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Adoption of climate-smart agricultural practices in sub-Saharan Africa: A review of the progress, barriers, gender differences and recommendations

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ABSTRACT

Climate change is one of the main challenges facing agriculture in sub-Saharan Africa, a region where many rely on rain-fed farming for their livelihoods. Climate-smart agricultural practices (CSAPs) have been identified as a promising solution to combat this problem. This paper reviews the literature on CSAPs in sub-Saharan Africa (SSA). Specifically, the review describes the existing literature on the adoption of CSAPs in the region, provides a more up-to-date summary of this expanding and important issue and presents an overview of the current evidence of CSAPs as a reliable means for farmers in SSA to address the climate change issues. The existing literature suggests that the rate of adoption of CSAPs in SSA is comparatively low. However, the adoption of CSAPs varies greatly across the region. The studies that constitute this review also provide evidence of the benefits of adopting CSAPs to farmers and the environment, ranging from increased productivity, resilience, and income for farmers, decreased greenhouse gas emissions to improved soil health. The decision to adopt particular CSAPs is influenced by several factors, including personal and social-psychological factors, environmental, physical, and ecological factors, farm and economic factors, as well as institutional, policy, and structural factors. Also, gender-based barriers in agriculture impact the adoption of CSAPs in SSA, placing women at a disadvantage. The review concludes that it is crucial to address the barriers and leverage the drivers to improve the adoption rates of CSAPs in SSA.

1. Background

Globally, climate change has led to increased variability in weather patterns, impacting different aspects of human lives and livelihood security (Mearns and Norton, 2009; FAO, 2022). Africa, including the sub-Saharan region, is highly vulnerable to climate change (IPCC, 2014; World Meteorological Organization, 2020). In sub-Saharan Africa (SSA), the effects of climate change are particularly evident with the increase in extreme temperatures, irregular precipitation patterns, and climate-related natural disasters that endanger the lives of millions, leaving them without shelter or food, while also causing significant economic losses (Serdeczny et al., 2017; Tadesse et al., 2019). These changes in the climate have also had significant impacts on agricultural productivity. For example, many farmers have experienced crop failures, reduced yields, and increased pest and disease pressures (Iannella et al., 2021; Ofori et al., 2021). The region's vulnerability to climate change is exacerbated by the relatively low levels of economic development (Maino and Emrullahu, 2022). Thus, small farmers find it increasingly difficult to produce enough food to feed their families and communities (Kanyama Phiiri et al., 2016; Tadesse and Dereje, 2018; Stuch et al., 2021).

To mitigate the impact of climate change on agriculture, farmers have to build upon or transform their agricultural systems by changing processes, practices and structures. One way of doing so is by adopting climate-smart agricultural practices (Shackleton et al., 2015; Rippke et al., 2016). Climate-smart agriculture (CSA) is an integrated approach to managing agriculture that aims to sustainably increase agricultural productivity and incomes while reducing greenhouse gas emissions and building resilience or adaptive capacity to climate change (FAO, 2013). CSA involves a combination of mostly long-existing practices, such as conservation agriculture, cover cropping, integrated crop-livestock management, better nutrient management, and better water management, among others (Aggarwal et al., 2013; Aryal et al., 2018). There has been a growing interest in scaling the adoption of climate-smart agricultural practices (CSAPs) in sub-Saharan Africa (Alemaw and Simalenga, 2015; Tesfaye et al., 2017; Notenbaert et al., 2017). Also, there is

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evidence of the pressing need to increase the adoption CSAPs (Suleman, 2017; Kombat et al., 2021). However, understanding key issues essential to meeting these goals requires a review study to provide a comprehensive, insightful, and efficient signpost to support decision making.

This paper employs a narrative literature review that summarizes the empirical evidence around adopting climate-smart practices. We assess the evidence on the potential for farmers in the region to adopt CSAPs, highlight the challenges and opportunities, provide holistic insights and point to areas for further research. Most importantly, the review synthesizes the state of the evidence about the topic area towards a cumulative understanding in order to inform stakeholders' decision making.

2. Methods

Due to the breadth of information on CSA, a narrative review was deemed more suitable. A combination of search methods was employed. Electronic searches for relevant studies were conducted mainly using AgEcon Search, Google Scholar, Scopus, and Web of Science for peer-reviewed research papers published in English. Relevant studies were also obtained by searching the reference sections of collected articles. Further, tailored searches were also performed, focusing on research outputs and reports from organizations actively engaged in CSA. This was achieved first by identifying these international development or specialised agencies and global partnerships (e.g., World Bank, African Development Bank, FAO and Consultative Group for International Agricultural Research). Thereafter, sections of their website that contained information, publications or documents related to CSA were located and used in the review.

