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Empowering Smallholder Farmers: Unveiling the Key Drivers of Climate Smart Agriculture Adoption Across Africa: A Systematic Review

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ABSTRACT

Climate change poses a serious threat to African agriculture, leading to food shortages; thus, the adoption of climate-smart agricultural (CSA) practices is crucial to ensuring food security and sustainability. However, smallholder farmers, particularly in Africa, have low adoption rates despite the potential benefits, such as higher yields, increased resilience and reduced input costs. This review aims to synthesise existing literature to identify key factors influencing CSA adoption among smallholder farmers, with an emphasis on gender disparities. This study conducted a systematic literature review following PRISMA guidelines, focusing only on peer-reviewed English-language articles and using keywords related to "climate-smart agriculture" (with/without hyphen) or "CSA" AND "smallholder farming/agriculture" OR "small-scale farmers" in titles, keywords, and abstracts. After screening and selection, 39 relevant studies published between 2013 and 2024 were included in the analysis. The review identified over 30 CSA practices, grouped into soil-based (e.g., zero/minimum tillage), crop-based (e.g., crop rotation), and water-based (e.g., irrigation), alongside adoption factors categorised as socio-demographic, institutional, and resource endowment. The findings indicate that factors such as

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age, gender, education, household size, farm size, income, access to credit, and livestock ownership have mixed effects on CSA adoption, reflecting geographic, practice-specific and cultural variations. In contrast, access to extension services, media exposure, market access, and membership in farmer groups consistently enhance adoption. Notably, many studies report lower adoption rates among female farmers, often linked to structural barriers such as limited land rights and access to inputs. These insights highlight key patterns in CSA adoption and provide a basis for gender-sensitive policy approaches. By providing evidence-based insights, this review can inform targeted extension programs, enabling interventions to promote CSA adoption and address gender disparities among African smallholder farmers.

Keywords: Adoption, Agricultural Policies, Climate Change, Empowering Farmers, Extension Services, Gender-Sensitive Approaches.

1. INTRODUCTION

As global food demand is projected to rise with a population of 9.7 billion by 2050, traditional agricultural practices, often linked to deforestation, excessive water use, and biodiversity loss, are no longer sustainable (Mrabet, 2023). The ecology and environment of sub-Saharan Africa make it especially vulnerable to climate change (Bedeke, 2023). This area is more susceptible due to heavy dependence on agriculture, the most climate-sensitive economic activity (Mutengwa *et al.,* 2023). In urban, peri-urban, and rural settings, climate change poses threats to food security by reducing agricultural output, increasing poverty levels, and elevating risks of food market disruptions (Aboye *et al*., 2024). Climatic factors such as rising temperatures, erratic rainfall, and shifting weather patterns make it increasingly difficult to produce food (Mirón *et al*., 2023; Abeysekara *et al*., 2023).

Various solutions have been recommended and practised to mitigate climate change and enhance food security worldwide, such as policies [e.g., taxes and subsidies] (Perino & Schwickert, 2023), industrial reorganisation (Mi & Sun, 2021; Ma & Rahut, 2024), and adoption of Climate–Smart Agriculture (CSA) practices (Issahaku *et al*., 2021; Waaswa *et al*., 2022), among others. Without intervention, emissions from food systems are projected to rise, exacerbating climate change (Dietz *et al.,* 2021). In recent times, global attention has rightly focused on the adoption of these

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practices (Shilomboleni, 2022). Smallholder farmers are at serious risk from climate change, which causes challenges such as poverty, food insecurity, malnutrition, and low agricultural productivity (Mbuli *et al.,* 2021). To adapt farming methods to climate change, CSA is a widely supported agricultural development strategy in developing countries (Zougmoré *et al*., 2021).

Although this approach is increasingly recognised as a key means of fostering resilience to climate change and improving food security in Africa, a significant gap remains in understanding the factors that shape its adoption across the continent. Smallholder farmers, who make up the majority of Africa's agricultural labour force, face unique challenges in adopting CSA practices due to diverse socioeconomic conditions, policy frameworks, cultural influences, and access to resources. The existing literature primarily consists of country-specific studies, with limited comparative research on regional disparities, contextual influences, and the determinants of CSA adoption across African countries. While studies across African countries highlight policies aimed at promoting CSA, there is a lack of comparative analysis of how these policies vary across countries and how institutional support mechanisms, such as extension services, subsidies, and credit systems, affect adoption rates. This review synthesises existing research to provide a comprehensive overview of CSA adoption across the African continent, emphasising variations driven by environmental, economic, and institutional factors. This review will provide new perspectives to inform policymakers, smallholder farmers, and other stakeholders on ways to improve technology adoption among smallholder farmers in Africa. This realisation led to this review, which aims to highlight regional differences in CSA adoption, particularly in Southern Africa, where diverse climates and socioeconomic conditions pose unique challenges.

2. REVIEW METHODOLOGY

2.1. Article Identification Strategy

This study employed a systematic literature review following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (Page *et al*., 2021). The study aimed to identify quality research papers on the drivers of CSA adoption. Based on a recent study examining the relevant and suitable academic system for systematic review (Gusenbauer & Haddaway, 2020). Google Scholar, Scopus, and Web of Science (WoS) databases were used as sources of information. Searches were limited to peer-reviewed articles and used the keywords

"climate-smart agriculture" (with/without hyphen) or "CSA" AND "smallholder farming/agriculture" OR "small-scale farmers," restricted to titles, keywords, and abstracts in English. The PRISMA flowchart (Figure 1) outlines the data collection process in accordance with the systematic review protocol. The final sample of 39 studies (focusing on the factors influencing the adoption of CSA technologies) published between 2013 and 2024 was recorded.

