germination or growth inhibitors.

and protect against wind erosion (Zougmoré, 2018).

A case study conducted in the semi-arid areas of South Ethiopia showed that plots with stone/soil bunds are more productive than plots without stone/soil bunds (Tarfasa et al., 2018). However, the bunds are not suitable in areas with high rainfall due to the moisture conserving effects of the technology. In the case of heavy rainfall events, the bunds could lead to production losses (Lankoski et al., 2018). The bunds help in controlling floods and soil erosion, thereby reducing sedimentation of water bodies. They also reduce the transportation of chemicals such as fertilizers, herbicides, and pesticides to water bodies, thus protecting biodiversity (Ahiale et al., 2019). Incorporating the use of biological measures, such as mulching, applying organic fertilizer, and planting grasses or trees with the bunds, can enhance the efficiency of water and nutrient utilization (Zougmoré, 2018).

On the flip side, the construction and maintenance of the bunds are labor-intensive and present added costs and more labor time requirements (Wolka et al., 2018). They also occupy a significant portion of the land and then reduce the areas available for crop cultivation (Tarfasa et al., 2018), presenting trade-offs concerning the allocation of scarce lands and labor resources. In areas with high rainfall, the bunds may cause water logging, thus having deleterious effects on crop production (Zougmoré, 2018). In mixed crop-livestock systems, if the bunds are not properly constructed, they could easily be destroyed by roaming animals (Teklewold et al., 2020). The implementation of the bunds could also involve a huge initial investment, but it will take a substantial period before the benefits are realized. Financially, resource-limited farmers may consider this as a trade-off and would rather invest their money in economically viable options. The benefit, however, lies in their longer lifetime compared to other practices. Tesfaye et al. (2016) found that the effective lifetime spans of stone and soil bunds are 12 and 8 years, respectively, if they are properly maintained.

3.5.6. Use of mineral fertilizers and/or manure

The use of mineral fertilizers and/or manure involves the utilization of either organic or mineral fertilizers since they present different benefits to soil texture and fertility (Wainaina et al., 2016). The combined use of both leads to greater yield responses than the use of one at a time or one alone (Kurgat et al., 2020). The application of fertilizer also requires better timing, precision, and effectiveness through improved placement and use of appropriate quantities. This helps to reduce the loss of nitrogen (Tongwane and Moeletsi, 2018). Also, applying fertilizer near the plant root, at smaller quantities or more frequent rates especially in periods of high crop demand, has the potential to reduce the losses and improve the yield quality and quantity (Olubode et al., 2018). When the use of fertilizers is incorporated with modern seed or improved seed varieties, they provide the synergistic effects of enhancing productivity and produce more crop residues that can be used as mulch in smallholder farming systems (Teklewold et al., 2020). The combination of the use of fertilizers with crop management strategies, such as intercropping or crop rotation, especially for leguminous crops, can improve the efficiency of fertilizer use (Homann-Kee Tui et al., 2015).

Although the majority of smallholder farmers in SSA rely on inorganic fertilizers to sustain crop production (Franzel et al., 2004), crop yields are still low. The study of Cedrez et al. (2020) indicated that this is attributed to the low fertilizer use among smallholder farmers in the region. The utilization of chemical fertilizers is low because of their high costs, difficulty to obtain, or limited availability to smallholder farmers (Njoroge et al., 2018). The adoption of integrated soil fertility management is labor-intensive and costly, especially because of the necessity of purchasing inorganic fertilizer (Kurgat et al., 2020) The manufacturing of nitrogen fertilizers also results in emissions of greenhouse gas (Tongwane and Moeletsi, 2018). Any excessive use, particularly in the vicinity of catchment areas, could lead to the pollution of waterways and aquifers, thereby damaging aquatic ecosystems (Beddington et al., 2012).

3.6. Water management strategies

Water management strategies are measures aimed at improving the efficient utilization of water resources as required for improved agricultural productivity (Table 1). Most smallholder farmers in SSA heavily rely on rainfall as the main water sources for crop cultivation and livestock production (Zougmoré, 2018).