This review considered papers from 2010 which marks the beginning of when the term was defined by the FAO up to 2023. The review explicitly focused on the adoption of CSA technologies and practices. It excluded studies that exclusively focused on climate-smart livestock production in SSA. In addition, the scope of the current paper does not cover the discussion of individual CSA technologies and practices which have been adopted to aid farmers in SSA in coping with climate-related risks. This aspect has been addressed in an extant review (see Zougmoré et al., 2018).

3. Synthesis of the existing research

3.1. Progress on CSAP adoption in sub-Saharan Africa

There is evidence that SSA countries are adopting a range of context-specific climate-smart technologies and practices. For example, among the popular CSAPs in order of prevalence are improved water management, conservation agriculture, agroforestry, and digital agriculture (World Bank, 2018). Also, other CSAs are showing great potential in SSA, such as the cultivation of climate-resilient crop varieties, sustainable intensification practices, and conservation of natural resources, e.g., rainwater harvesting and soil water conservation (Tesfaye et al., 2017).

Several studies have documented the adoption rates of CSAPs in SSA (Ouédraogo et al., 2019; Kurgat et al., 2020; Musafiri et al., 2022). However, the reported adoption rate varied with CSAPs between and within countries. For example, the adoption rate in Mali was between 39% and 77% (Ouédraogo et al., 2019). Similarly, in Kenya, the adoption level of individual CSAPs ranged between 30% and 78% (Musafiri et al., 2022). In contrast, Kurgat et al. (2020) reported an adoption rate of between 25% and 34% of at least one CSAPs in Tanzania. Notably, most of the reported adoption rates are based on estimations from surveyed households. There is also evidence of variation in the adoption of CSAPs between crops (Kangogo et al., 2021). Collectively, these studies reveal that the adoption levels of CSAPs in SSA are unevenly distributed.

Comparison of CSAPs adoption across regions in SSA also reveals important findings. For example, de Jalón et al. (2018) found that between East and West Africa, it appeared that the adoption rate was higher in East Africa. Also, in East Africa for example, the difference in awareness and adoption of practices such as legume intercropping and seed selection is small compared to a large difference in awareness and adoption of practices such as agroforestry and minimum tillage (Kombat et al., 2021). In West Africa, widely adopted CSA practices include organic manure and compost, crop association and intercropping (Ouédraogo et al., 2019). The preference for these practices were mainly attributed to their ability to enhance crop productivity, improve soil fertility, and minimize the risk of crop failure.

The adoption of several CSAPs is found to be complementary (Teklewold, 2023). For example, crop diversification and inorganic fertilizer adoption among farmers in Tanzania (Ogada et al., 2020). In Ethiopia, soil and water conservation and improved agronomy, on the one hand; integrated disease, pest and weed management and soil and water conservation, on the other hand, and integrated soil fertility management and drought tolerant high-yielding crop variety are found to be complementary (Negera et al., 2022). In contrast, Musafiri et al. (2022) found that CSAPs such as crop-livestock integration and agroforestry, and crop-livestock integration and soil water conservation are considered substitutes in Kenya. In comparison to substitution adoption (where a new technology or practice is adopted to replace an existing one) with complementary adoption, farmers are more likely to adopt a new CSAP since they perceive this approach to be a way to maximize the benefits of existing practices and reduce the risks associated with adopting a completely new set of practices.

While there is evidence that farmers in sub-Saharan Africa are increasingly employing several CSAPs and that these practices can be expanded on a larger scale. However, Bastos Lima (2014) notes that the promotion and adoption of CSA practices remain constrained despite this potential.

3.2. Evidence of the benefits of adopting climate-smart agricultural practices in sub-Saharan Africa

Despite the challenges to their adoption, climate-smart agricultural practices offer many potential benefits to farmers and the environment in sub-Saharan Africa. Among smallholder farmers in sub-Saharan Africa that have adopted one or more CSAPs, there are findings to suggest that these practices have helped to increase crop yields (e.g., Tesfaye et al., 2017; Gram et al., 2020), reduce soil erosion and improve soil health (e.g., Gram et al., 2020; Taylor et al., 2021), reduce greenhouse gas emissions from agriculture, reduce pest and diseases while enhancing biodiversity (Antwi-Agyei et al., 2021), increase farmers' resilience to climate change (e.g., Issahaku and Abdulai, 2020) and resultant improved profitability (e.g., Mutenje et al., 2019; Issahaku and Abdulai, 2020; Akinyi et al., 2022) and livelihoods (e.g., Thornton and Herrero, 2015; Abegunde et al., 2022; Egeru et al., 2022). However, not all of the practices individually result in attaining the triple aim of CSA i.e., sustainably increasing agricultural productivity and incomes, reducing greenhouse gas emissions and building resilience or adaptive capacity to climate change.