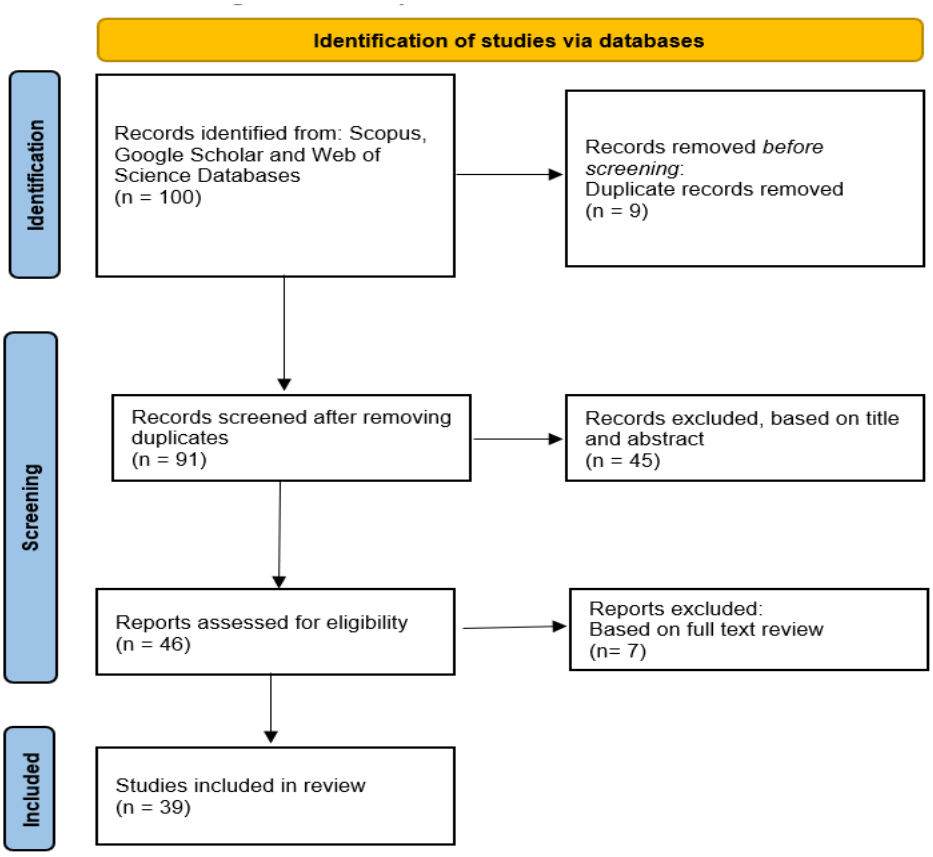

FIGURE 1: PRISMA Flowchart of the Literature Review Selection Process (Source: Own Computation, 2025)

2.2. Article Eligibility

The outcomes of the review depend heavily on the quality of the papers used in the study. The following technique was employed to ensure the quality of the selection. The titles and abstracts of the papers retrieved through keyword searches in the search engines were examined. The entire content was thoroughly examined to ensure that the abstract lacked clarity. The inclusion and

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exclusion criteria were defined for selecting relevant articles that were used in the study (see Table 1)

TABLE 1: Article Selection Criteria

Criteria	Inclusion	Exclusion
Language	English	Other languages
Population	Smallholder farmers in Africa	Commercial/large-scale farmers; studies not conducted in Africa
Publication status	Peer-reviewed journal articles, published	Grey literature (e.g., thesis, reports), unpublished manuscripts
Topic of interest	Focus on the adoption of CSA technologies.	Studies focusing solely on climate change perceptions without linking them to action.
Methodology	Studies using quantitative, qualitative or mixed-methods and econometric methods	_

Source: Own Computation, 2025

2.3. Risk of Bias Assessment

Studies were rigorously assessed for bias risk by examining essential methodological domains, such as sampling techniques, variable measurement, and suitability for analysis. This evaluation was employed to assess the robustness of evidence underpinning the study's conclusions.

3. RESULTS AND DISCUSSION

3.1. The Yearly and Geographical Distribution

The composition of the selected articles is diverse, with the earliest published in 2013, reflecting the relatively recent emergence of the climate-smart agriculture (CSA) concept. Between 2013 and 2016, the number of published articles remained consistently low, at one per year, indicating limited research interest, a lack of publications, or the nascent stage of the issue within the academic literature. In 2017, there was a slight increase to two publications, signifying a gradual

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increase in academic activity. Following a decline to one article in 2018, research activity increased significantly, resulting in five publications in 2019, four in 2020, and five in 2021. This general upward trend may indicate heightened awareness, expanded funding opportunities, and a growing research community in the domain.