3.6.1. Water storage or water harvesting

Smallholder farmers have constructed water harvesting structures on their farms, such as water tanks, open earth dams, boreholes, and ponds, to meet their domestic and productive water demands (Recha et al., 2016). Without any additional water requirements from the ecosystems, these measures help greatly in improving food production, thereby contributing to the conservation of biodiversity (Oremo et al., 2019). If these systems are well designed and consistently maintained, they can effectively improve crop yields, reduce production variability, and increase climate resilience (Lankoski et al., 2018). Roof water harvesting could reduce excessive flow on land, thus decreasing soil erosion (Recha et al., 2016). It also acts to bridge the irrigation water gap, thereby relieving any excess pressure for water requirements from local water sources such as streams and rivers (Oremo et al., 2021) and further promoting responsible water use (Hölscher et al., 2017).

However, the construction of water storage facilities requires huge investment. Under suitable conditions, the investment cost can be recovered within 2–4 cropping seasons (approximately two years) (Oremo et al., 2021), which presents trade-offs in terms of added costs and reallocation of financial resources among different household uses. In addition, smallholder farmers who have implemented open earth dams and ponds may face the challenges of increased evaporation rates in the dry season, seepage losses, and siltation, which will result in the decline of water quality and quantity (Recha et al., 2016). In the long run, this have a substantial negative impact on water and food security for the households.

3.6.2. Irrigation

Irrigation provides reliable access to water required for crop production and protects farmers from the periodic shocks of climate change and variability (Njoroge et al., 2018; Kurgat et al., 2020). Efficient systems such as micro-irrigation (drip irrigation and sub-surface irrigation) should be favored in place of macro-irrigation (overhead irrigation or sprinkler irrigation). This is based on the fact that micro-irrigation systems can use scarce water resources efficiently without causing too much wastage (Mabhaudhi et al., 2018). As stated by FAO et al. (2018), drip irrigation technology can increase the water use efficiency up to 90% compared with the flood irrigation (50%). A survey of 685 farming households in rural and peri-urban regions of Kenya found that improved irrigation systems are also less labor-intensive and can conserve more water compared with the use of traditional methods, such as watering cans, which might require 13% of the total cost and a higher application rate (approximately 640–1600 mm/a) (Kurgat et al., 2018). The use of improved irrigation systems can reduce the production costs and ensure an increase in household income even during the dry season. The majority of farming households combine irrigation with land/soil management practices, such as soil fertilizer application or crop diversification (Tarfa et al., 2019), which maximizes productivity and improves harvest quality (Olubode et al., 2018); it also considers year-round agriculture, reducing greenhouse gas emissions, enhancing water security, increasing incomes, and improving household food and nutrition security (Suckall et al., 2018).

Deficit irrigation refers to the activity of intentionally and systematically underirrigation of crops (Gadédjisso-Tossou et al., 2018). This strategy increases water productivity, thereby reducing energy consumption and improving water use efficiency (Mabhaudhi et al., 2018). Intermittent irrigation is a mostly applicable strategy under the System of Rice Intensification, which adopts passive or active drought irrigation for several consecutive days (Beddington et al., 2012). This strategy may reduce methane emissions by more than 40% without any negative effects on the yields (Jarvis et al., 2011).

The expansion of areas suitable for irrigated agriculture provides opportunities for smallholder farmers to increase yield and productivity in a sustainable way. However, this may bring challenges, particularly resource management, which could negatively impact riparian ecosystems (Oremo et al., 2021). The management challenges arise from resolving conflict over the use of resources, especially between public and private users or between the upstream and downstream users of a river (Bjornlund et al., 2017). This further increases the challenge of supplying the irrigation water to the farmlands through increased investment costs for operations and maintenance (Mekonnen et al., 2020). The costs are even more when the farmland is located far from the water sources. In the initial stages of the implementation of an irrigation system, cash is an important requisite for purchasing equipment (such as generators, drill boreholes, and wells) and labors (Nigussie et al., 2017; Toth et al., 2017).