3.3. Gender differences in adoption of climate-smart agricultural practices in sub-Saharan Africa

The role that gender inequality in agriculture plays in the adoption of sustainable agricultural practices in developing countries has been vastly examined. Similarly, the adoption levels of different CSAPs in SSA are affected by gender barriers. This aspect warrants a detailed discussion as climate change exacerbates the gender gap in agriculture, e.g., by causing men to migrate for work while women take on additional agricultural responsibilities (Gondwe et al., 2022). Also, in SSA, many agricultural practices are deeply embedded in local cultural and social contexts, and the adoption of new practices may warrant changes in long-established beliefs and norms. For example, if such practices are linked to distinct gender roles in agriculture, and the new practices challenge these norms, they may face resistance (Makate, 2020; Kinyili and Ndunda, 2022).

Often cultural and social norms restrict women's capacity to adopt CSAPs. Previous findings highlight that in some cultures in SSA, women are often discouraged from participating in agroforestry as it is often deemed culturally inappropriate for women (Kiptot & Franzel, 2012). Studies have also highlighted the importance of challenging some gender norms in SSA if it positively alters gender relations in favour of women's participation or adoption of CSAPs (Wekesah et al., 2019).

There is empirical evidence that suggests gender-linked adoption of CSAPs in SSA. For example, in Ethiopia and Nigeria, CSAPs are more widely adopted on plots managed by men than those managed by women (Teklewold, 2023). In contrast, in Malawi, the adoption of CSAPs is more likely on plots managed by women (Teklewold, 2023). Also, the disparity in the adoption of combinations and categories of CSAPs based on gender varies across countries. For example, the adoption of a portfolio of CSAPs in Ethiopia and Nigeria is greater on plots managed by men only or jointly with women. In contrast, the opposite is observed in Malawi and Tanzania (Teklewold, 2023). Similarly, findings show that a greater proportion of women tend to adopt crop-related CSAPs, while men tend to adopt livestock and agroforestry-related CSAPs (Ngigi et al., 2017; Nchanji et al., 2022).

Differences have also been reported in the preference for information source and access to information gender. For example, in Kenya, the preferred information sources reported by men are extension officers, print media, television and local leaders, which differ from those of women, which consisted of radio and social groups (Ngigi et al., 2017; Ngigi and Muange, 2022). These preferences are curious. In addition, compared to men, women who live in households headed by men experience limited access to extension services (Tsige et al., 2020). Having less access to extension services compared to men may limit women's ability to learn about and adopt new CSAPs. Besides, some CSA practices are more likely to be adopted by farmers that own land (Jones et al., 2023), which can create a barrier for women farmers that are landless or do not have land ownership rights.

Decision-making power is another significant factor influencing the adoption of CSAPs by women farmers. Haug et al. (2021) examines women's involvement in farm decision-making regarding agricultural production in six African countries and found that decision-making patterns differ by country, with South Africa having the highest proportion of women making sole decisions, and Rwanda having the highest proportion of women in both sole and joint decisions. In contrast, men tend to be more involved in sole decision-making in Ethiopia and Tanzania. Cultural barriers portraying women as playing supportive roles on-farm rather than primary contributors affect their decision-making capacity (Nchanji et al., 2022). This impacts women's role as decision-makers and prevents women from being able to engage in CSA more actively.

Notably, there is also the issue of gender-related time poverty that may impact the adoption of CSAPs. For example, in Mozambique, although the agricultural system is mainly based on collective effort and both men and women dedicate similar amounts of time to cultivating crops, women also have to allocate significantly more time to fulfilling household needs (Arora and Rada, 2020). Similarly, in Ethiopia, women experience a greater degree of time poverty due to their disproportionate responsibility for food production, processing, and household chores. As a result, women are more likely to be disadvantaged in terms of time (Aryal et al., 2022). This may well have been reflected in findings (e.g., Aryal et al., 2021) that find considerable variations in the selection of CSAPs among households headed by men compared to those by women.