The highest number of articles was published in 2022, accounting for almost 20% of the total publications (see Figure 2). The factors contributing to this may include the worldwide imperative on climate change, sustainability, and associated technologies, along with heightened regulatory and financial backing for climate-smart and agricultural innovation research. Following this peak, publications declined to five in 2023 and four in 2024. While lower than the peak year, these values remain higher than pre-2019 levels, suggesting a sustained but slightly reduced interest compared to the boom year. This reduction may stem from shifts in funding priorities, academics transitioning to other burgeoning fields, and the completion of several major studies in 2022, which led to a temporary slowdown.

The studies predominantly focus on African nations, which are particularly susceptible to climate change due to limited resources, reliance on rain-fed agriculture, and socioeconomic challenges. These characteristics provide distinct obstacles to the adoption of CSA techniques. Among the 39 papers, Ethiopia, Kenya, and Zimbabwe are the most frequently examined, likely due to their substantial climate-related difficulties and a well-established emphasis on Climate-Smart Agriculture research and policy. The prevalence of research in these nations signifies a broader regional commitment to mitigating the effects of climate change through CSA.

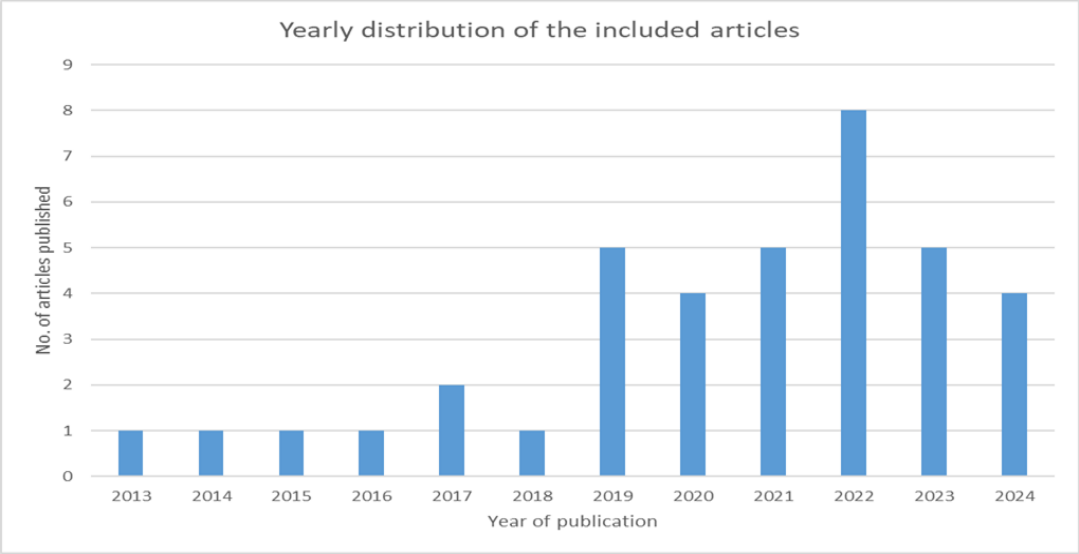

FIGURE 2: Shows the Yearly Distribution of Included Articles (Source: Own Computation, 2025)

3.2. Discussed CSA practices

According to the analysis of CSA practices in Table 1 below, farmers primarily use crop-focused and soil conservation techniques, though agroforestry and water management also play important roles. The most used methods, crop rotation and mixed/inter/cover cropping, emphasise improving soil fertility and crop resilience. Likewise, mulching and zero - or minimum tillage are frequently used to enhance soil structure and moisture retention. Farmers may prioritise crop and soil management over livestock adaptation strategies, as evidenced by lower adoption rates of livestock-focused practices and of pest and fertiliser management techniques.

TABLE 1: **The CSA Practices and the Number of Times They Were Studied**

CSA Category	Practice	Explanation	Frequency	Source
Water-Focused	Irrigation	Artificial application of water to crops to augment rainfall. It is crucial for enhancing crop yields, mitigating	8	Bryan *et al.* (2013), Kangogo *et al.* (2021), Kassa & Abdi (2022), Kurgat *et*

CSA Category	Practice	Explanation	Frequency	Source
		drought effects, and ensuring consistent agricultural production.		*al*. (2020), Mango *et al*. (2018), Mthethwa *et al*. (2022), Zakaria *et al*. (2020a)
	Water management	Effective allocation, storage and utilisation of water resources, encompassing methods such as rainwater collecting, regulated distribution and enhanced storage to reduce water.	1	Diro *et al*. (2022); Djido *et al*. (2021)
	Bunding	Construction of banks to mitigate runoff, minimise erosion, and enhance drainage.	3	Petros *et al*. (2024); Zakaria *et al*. (2020a, 2020b)
	Ridges and Bunds	Raised planting beds with bunds for drainage, moisture retention, and crop protection.	1	(Musyoki *et al*., 2022)
Crop focused	Crop diversification	Cultivating diverse crop species helps mitigate risk, bolster food security, and improve soil health.	6	(Abegunde *et al*., 2019; Brüssow *et al*., 2017; Kifle *et al*., 2022; Musafiri *et al*., 2022; Nyang'au *et al*.,