Although irrigation may be an effective adaptation option, it could significantly result in increased greenhouse gas emissions if the system is powered by fossil energy (Swart, 2009). Specifically, if irrigation water is not managed efficiently, it could influence the dynamics of nitrogen in soil and ultimately lead to N_2O emissions to the atmosphere (Tongwane and Moeletsi, 2018). This is because nitrogen is highly volatile. In addition, it is a challenge to incorporate livestock production within the irrigation system because of the competing uses, that is, livestock can destroy or disturb the irrigation lines, especially if it is an improved system, such as drip irrigation (Kurgat et al., 2020).

3.7. Livestock management strategies

The indirect effect of climate change caused by heat stress has significantly increased the vulnerability of livestock to diseases and reduced the milk production and fertility (Lankoski et al., 2018). Main climate adaptation strategies under livestock management include: breeding climate-tolerant species, matching stocking rates to pasture production, changing animal feeds or improving the feed, and adopting livestock insurance and good animal health and husbandry (Bjornlund et al., 2017; Descheemaeker et al., 2018) (Table 1).

Livestock keeping promotes the use of organic manure in crop production, which is also attributed to the lower rates of fertilizer use among smallholders in SSA, as farmers may use them as substitutes (Wainaina et al., 2016). The application of manure from livestock waste serves to improve soil fertility and soil organic matter, enhance soil water holding capacity, and increase carbon sequestration (Rosenzweig and Tubiello, 2007; Mekonnen et al., 2020). The livestock also provide food (meat and milk), land tillage, social status, and income; they can be used as collateral in credit or loan applications and as a buffer against risks. Thus, it allows for the uptake of other adaptation and mitigation options (Tarfa et al., 2019). The integration of livestock into irrigation system has the potential of improving productivity. However, system without fence or unrepaired fence may allow the livestock in the farms to cause damage. If there is no alternative water source for livestock, the fence could also be perceived as a barrier in preventing the livestock from accessing water (Bjornlund et al., 2017).

It was estimated that the livestock husbandry contributed to approximately 18% of the total greenhouse gas emissions by the year 2000 (Loboguerrero et al., 2019). The study predicts that this figure is expected to rise by 40% by the year 2050 if business as usual continues. The main emissions from livestock production are through enteric fermentation[3] by ruminants and livestock manure. In SSA, enteric fermentation contributed to about 85% of the total methane emissions during the period of 1994–2010 (Tongwane and Moeletsi, 2018). One possible measure to reduce these emissions is the provision or cultivation of forage with higher digestibility and energy-dense foods (Tongwane and Moeletsi, 2018). Other options may include recycling biogas from energy production on farms (Rosenzweig and Tubiello, 2007), as well as reducing the quantity and quality of feed (Campbell et al., 2016); further, proper management of pasture lands can also aid in carbon sequestration and offset some of the emissions from livestock production (Lankoski et al., 2018).

Areas with high sustained rainfall may increase the incidences of diseases and pests to which some livestock breeds may not be

[3] It is a process that occurs within the digestive system of ruminant animals (cattle, buffalo, sheep, and goat) where the microbes' resident in the animal ferment the consumed feed and methane is emitted as a by-product when the animal exhales.

adapted, which will lead to a trade-off because it may require farmers to change their livestock composition and management strategies, thereby increasing the additional costs of investment (Zougmoré, 2018). These are also based on an index designed to protect the main productive assets of pastoralists in the event of an emergency or loss of the herd (Zougmoré, 2018; vom Brocke et al., 2020). Although the initial purchase of insurance may increase the costs of farmers/pastoralists and thus affect their income, they can receive compensations from the insurance company in the event of a shock. Thus, this has a positive effect on the farm economy, thereby increasing productivity or buying more livestock and feed (Wiréhn et al., 2020).