Despite these barriers, the successful adoption of CSAPs by women in SSA has been documented. For example, across nine countries of East and Southern Africa, Climate Smart Agriculture regional programmes supporting women with knowledge, skills and access to time and labour-saving technologies have led to women taking the lead in implementing climate-smart practices (UN Women, 2022). There is also evidence that gender-sensitive CSAPs yield practical advantages such as higher yields and incomes and reduced labour burdens for all gender of farmers (Gondwe et al., 2022). In addition, such programmes have led to resilient and sustainable agriculture in areas in rural Africa now being led by women (CAMFED, 2021).

Gender association with CSA technologies or practices adoption are thus intertwined with differences in roles and responsibilities, access to resources that affect adoption decision-making processes, knowledge, norms and decision-making power, with women often at a disadvantage (Murray et al., 2016; Bryan et al., 2017). Studies on gender and CSA underscore the importance of recognizing the different barriers men and women face regarding their adaptive capacity, preferences, and needs in taking action towards climate change. Addressing these factors is critical to promoting gender equity in agriculture and enhancing the resilience of agricultural systems in SSA in the face of climate change.

3.4. *Factors that influence the adoption of climate-smart agricultural practices in sub-Saharan Africa*

Although the adoption of climate-smart agricultural practices offers potential benefits to farmers and the environment, the adoption process can be inhibited by barriers. Understanding the factors (both drivers and barriers) that influence farmers' adoption decisions are crucial to scaling the adoption of CSAPs in SSA. In the section that follows, we synthesise into a cohesive summary the empirical evidence of the association between the adoption of CSAPs and (1) Personal and social-psychological factors, (2) Farm and economic factors, (3) Environmental, physical and ecological factors, (4) Institutional, policy and structural factors (5) Socio-cultural factors (Fig. 1).

3.4.1. *Personal and social-psychological factors*

Many previous adoption studies have shown a relationship between the age of the farmers and their adoption decision. Similarly, with CSAPs, there are numerous findings that suggest that older farmers are more likely to be resistant to change and, thus, less likely to adopt new practices. In contrast, younger farmers are more likely to have received formal education or training in agriculture and tend to be more willing to take risks. Thus, they are more open to adopting CSAPs (Justin et al., 2017; Negera et al., 2022).

The CSA literature also provides evidence in support of the assertion that education improves the likelihood of adopting improved practices and technologies. These studies (e.g., Abegunde et al., 2019b; Negera et al., 2022) found that more educated tend to adopt CSAPs the most. It is argued that educated farmers better understand the benefits of improved practices and may be in a better position to access and understand information.

Awareness of CSA practices is an important factor that drives the adoption of CSAPs. The literature did not support the generalisation that farmers in sub-Saharan Africa uniformly lack awareness and knowledge of climate-smart agricultural practices. On the one hand, Quarshie et al. (2023) found that in Ghana, the majority of farmers lack sufficient awareness about approximately 82% of the CSAPs they examined. In contrast, in Ethiopia, 96.5% were aware of CSA (Kassa and Abdi, 2022). Among Nigerian farmers, Terdoo and Adekola (2014) found that there was a general lack of awareness of CSA from farmers and many stakeholders even though CSAPs were already entrenched in indigenous practices, thus, suggesting that CSA terms understood by the farmers may not have been used in referring to these practices.

Linked to access to extension services and information, participation in capacity building and training results in a substantial increase in the uptake of CSA (Onyeneke et al., 2018; Zakaria et al., 2020; Zerssa et al., 2021). Training increases farmers' knowledge, enhances their skills, builds confidence, and encourages collaboration among farmers and between farmers and extension agents, thus, helping farmers to overcome several barriers to adoption.

Farming experience is found to mostly have a positive association with the adoption of CSAPs, i.e., the level of CSAP adoption increases with the years of farming experience (Abegunde et al., 2019a; Nyang'au