				2021; Sanogo *et al*., 2023)
	Mixed/Inter/cover cropping	Intercropping or utilising vegetation cover to save moisture, inhibit weeds, and enhance biodiversity.	11	Arslan *et al*. (2014); Diro *et al*. (2022); Gashure & Wana (2023); Gwambene *et al*. (2015); Kangogo *et al*. (2021); Kifle *et al*. (2022); Mailumo *et al*. (2021); Mujeyi *et al*. (2020, 2021); Nyang'au *et al*. (2021)
	Drought-resilient crop varieties	Crops developed to sustain harvests during water scarcity and drought conditions.	5	(Mujeyi *et al*., 2021, 2020; Mutombo and Musarandega, 2023; Zakaria *et al*., 2020a, 2020b)
	Crop rotation	Implementing crop rotation on the same land to disrupt insect cycles, enhance soil fertility, and augment productivity.	14	Alemayehu *et al*. (2024); Arslan *et al*. (2014); Gwambene *et al*. (2015); Kangogo *et al*. (2021); Kifle *et al*. (2022); Mujeyi *et al*. (2020, 2021);

				Nyang'au *et al*. (2021); Oyawole *et al*. (2021); Petros *et al*. (2024); Sanogo *et al*. (2023)
	Improved crop varieties	Varieties that are high-yielding or resistant to pests, tailored to climate variations.	7	Alemayehu *et al*. (2024); Arslan *et al*. (2014); Bate *et al*. (2019); Mailumo *et al*. (2021); Mujeyi *et al*. (2021); Sanogo *et al*. (2023)
	Row planting	Planting crops in uniformly spaced rows to optimise sunshine exposure, facilitates weed management, and enables mechanisation.	3	(Alemayehu *et al*., 2024; Zakaria *et al*., 2020b)
	Early maturing varieties	Crops that exhibit rapid maturation are used to mitigate the risks of drought or pest damage.	1	Zakaria *et al*. (2020b)
	Pest-resistant crops	Crops developed for pest resistance minimise pesticide	1	(Djido *et al*., 2021)

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		application and mitigate yield losses.		
Residue-Focused	Composting	The systematic breakdown of organic matter into humus enhances soil fertility.	1	(Ndung'u *et al*., 2023)
	Organic manure	Manure derived from animals or plants is utilised to improve soil nutrient content.	5	Abegunde *et al*. (2019); Anuga *et al*. (2019); Kassa & Abdi (2022); Mthethwa *et al*. (2022); Oyawole *et al*. (2021)
	Residue incorporation	Incorporating crop residues into the soil enhances organic matter content and structural integrity.	1	(Gwambene *et al*., 2015)
Soil-Focused	Zero/minimum tillage	Implementing planting techniques that minimise soil disturbance to enhance moisture conservation and mitigate erosion.	9	Anuga *et al*. (2019); Arslan *et al*. (2014); Diro *et al*. (2022); Gwambene *et al*. (2015); Mujeyi *et al*. (2020, 2021); Oyawole *et al*. (2021); Petros *et al*. (2024); Zakaria *et al*. (2020b)

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	Erosion control	Utilisation of plants or obstacles to mitigate soil erosion	1	(Djido *et al*., 2021)
	Soil fertility management and soil testing	Utilising fertilisers and performing soil analyses to enhance nutrient utilisation.	3	(Kangogo *et al*., 2021; Kifle *et al*., 2022; Mthethwa *et al*., 2022)
	Soil and water conservation	Consolidated approaches to sustain soil fertility and safeguard water resources.	1	(Bryan *et al*., 2013)
	Mulching	Applying organic matter to the soil helps conserve moisture, inhibit weed growth, and control temperature.	6	Benson & Ayiga (2022); Gwambene *et al*. (2015); Kpadonou *et al*. (2017); Mujeyi *et al*. (2020, 2021)
Tree-Focused	Agroforestry	Incorporating trees into agricultural and livestock systems to enhance biodiversity, soil fertility, and revenue.	8	Bryan *et al*. (2013); Gashure & Wana (2023); Gwambene *et al*. (2015); Kurgat *et al*. (2020); Musafiri *et al*. (2022); Mutombo & Musarandega (2023); Ndung'u *et al*. (2023)

	Tree planting	Establishing trees helps rehabilitate land, sequester carbon, and offer shade, fodder, or fruit.	5	(Benson and Ayiga, 2022; Brüssow *et al*., 2017; Bryan *et al*., 2013; Kassa and Abdi, 2022; Sanogo *et al*., 2023)
Pest & Fertilizer	Fertiliser use	Utilisation of inorganic fertilisers to enhance crop yields.	2	(Benson and Ayiga, 2022; Bryan *et al*., 2013)
	Integrated pest management	Integration of biological, cultural, and chemical strategies for sustainable pest management.	1	(Djido *et al*., 2021)
Seed-Focused	Improved seeds	Verified seeds exhibiting superior growth rates, insect resistance, and yield capacity.	1	(Arslan *et al*., 2014)
Livestock-Focused	Stress-tolerant livestock	Breeds resilient to harsh climatic conditions.	1	(Musyoki *et al*., 2022)
	Crop-livestock integration	Integrating crops with animals to achieve reciprocal advantages, including manure for	1	(Musafiri *et al*., 2022)