4. Conclusions

The study utilized the Systematic Literature Review approach and provides evidence from available literature in SSA on the potential trade-offs and synergies associated with various climate adaptation innovations and strategies. The discussion focused on five broad categories: crop management, risk management, soil/land management, water management, and livestock management strategies. On the whole, soil/land management strategies are implemented by most smallholder farmers. Also, the strategies discussed herein fall under the category of planned strategies as opposed to autonomous or transformative strategies.

Results indicated that the potential trade-offs and synergies are either related to productivity changes, climate change mitigation, and labor requirements, or to competition for available resources (financial and natural). These are considered as substantive trade-offs since the process of trade-offs only arise from the decision to adopt a particular climate adaptation strategy or not. Knowledge of these potential trade-offs and synergies suggests that efforts and policies aimed at one particular adaptation innovation could affect the uptake of other adaptation innovations. The development of a range of complementary climate adaptation strategies that minimize the trade-offs, maximize the synergistic effects of improving productivity, efficient allocate and use of resources, and improve food and water security, could prove helpful in ensuring the sustainability of the agricultural systems in the face of climate change.

Adaptation strategies that result in substantive trade-offs that do not meet the sustainability criteria (trade-offs that do not consider the rights of future generations) are often structured in a way that the economic, social, and environmental aspects are evaluated separately. For example, the use of fertilizers or the adoption of new varieties cultivated in intense systems can result in increased environmental degradation. Therefore, a proper selection of appropriate indicators and the identification of potential conflicts that may arise should be done at an early stage to better manage the trade-offs.

Research into achievable adaptation innovations or combinations of strategies can help significantly reduce poverty among vulnerable groups. Strategies that involve huge initial capital investments can be best implemented by taking advantage of group dynamics, such as collective action strategies, establishment of institutions at the local scale, and community-based or landscape-based participatory approaches.

5. Recommendations

Here, we propose the following recommendations based on a thorough review of the literature on the potential trade-offs and synergies of climate adaptation strategies among smallholder farmers in SSA.

Constant provision of education to farmers can enhance the knowledge base of how to operate a new technology. This is especially applicable when the discussion is focused on planned adaptation strategies. During the process, new knowledge will also emerge, which may greatly improve the efficiency of technology use and simplify the decision-making process in choosing competitive alternatives. For example, Vermeulen et al. (2012) opined that a more operative utilization of farm chemicals (such as fertilizers and pesticides), fossil fuels, proper breeding, and good agronomic practices, will reduce the carbon intensity and footprint for most agricultural products. At the same time, increased resource use efficiency will reduce the use of inputs that may result in environmental degradation (Olubode et al., 2018).

The cost related to the implementation (initial investment), periodic or annual maintenance, and operations of the adaptation strategies is one of the factors that constrain the uptake and up-scaling, especially among resource-poor farmers. The availability of low-cost innovations would therefore result in major improvements in productivity and resources utilization. Also, the development, research, and application of more powerful and useful frameworks for trade-off assessment are required, for instance, the Gibson trade-off rules. These rules require that each chosen alternative should have a net sustainable increase, burden of argument on trade-off proponent, avoidance of significant adverse effects, protection of future generations, and explicit justification, and that the decision-making should be an open and effective participatory process (Gibson, 2006). Although these measures are often implemented in sustainability assessment processes, their application to climate change adaptation will ensure the selection of cost-effective strategies to help build resilience capacity for smallholder farmers in SSA.

Finally, farmers need an amalgamation of knowledge and skills in selecting, operating, and properly maintaining innovations to ensure sustainable development. The main challenge, however, is that the smallholder farmers in SSA are unable to respond quickly and congruously to the increasing risks associated with climate change. Unless this is achieved at the local farm level, the projected climate would result in a significant reduction in crop yields and yield stability. Further, a policy designed within the climate change adaptation discipline should be geared towards minimizing the trade-offs and maximizing the synergies.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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