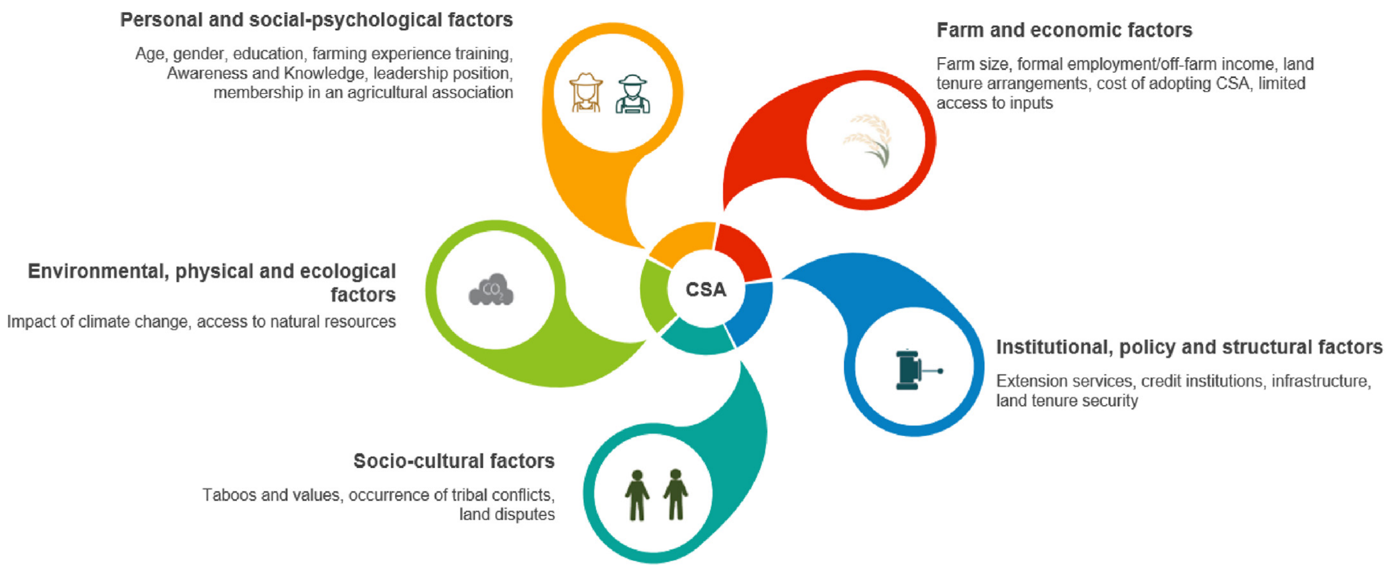

Fig. 1. Determinants of the adoption of climate-smart agricultural practices in sub-Saharan Africa.

et al., 2021). This association could be explained from several dimensions. Farmers who have experience with similar or complementary practices may be more likely to adopt new practices as they may be more confident in their ability to implement these practices effectively. Also, farmers with more farming experience i.e., years of farming or accumulated important farming skills tend to adopt CSAPs to improve their resilience, as they may be familiar with and recognise the impact of environmental changes first-hand.

Other factors, such as leadership position and membership in an agricultural association, are positively correlated with the level of CSA adoption (Onyeneke et al., 2018; Abegunde et al., 2019a). In addition, farmers' behavioural characteristics, such as risk-taking behaviour and social pressure on farmers to adopt sustainable practices, tend to increase the level of CSA adoption (Onyeneke et al., 2018; Mutenje et al., 2019; Atta-Aidoo et al., 2022).

Evident from a large number of CSA studies is the role personal and social-psychological factors play in CSAP adoption. However, this review is unable and not intended to infer whether these factors are the most important drivers of adoption.

3.4.2. Farm and economic factors

The findings on farm size and CSAP adoption are mixed. On the one hand, some studies (e.g. Kassa and Abdi, 2022; Negera et al., 2022; Teklu et al., 2023) found that larger farms are more likely to adopt CSAPs. The CSAPs mostly adopted by larger farms include water harvesting and better water management, livestock manure management and use of organic manure, effective use of nitrogen fertilizer, agroforestry, crop diversification, crop rotation and minimal tillage. It is contended that economies of scale and having more resources, such as financial capital, labour, and equipment, can facilitate the adoption of new practices and technologies. On the other hand, smaller farms were more likely to adopt CSAPs such as drought-tolerant varieties, improved rice varieties and climate-smart irrigation (Azumah et al., 2022).

In contrast,the negative effect of farm size on CSAP adoption could be attributed to decision-making in smaller farms may be more rapid, and such farms may be able to quickly adapt to changing practices or be more open to new technologies that can increase productivity and help them become climate resilient. Other studies (e.g., Bernier et al., 2015; Issahaku and Abdulai, 2020) report mixed effects of farm size on CSAP adoption. In some cases, larger farms were less likely to adopt CSAPs e.g., certain improved crops while in other cases, the tendency of not adopting CSAPs such as soil and water conservation was higher among smaller farms. Notably, the direction of the effect was dependent on the type of CSAP examined and the location.