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		soil fertility and crop waste for animal feed.		
	Livestock diversity	Cultivating diverse species/breeds to mitigate risk and improve tolerance.	2	(Kurgat *et al*., 2020)
Information-Focused	Cultivation calendar	Periodic guidelines for best planting and harvesting in accordance with weather conditions.	2	(Kangogo *et al*., 2021; Mailumo *et al*., 2021)
Sloped Land	Contour farming	Establishing vegetation around land boundaries to mitigate water runoff and diminish erosion.	2	(Kpadonou *et al*., 2017; Petros *et al*., 2024)
	Terraces	Stepped fields on slopes to reduce erosion and retain water.	1	(Musyoki *et al*., 2022)
Combined	Organic farming	Disregarding synthetic inputs in favour of organic fertilisers and ecological pest management.	1	(Zakaria *et al*., 2020b)
	Conservation agriculture	System combining minimal tillage, permanent soil cover, and crop rotation to	3	Benson and Ayiga (2022); Mutombo and Musarandega (2023); Ndung'u *et al*. (2023)

		improve resilience and productivity		

3.3. Factors Affecting the Adoption of CSA Technologies

The factors influencing or driving CSA adoption among smallholder farmers in Africa are numerous. The review has shown that these factors can be categorised into socio-demographic, institutional, and resource-endowment factors (Table 2).

TABLE 2: Summary of Factors Influencing the Adoption of CSA Practices

Category	Factors	Impact direction	Studies	Comments
Socio-demographic	Age, education, gender and household size	[+/-]	Abegunde *et al*. (2019); Alemayehu *et al*. (2024); Arslan *et al*. (2014); Belay *et al*. (2023); Benson & Ayiga (2022); Brüssow *et al*. (2017); Bryan *et al*. (2013); Diro *et al*. (2022); Djido *et al*. (2021); Feleke *et al*. (2019); Gashure & Wana (2023); Gwambene *et al*. (2015); Kassa & Abdi (2022); Kpadonou *et al*. (2017); Kurgat *et al*. (2020); Mailumo *et al*. (2021); Mango *et al*. (2018); Mthethwa *et al*. (2022); Mujeyi *et al*. (2021); Mujeyi *et al*.	Greater adoption of CSA technologies is associated with higher educational attainment, and adoption is often positively impacted by both gender and education. Some studies suggest that younger farmers are more inclined to adopt new practices, while others indicate that older farmers possess valuable traditional knowledge beneficial for CSA. Adoption can be influenced by household size through

Category	Factors	Impact direction	Studies	Comments
			(2020); Musafiri *et al*. (2022); Mutombo & Musarandega (2023); Ndung'u *et al*. (2023); Nyang'au *et al*. (2021); Oyawole *et al*. (2021); Petros *et al*. (2024); Sanogo *et al*. (2023)	labor availability. In some contexts, women may face barriers due to limited access to resources and information, while in others, they are key drivers of sustainable agricultural practices.
Institutional	Access to extension services, access to credit, media exposure, market access and farmer group membership	[+]	Abegunde *et al*. (2019); Alemayehu *et al*. (2024); Anuga *et al*. (2019); Bate *et al*. (2019); Diro *et al*. (2022); Djido *et al*. (2021); Gashure & Wana (2023); Gwambene *et al*. (2015); Kifle *et al*. (2022); Mango *et al*. (2018); Mujeyi *et al*. (2020); Musafiri *et al*. (2022); Mutombo & Musarandega (2023); Ndung'u *et al*. (2023); Nyang'au *et al*. (2021); Sanogo *et al*. (2023); Zakaria *et al*. (2020a)	Access to extension services and credit significantly promotes adoption. Market access enhances profitability, making CSA practices easier to implement. Media exposure distributes information, increasing farmers' awareness of CSA practices. Membership in farmer groups promotes peer influence and knowledge exchange.

Category	Factors	Impact direction	Studies	Comments
Resource endowment	Farmland size, household income and livestock ownership	[+]	Abegunde *et al*. (2019); Alemayehu *et al*. (2024); Bate *et al*. (2019); Belay *et al*. (2023); Brüssow *et al*. (2017); Bryan *et al*. (2013); Feleke *et al*. (2019); Gashure & Wana (2023); Kassa & Abdi (2022); Kifle *et al*. (2022); Kpadonou *et al*. (2017); Mailumo *et al*. (2021); Mujeyi *et al*. (2021); Musafiri *et al*. (2022); Mutombo & Musarandega (2023); Ndung'u *et al*. (2023); Oyawole *et al*. (2021); Petros *et al*. (2024); Zakaria *et al*. (2020a)	Farmers who are well-off, with extensive farmland and more livestock, are more inclined to adopt CSA practices due to greater financial resources and reduced risk perception. Increased household income endows the necessary resources for investment in CSA, whereas livestock ownership can act as a financial safeguard, facilitating adoption.

3.2.1. Socio-Demographic Factors

3.2.1.1. Age

As farmers age, their physical characteristics, labour supply, and risk tolerance change (Donkor, 2024). As farmers age, both their physical capabilities and labour supply deteriorate (Zheng *et al*., 2021). Older farmers tend to be less likely to adopt CSA practices, probably due to lower risk tolerance, inadequate access to information, labour-intensive or resistance to change (Mujeyi *et al*., 2020). Elderly farmers are afraid to adopt new technologies and practices that entail major risks and higher-return trade-offs (Mango *et al*., 2018; Petros *et al*., 2024; Mujeyi *et al*., 2021;

Alemayehu *et al*., 2024). On the contrary, younger farmers are usually more receptive to adopting new technologies, most likely because of their greater access to information, higher educational attainment, and familiarity with information and communication technologies and modern farming methods (Bryan *et al*., 2013; Djido *et al*., 2021). (Kpadonou *et al*., 2017) found that households with more members aged 6 to 14 were more likely to adopt CSA practices.

Petros *et al*. (2024) identified age as a significant factor influencing CSA adoption, with older farmers demonstrating higher adoption rates within the study area, as their accumulated resources could enable them to invest in CSA practices. Similarly, Mailumo *et al*. (2021) found that older farmers with more farming experience and experience in assessing long-term benefits were more likely to adopt mixed cropping as a CSA practice to alleviate the adverse effects of climate change on crop production. Kalu and Mbanasor (2023) also reported a positive and important connection between age and CSA adoption, indicating that each additional year of a farmer's age increases the chances of adopting CSA practices by 0.64%, as farmers may use CSA practices as risk mitigation strategies in response to past climate shocks. Age interacts with other socioeconomic factors such as education, income, and household size. Gwambene *et al*. (2015) found that older farmers were less likely to adopt specific CSA practices because they had more farming experience.

3.2.1.2. Education

The adoption of CSA practices is frequently acknowledged to be positively influenced by education (Mazhar *et al*. 2021). Farmers with advanced levels of education comprehend the value of CSA practices in adapting to climate change and improving input use (Kpadonou *et al*., 2017). Farmers' willingness to embrace CSA practices can be enhanced by higher education (Kassa & Abdi, 2022; Sanogo *et al*., 2023; Gwambene *et al*., 2015; Belay *et al*., 2023).

The adoption of practices such as soil and water conservation and agroforestry is strongly influenced by education (Mujeyi *et al*., 2021; Alemayehu *et al*., 2024; Ndung'u *et al*., 2023). This aligns with findings from Zakaria *et al*. (2020a) and Feleke *et al*. (2019), which state that higher education levels positively influence CSA adoption.

Some studies indicate that higher education levels may divert farmers toward non-agricultural livelihoods, decreasing their CSA adoption (Mthethwa *et al*., 2022). Offer an alternative argument,

suggesting that education negatively affected CSA adoption. This demonstrates the complex nature of education's role in CSA adoption: while it typically encourages willingness and adoption, in some situations it may steer farmers toward other sources of income. Similarly, Mailumo *et al*. (2021) demonstrated a negative connection between education and adoption of multiple planting dates, suggesting that more educated farmers might prefer uniform planting.

3.2.1.3. Gender

In many African societies, women may lack control over critical farm resources [land, credit, labour], which can limit their ability to implement CSA practices. For instance, Kurgat *et al*. (2020) highlighted that female control over farm resources was a determinant in CSA adoption.

Due to substantial differences in social capital, labour endowments, and biological traits, males and females are exposed to and perceive CSA practices differently (Waroga, 2019). This contributes to lower adoption rates among women (Mutombo & Musarandega, 2023; Benson & Ayiga, 2022). However, women's empowerment, including increased access to education, has started to shift this dynamic (Brüssow *et al*., 2017). Studies indicate that as women gain more decision-making power, they are increasingly adopting CSA practices (Musafiri *et al*., 2022; Oyawole *et al*., 2021).

Zakaria *et al*. (2020b) emphasised the significance of training programs that enhanced access to knowledge regarding CSA practices for both genders, thereby addressing the gender disparity in CSA adoption. Similarly, Kpadonou *et al*. (2017) found that engagement in collaborative activities, such as cooperative membership, enhanced access to CSA technologies for both men and women. Involving women in extension programs that provide CSA knowledge tailored to their needs has increased adoption among female farmers. Bryan *et al*. (2013) found that involving women in policy development and ensuring they have access to both land and capital were crucial for enhancing CSA adoption.

3.2.1.4. Household Size

Larger households often provide more labour, which can facilitate the adoption of labour-intensive CSA technologies such as intercropping, minimum tillage, and soil conservation practices (Sanogo *et al*., 2023; Phiri *et al*., 2022; Mogaka, Bett, & Karanja Ng'ang'a, 2021).

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Several studies across different regions consistently highlight household size as a significant factor driving CSA adoption (Kifle *et al*., 2022; Nyang'au *et al*., 2021; Belay *et al*., 2023; Feleke *et al*., 2019).

However, some studies suggest that the influence of household size can be conditional, depending on other factors like income levels, gender roles, access to extension services, and credit availability. Musafiri *et al*. (2022) found that household size negatively influenced the adoption of agroforestry. The results indicated that larger households were less inclined to adopt agroforestry practices. Household size is a crucial variable, as it indicates the labour capacity to implement an agricultural practice. The results corroborated those of Kpadonou *et al*. (2017), who stated that household size negatively affects agricultural practices.

3.2.2. Institutional Factors

3.2.2.1. Access to Extension Services

Extension services in developing nations with underdeveloped agricultural markets are usually the principal source of CSA practices for farmers (Osumba *et al*., 2021). These services enable CSA adoption in three important ways: first, by raising farmers' awareness of climate change and CSA practices through the provision of information; second, by making available critical inputs like machinery and transport to simplify the adoption of CSA practices; and third, by speeding up the general adoption of CSA practices among farmers (van Asseldonk *et al*., 2023).