A higher farm income increases the likelihood of adopting CSAPs (García de Jalón et al., 2017; Kassa and Abdi, 2022; Negera et al., 2022). One could argue that as farmers earn more income, they have more financial resources to invest in their farms which may be in the forms of new equipment, technology or better inputs such as seeds and fertilizers or farming practices that require substantial investment. From a different perspective, farmers who have higher incomes may also be less risk-averse (as reported in past studies, e.g., Yesuf and Bluffstone, 2009), meaning they may be more willing to try new CSAPs that have higher potential returns but may involve risk since this category of farmers has a larger cushion to absorb any potential losses, compared to farmers with lower incomes.

There are also findings that show that having formal employment or an off-farm income source decreased the likelihood of adopting more CSAPs (Justin et al., 2017; Abegunde et al., 2019b; Kassa and Abdi, 2022). Farmers that have formal employment or off-farm jobs may be unable to devote sufficient time to farm operations. This can make it more difficult to adopt CSAPs, which involves additional time and attention. Also, being less dependent on farm income can reduce the willingness to commit competing resources to the farm.

Agricultural land tenancy (Kpadonou et al., 2017), high cost of adopting CSA (Antwi-Agyei et al., 2021), challenging soil topography (Negera et al., 2022) and distance of farm to homestead (Abegunde et al., 2019b; Kassa and Abdi, 2022) was negatively correlated with the CSA level of adoption while poor soil health motivated the adoption of CSAPs (Musafiri et al., 2022). Also, many smallholder farmers in SSA have limited access to inputs such as improved seed varieties or water harvesting and management facilities which can limit the adoption of CSAPs (Antwi-Agyei et al., 2021; Mutombo and Musarandega, 2023).

3.4.3. Institutional, policy and structural factors

Institutional factors such as access to extension services influence CSAP adoption in SSA (Abegunde et al., 2019a; Negera et al., 2022; Musafiri et al., 2022). Extension services provide farmers with information and training on CSAPs, which can increase adoption rates. The implications of limited extension have been discussed earlier. Also, some government policies, policy incoherence and institutional structures may not be conducive to the adoption of CSAPs (Suleman, 2017). We return to this aspect in the section policy and institutional environment.

Another important factor is availability of formal credit institutions and access to credit. In many SSA countries, the lack of credit to support farmers taking up those CSAPs that involve additional cost inhibits farmers' ability to adopt CSAPs even if the farmer is willing to do so (Mujeyi et al., 2020; Antwi-Agyei et al., 2021; Teklu et al., 2023). However, where policies that support rural finance programs exist, farmers have adopted new CSAPs.

Availability and proximity to infrastructure and resources are also found to influence CSAP adoption. For example, the further the distance to the market (Onyeneke et al., 2018; Mujeyi et al., 2020) and to water resources (Onyeneke et al., 2018), the less likely farmers were to adopt CSAPs.

Land tenure also plays a critical role in CSAP adoption. Farmers with secure land tenure are more likely to invest in certain CSAPs that require long-term investments and use of the land. Conversely, previous studies have shown that where policies that improve land tenure security are lacking, it discourages farmers from investing in their land and adopting new practices (Kpadonou et al., 2017; Kurgat et al., 2020; Mizik, 2021). This is particularly evident in CSAPs such as agroforestry, where there is a delay before reaping benefits from trees, thus requiring a secure land tenure (Nkomoki et al., 2018; Kurgat et al., 2020).

3.4.4. Environmental factors

The perception of the impact of climate change has a positive correlation with CSA adoption (Kassa and Abdi, 2022). This finding is expected as farmers who perceive climate change as a real and significant threat are more likely to take action to protect their livelihood. Also, perception may have been shaped by past climatic experiences of the challenges posed by climate change and thus understand and recognise the need to adapt their practices accordingly. In addition, access to natural resources such as water also plays a crucial role in shaping the adoption of CSAPs in SSA (Kifle et al., 2022). These factors can either create incentives or disincentives for farmers to adopt CSAPs.

Notably, several studies find no statistically significant association between the adoption of specific CSAPs and the individual components of personal and social-psychological factors; environmental, physical, and ecological characteristics; farm and economic factors; and institutional, policy and structural factors (e.g., Agbenyo et al., 2022; Kifle et al., 2022; Phiri et al., 2022). However, we did not focus on these studies beyond acknowledging their existence here.

3.4.5. Socio-cultural factors

As discussed in the section on gender barriers, socio-cultural factors such as norms, customs or convention play in role in the adoption of CSA. In addition, it has been reported that conflicts inhibit the adoption of CSAPs (Anugaet al., 2019). For example, rising temperatures which have led to droughts and desertification, have caused a surge in the migration of nomadic herders from the northern region of Nigeria to the central and southern regions and led to land resource disputes between farmers and herders (Ibrahim-Olesin et al., 2022; Nnaji et al., 2022). Similar cases have been documented in other countries in SSA (Antwi-Agyei et al., 2021). In such conflicts, farmers' crops are destroyed, livelihoods are lost, there are human casualties, and farmers are unable to return to their land for extensive periods.