Several studies emphasise the important role of extension services in promoting CSA adoption. Digital extension services, including mobile phones, radio, and television, provide essential information on CSA techniques, weather patterns, and market prospects, greatly enhancing farmers' capacity to implement CSA practices. Diro *et al*. (2022) discovered that access to extension services and possession of communication devices [e.g., radio] positively impacted the adoption of CSA, indicating that digital extension tools can effectively disseminate CSA knowledge. Similarly, Djido *et al*. (2021) highlighted the importance of information sources such as radio and TV in influencing CSA adoption, demonstrating the potential of digital platforms for extension service delivery.

3.2.2.2. Access to Credit

Studies indicate that credit availability enhances farmers' capability to capitalise on CSA technologies. For example, Alemayehu *et al*. (2024) observed that access to credit significantly promoted the use of row planting, crop rotation, and improved wheat varieties. In the same vein, Kalu and Mbanasor (2023) emphasised the need to enhance farmers' access to credit to promote CSA adoption.

Although credit is essential for advancing CSA practices, numerous farmers in developing nations face substantial credit constraints, limiting their ability to invest in sustainable agriculture (Kifle *et al*., 2022; Mutombo & Musarandega, 2023). Informal credit sources, such as borrowing from landlords, may have adverse effects and limit farmers' investments in long-term sustainability, whereas formal credit sources, such as bank loans, have been shown to promote the adoption of CSA (Musyoki *et al*., 2022).

3.2.2.3. Media Exposure

The digital era of today has brought about new cultural phenomena such as social media, radio, and television (Casciani *et al*., 2022). Abegunde *et al*. (2019) indicated that farmers with ample exposure to media information are better equipped to cope with the effects of climate change and respond quickly to them.

Djido *et al*. (2021) found that information sources such as radio and TV play an essential role in shaping CSA implementation by influencing farmers' perceptions of climate change. Abegunde *et al*. (2019) emphasised that media exposure, along with climate change education and extension services, strengthens farm activities and improves farm income. It is possible to mitigate the impacts of climate change by implementing weather-smart farming practices and using mobile phones or the internet to access weather information (Anuga *et al*., 2019).

3.2.2.4. Market Access

Market accessibility allows farmers to invest in CSA practices with greater confidence, as they can secure better prices for climate-resilient crops and livestock products (Tesfaye *et al*., 2023). Farmers with reliable market access are more likely to adopt CSA practices. Mujeyi *et al*. (2021) found that improved market access incentivised investment in labour-intensive CSA practices by

ensuring financial returns. Feleke *et al*. (2019) also reported that proximity to markets facilitated access to essential CSA inputs, such as organic fertilisers and improved seeds, thereby increasing adoption rates.

Conversely, limited market access presents a barrier to CSA adoption. Kifle *et al*. (2022) observed that remote farmers faced higher transaction costs and struggled to obtain necessary inputs, which restricted adoption. Mujeyi *et al*. (2021) also emphasised that inadequate market infrastructure and weak extension services constrained the integration of CSA into farming systems.

3.2.2.5. Farmer Group Membership

Empirical evidence from reviewed studies highlights the positive influence of farmer group membership on CSA adoption. For example, Zakaria *et al*. (2020b) found that membership in a farmers' group significantly influenced the intensity of CSA adoption. These organisations create an enabling environment where farmers can exchange best practices, gain technical knowledge, and collectively negotiate for better access to resources such as inputs, credit, and market linkages (Sanogo *et al*., 2023; Abegunde *et al*., 2019).

Beyond disseminating knowledge, farmers' organisations help reduce the financial and logistical barriers associated with CSA adoption. Additionally, participation in cooperatives and associations has been linked to increased resilience and improved access to climate-related information (Gashure & Wana, 2023; Bate *et al*., 2019; Anuga *et al*., 2019).

3.2.3. Resource Endowment Factors

3.2.3.1. Farmland Size

Farm size is an indicator of wealth and social status that influences within the community. Bigger farms often enable economies of scale, which can reduce the per-unit production costs associated with CSA adoption, thus making it more feasible for farmers (Akinyi *et al*., 2022). A larger farm size not only generates greater agricultural outputs but also provides a solid foundation for the benefits of CSA practices, as it offers more land for implementing diverse technologies (Zakaria, Alhassan, *et al*., 2020; Kifle *et al*., 2022; Muriithi *et al*., 2023).

Several studies have reported that farm size directly influences the probability of adopting CSA practices (Petros *et al*., 2024; Kifle *et al*., 2022; Alemayehu *et al*., 2024). This was observed by Zakaria *et al*. (2020a), who found that larger farms exhibited lower adoption intensity due to the high input costs associated with extensive farm management practices.

Kassa and Abdi's (2022) study indicated that farmers with larger agricultural holdings were more likely to implement CSA techniques, suggesting that promoting CSA adoption among farmers is beneficial. The results support the findings of Petros *et al*. (2024) and Gashure and Wana (2023), who found that land fragmentation may be a barrier to CSA implementation.

3.2.3.2. Household Income

Higher income allows farmers to access resources, inputs, and services that facilitate adoption. Mthethwa *et al*. (2022) identified that farm income, particularly on-farm income, positively influenced CSA adoption, whereas off-farm income sources had a negative effect. The findings suggest that farmers with higher on-farm income are more likely to invest in technologies. The impact of household income on adoption is also evident in the study by Abegunde *et al*. (2019), in which farm income was a key determinant of CSA adoption alongside farming experience and media exposure.