3.5. Policy, institutional environment and programme funding

Without exception, the countries in SSA have CSAPs that are indigenous or research-based, introduced or modified practices (Antwi-Agyei et al., 2021). However, there is evidence some of these are not mainstream thus, do not receive the necessary level of support (Bastos Lima, 2014). Also, many countries in Eastern and Southern Africa have agricultural and climate change policies which acknowledge the impact of climate change on agriculture, however, the insufficient coordination between sectors stifle the potential of such policies to achieve their stated objectives (Bastos Lima, 2014).

The set of CSA Policy Indicators (World Bank, 2016) aimed at assessing the enabling environment of CSA indicates a low performance of countries in SSA on providing policy frameworks for CSA implementation in aspects of readiness, services and infrastructure. Specifically, of 88 countries which included 32 from SSA, countries in SSA scored below the global average for Readiness Mechanism (59 percent), Services and Infrastructure (63 percent), and Coordination Mechanism (34 percent) (Braimoh et al., 2017). The low performance of countries in SSA on providing policy frameworks for CSA implementation indicates that more needs to be done towards providing policies and institutional arrangements that are critical for enabling CSA.

Across SSA, there are many state-led visions, plans or strategies with the majority depending on donor funding through multilateral, bilateral, and other agreements (Newell et al., 2019). While these funding have benefited many farmers in the region, the funding provided by donors are sometimes constrained by negative effects of government policies and the absence of sufficient domestic resources. On the other hand, there are implications for policy autonomy for programmes dependent on donors (Binswanger-Mkhize et al., 2010). Besides, a heavy reliance on donor funding for agricultural programs can create an unsustainable dependency on such external funding which may result in situations where counties may struggle to sustain progress if the funding is reduced or withdrawn. Also, in cases where donor-funded programs are designed and implemented with inadequate consultation with local communities and institutions or promote approaches incompatible with local contexts and needs, there is evidence to show that it limits local ownership and sustainability of such programmes (Havnevik et al., 2007; Islam, 2011; Poulton and Chinsinga, 2018; Bjornlund et al., 2020).

3.6. Recommendations to increase adoption of climate-smart agricultural practices in sub-Saharan Africa

Drawing from the findings in the CSA literature, several recommendations are proposed to address barriers to the adoption of CSAPs, and inform programmes whose objectives are to scale up these practices in order to fully realise the potential of CSA.

Promoting mitigation as a benefit to small farmers should be accompanied with highlighting the economic benefits of adopting adaptation strategies, as it can be an effective way to engage farmers. According to Abegunde et al. (2019b), this approach is particularly useful because adaptation and mitigation are complementary components of CSA, and the attractiveness of the former can yield synergistic co-benefits.

An implementation process which recognises and encourages a step-by-step approach to adoption is paramount. This approach involves gradually introducing CSAPs where each new CSAP adopted builds or complements the previous CSAP. This approach is effective in encouraging adoption as it enables farmers to become familiar and comfortable with and adjust to changes in a manageable way. In some cases, it can help farmers experience the benefits of one CSAP before adopting another. However, it is important to involve farmers in the process of designing and implementing each step to ensure that the approach is tailored to the needs and goals of the farmers.

Where applicable, farmers can also be supported to start using CSAP first on small parts of their farms, as small plots are easier to manage and may help reduce costs and resources needed, such as labour and inputs. This approach will also help to reduce both perceived and actual risks involved in the adoption of CSAPs. The experience, knowledge and lessons learned can then be transferred to the larger farm over time with less risk of failure.

Improving access to resources is a critical intervention to encouraging the adoption of CSAPs. This could include policies, interventions or programmes that provide farmers with access to credit, improve land tenure systems, increase access to education and extension services and organise tailored training programs. Further collaborations among governments, NGOs, and other relevant stakeholders with the aim of equipping farmers with the essential resources and assistance to implement CSAPs are pivotal, particularly if it considers local peculiar circumstances and requirements. In addition, incentives that promote the adoption of CSAPs, such as targeted subsidies or recognition or certification schemes for sustainably produced crops, can further encourage adoption.

Reducing the barriers female farmers face is critical to increasing the adoption of CSAPs. This could take the forms of creating opportunities for women to have equal access to extension agents and information sources, designing and implementing programmes that provide the platform for women to participate in farm management processes and that actively seeks out and considers women's input in decision-making processes. In addition, shifting perceptions and gender norms from those that inhibit women's capacity in agriculture and supporting women farmers to defying gender stereotypes is a critical step to address the gender barriers in the adoption of sustainable agricultural practices. Recognizing and addressing the needs and priorities of men and women in equal measure is crucial in adopting a gender-responsive approach to CSA, which is essential in bridging the gender gaps for climate resilience in agriculture (Gondwe et al., 2022).

It is crucial to recognise that there is no universal approach to facilitate the adoption of (CSAPs). Various regions in SSA have distinct climatic conditions and indigenous agricultural practices, and they differ in socio-economic composition. Therefore, it is imperative to develop tailored approaches that account for local contexts and heterogeneity among farmers. This paper also reiterates the importance of acknowledging indigenous knowledge and local institutions in scaling up CSA, as mentioned in Makate (2020). In other words, agents of change should not overlook the importance of identifying and building upon relevant and indigenous knowledge systems in favour of aiming to override such important local knowledge.

3.7. Suggestions for future CSA research

The objective of many of the adoption studies was to obtain information necessary to understand the use of CSAPs and to identify any factors that impede its adoption. The findings that ensued from these works have been insightful. Building on these contributions, future works should aim to collect and analyse data over a period of time to observe changes and trends in the adoption of CSAPs. This data will provide additional information on adoption rates, patterns of adoption, and the impact of interventions aimed at promoting adoption, which is crucial for better forecasting.

Most studies estimate a probit or logit regression model where the dependent variable is binary (adopt or have not/did not adopt). These models are important in examining farmers' adoption because they provide a relatively straightforward way to analyse the factors influencing adoption. However, as with binary models, these only predict whether a farmer will adopt a particular technology. These models do not provide information on the extent to which a farmer will adopt a technology. Alternatives models that would provide more insight beyond the binary indicator of adoption, for example, Weersink and Fulton (2020) suggest employing models in which the adoption process is viewed as a series of stages, where the ultimate decision to utilize the new technology is contingent upon the completion of preceding stages.

To provide a comprehensive view of the challenges related to the adoption and scaling of CSAPs in SSA, future studies could consider focusing the review on the barriers to adoption taking into account issues such as the inadequacy of the current public extension system where many extension agents lack knowledge of climate-smart agriculture, the limited exploration of private-public partnerships to facilitate knowledge creation and other macro-economic barriers that hinder the expansion of CSAPs.

It is also important for research to focus on institutional, policy and structural factors as well as socio-cultural factors for example conflicts and land disputes which have been shown to be equally important but have so far received less attention in the literature.

4. Conclusion

Agriculture, food security and rural livelihoods in SSA are under threat from climate change. The adoption of CSAPs is crucial for mitigating the negative impact of climate change on agriculture. This paper reviews the evidence on the adoption of CSAPs in SSA, highlighting the reasons why it is necessary to adopt CSA, the challenges to their adoption, and the potential to scale. The findings in the studies reviewed indicate that adoption rates of CSAPs in SSA are comparatively low. But taking all of SSA together, the adoption of CSAPs is unevenly distributed. The paper also presented evidence of the benefits of adopting CSAPs to farmers and the environment in terms of increased productivity, resilience, and income for farmers and reduced greenhouse gas emissions and improved soil health.

The adoption of specific CSAPs is influenced mainly by factors categorised as personal and social-psychological factors, environmental, physical, ecological factors, farm and economic factors, and institutional, policy and structural factors. Addressing the barriers among these factors and building on the drivers is crucial for increasing the adoption rates of CSAPs in SSA. Some of the barriers to adoption can be overcome through increased investment in agricultural research and extension services to provide farmers with the necessary knowledge and skills to adopt CSA practices. Efforts to promote CSA adoption should be tailored to the local context. There is also a need for greater collaboration between governments, NGOs, and private sector actors to provide farmers with access to finance and credit. Incentivising CSA adoption can be achieved by equipping farmers with other important resources and market opportunities. Further, addressing the policy and institutional barriers and challenges is crucial to increasing adoption.

Considering that gender-based barriers play an important role in the adoption of CSAPs in SSA, initiatives that empower women, support them with the necessary skills and resources, most importantly, climate-smart agricultural programmes that are gender-sensitive and gender-responsive in both design and implementation would reduce gender barriers to adoption. Lessons should also be learnt from successful case studies to aid in scaling up efforts across SSA.

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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