Belay *et al*. (2023) observed that higher per-hectare farm income improved both food consumption and farm income among CSA adopters. This connection between income and adoption is further supported by Kurgat *et al*. (2020), who noted that household income was crucial for CSA adoption. Similarly, Musyoki *et al*. (2022) and Nyang'au *et al*. (2021) showed that household income, combined with land ownership and access to climate information, significantly influenced CSA adoption, especially in agroforestry and crop diversification.

3.2.3.3. Livestock Ownership

Farmers with more livestock have better access to credit; those with more livestock are likely to adopt more innovations than those with fewer animals. Musafiri *et al*. (2022) found that livestock was also a key determinant in the uptake of CSA practices. This suggests that livestock owners might have more resources to diversify their farming practices and invest in sustainable agricultural techniques. Studies by Kurgat *et al*. (2020) and Musyoki *et al*. (2022) highlighted that

livestock owners with better access to resources and greater financial stability are more likely to engage in CSA practices. According to Petros *et al*. (2024) and Alemayehu *et al*. (2024), livestock owners may have more resources to invest in sustainable agricultural techniques and to support the implementation of climate-smart practices.

Although there are trade-offs between irrigation adoption and livestock diversity, Kurgat *et al*. (2020) also discovered that livestock diversity is an important CSA practice. Furthermore, Feleke, Regasa, and Muche (2019) highlighted that home feeding and forage conservation are two essential adaptive strategies for sustaining livestock in CSA systems.

3.3. Comparing Studies Conducted in South Africa with Other African Countries on Factors Influencing CSA Adoption by Smallholder Farmers

TABLE 3: Comparative Factors Influencing CSA Adoption

Factor	South Africa	Other African Countries
On-Farm Income	Mthethwa *et al*. (2022). (Positive correlation)	Ethiopia (Gashure & Wana, 2023) (Positive correlation)
		Malawi/Mozambique/Zambia (Mango *et al*., 2018) (-)
Household Size	Labour advantage (Mthethwa *et al*., 2022) (Positive correlation)	Rwanda (Musafiri *et al*., 2022) (Negative correlation)
	(Abegunde *et al*., 2019) (No significant relationship)	Ethiopia (Feleke *et al*., 2019) (No significant relationship)
Farm Size	(Abegunde *et al*., 2019) (+)	Ghana (Zakaria *et al*., 2020a) (Positive correlation)
		Zambia (Petros *et al*., 2024) (-)

Studies on CSA adoption highlight both similarities and differences between South Africa and other countries. Mthethwa *et al*. (2022) found a positive association between on-farm income and CSA adoption in South Africa, indicating that farmers who earn income from selling agricultural products are likely to adopt CSA practices. Similarly, Gashure and Wana (2023) observed in

Ethiopia that, because off-farm income contributes minimally to total household earnings, most farmers depend on agriculture as their primary livelihood, thereby encouraging CSA adoption. In contrast, Mango *et al*. (2018) found that in Malawi, Mozambique, and Zambia, off-farm employment negatively affected CSA adoption, as these farmers were less likely to invest in CSA practices.

Mthethwa *et al*. (2022) in South Africa also identified a positive correlation between household size and CSA adoption, suggesting that larger families benefit from increased labour availability and access to diverse information sources, enhancing climate adaptation strategies. However, contrasting results were observed in Rwanda, where Musafiri *et al*. (2022) found that larger families have a lower likelihood of adopting labour-intensive CSA practices, while smaller households tended to hire labour for CSA implementation. Additionally, Abegunde *et al*. (2019) in South Africa and Feleke *et al*. (2019) in Ethiopia found no significant relationship between household size and CSA adoption.

In South Africa, Abegunde *et al*. (2019) reported a positive association between farm size and CSA adoption, with larger farms more likely to adopt CSA practices. This aligns with Zakaria *et al*. (2020), who found similar trends in Ghana. However, conflicting evidence from Petros *et al*. (2024) suggests that larger farms may hinder CSA adoption, as farmers in Zambia with extensive landholdings may prioritise conventional methods over climate-smart innovations. Likewise, Kpadonou *et al*. (2017) found that smallholder farmers in the West African Sahel encounter challenges such as constrained access to funding and information, which hinders CSA adoption.

4. CONCLUSION AND RECOMMENDATIONS

Empowering smallholder farmers is essential for enhancing the implementation of CSA. This emphasises the need for targeted educational initiatives that equip these farmers with the knowledge and skills to adopt CSA innovations. Smallholder farmers can increase their resilience to climate change by making better decisions if they have a better understanding of CSA and its advantages.

Gender disparities in CSA adoption also emerged as a key finding, with female farmers adopting CSA at lower rates compared to their male counterparts. A variety of resources could be offered

to women, such as credit, land, and training, and efforts could be made to ensure that both men and women benefit equally from agricultural activities. Smaller farms may struggle to access funding and information for CSA because they lack the resources of larger farms. This highlights the need for targeted policies and financial mechanisms to support smallholder farmers, especially those in resource-constrained areas. Creating a permitting framework that enables farmers to adopt CSA involves providing them with tools, information, and financial support, regardless of farm size.

Policies and stakeholders can cultivate an environment that encourages the adoption of CSA, resulting in more resilient agricultural systems and improving food security and climate resilience throughout Africa.

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