

Climate-smart agricultural practices and its implication in Ethiopia: a systematic review

Getasew Daru Tariku and Sinkie Alemu Kebede
*Department of Rural Development and Agricultural Extension,
Mekdela Amba University, Tulu Awlya, Ethiopia*

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Abstract

Purpose – The purpose of this paper is to assess the adoption of climate-smart agriculture (CSA) and its implication on improving the farming household food security status, their resilience and livelihood risk management of farmers.

Design/methodology/approach – This systematic review has followed procedures to accomplish the review, including literature searches, screening studies, data extraction, synthesis and presentation of the data.

Findings – Based on the result of the review, the determinants of CSA adoption can be categorized into five categories, including demographic factors (age, sex, family size, dependency ratio, education), economic factors (land size, household income, livestock ownership), institutional factors (extension services, training access, credit services, farm input, market distance), environmental factors (agroecology, change in precipitation, slope of land) and social factors (cooperatives membership, farmers perception). The result also shows that applying CSA practices has an indispensable role on increasing productivity, food security, income, building resilient livelihoods, minimizing production risk and alleviating poverty. This concluded CSA practice has a multidimensional role in the livelihood of agrarian population like Ethiopia, yet its adoption was constrained by several factors.

Originality/value – This review mainly emphasizes on the most commonly practiced CSA strategies that are examined by different scholars.

Keywords Climate change, Climate-smart, Adoption, Food security, Resilience, Livelihood

Paper type General review

1. Introduction

The issue of climate change is one of the recent global problems that has been recognized as a major environmental risk of the 21st century. It is the major cause of food insecurity and poverty throughout Sub-Saharan African (SSA) countries. The rise of temperatures, cyclones, floods, droughts and sea level rise has had a critical impact on impeding food production and distribution (Alemu and Mengistu, 2019; Baptista *et al.*, 2022). Especially in 2022, 12% of the population was malnourished and unable to achieve their daily food



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requirements due to the impact of this problem. The events of climate change cause several peoples to die and have a long-term negative impact on early childhood development, educational success and economic capacity. The increased food insecurity has had a multidimensional threat to income, education and health outcomes across SSA (Serdeczny *et al.*, 2017; FAO, 2020; Alexandridis *et al.*, 2023).

Agriculture is the primary source of income for the majority of Ethiopia's population and an important part of the nation's economy. It generates 80% of Ethiopia's employment, produces 33.3% of the GDP and accounts for 75% of the country's exports of goods (Tesso, 2020; CGIAR, 2018). Smallholder farmers in Ethiopia cultivate more than 90% of the country's cropland and produce more than 97% of the nation's agricultural output using a traditional production system that is extremely vulnerable to natural disasters and climate change (Mekonnen *et al.*, 2020).

Climate change in Ethiopia has been making it even harder to supply the country's expanding population with the food they need (Solomon *et al.*, 2021). The sector is unable to feed more than 115 million people in Ethiopia because of the stagnant growth of agriculture as a result of the interactional effects of climate change (such as recurrent droughts, floods, heat waves and rainfall failure) social and institutional factors that lead to low production and productivity (Thomas *et al.*, 2019; Ogola, 2021).

More than 87% of the poor reside in rural areas, where they depend on rain-fed agriculture, which is highly vulnerable to a variety of climate-related hazards. Droughts, rising temperatures and floods are major threats to agricultural productivity, food systems and the livelihoods of farming households (MOA, 2018). For instance, between 2015 and 2016, the nation faced a drought that caused the worst famine in the nation's history and left over ten million people in need of immediate food aid assistance. Ethiopia also ranks 157th out of 181 nations in terms of its susceptibility to climate change and willingness to increase resilience, making it the 20th most vulnerable nation (Ogola, 2021; Omotoso *et al.*, 2023).

As a pressing concern for the nation, Ethiopia's government has been constructing resilience in response to climate change stressors. In reality, the government introduced the Climate Resilient and Green Economy Strategy (CRGE) in 2011 to address concerns about climate change (FDRE, 2011), and the National Adaptation Plan (NAP) in 2019 to incorporate climate change adaptation strategies with current development efforts (FDRE, 2019).

Without the execution of improved farm technology, such as climate-smart agriculture (CSA) practices and technologies that offset production losses, it is difficult for developing nations, such as Ethiopia, to achieve agricultural productivity, food security and resilient livelihoods. To address the food desires of the global population while preserving the environment and adapting to climate change, CSA has been advocated for farming practice (Wakweya, 2023; Quarshie *et al.*, 2023).

The adoption status and effects of CSA practices on farm productivity, food security and the resilience of farming households' livelihoods has been the subject of various research findings in Ethiopia. Previous research suggests that smallholder farmers adopted CSA techniques singly or in combination in different regions of the nation. To examine the factors influencing the adoption of CSA practices and their implications on household food security, livelihood resilience and risk minimization among smallholder farmers in Ethiopia, a systematic study was conducted.

2. Climate change and climate-smart agriculture practice in Ethiopia

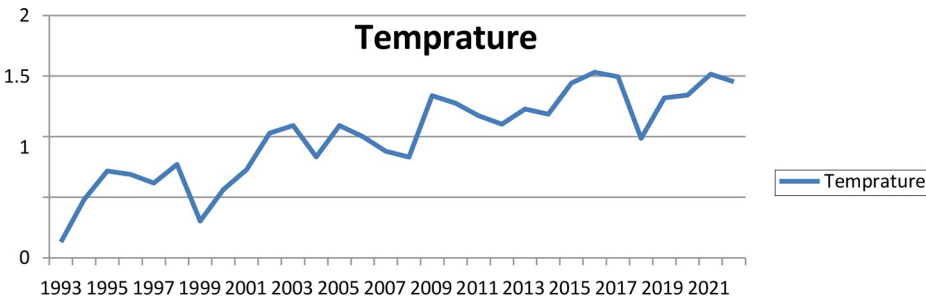
2.1 Trend of climate change and its impacts on agriculture and food security in Ethiopia

In Ethiopia, agriculture is the most vulnerable sector to the impacts of climate change, as it is dominated by rain-fed smallholder farmers, who produce 97% of the annual total gross agricultural output (Mekonnen *et al.*, 2020).

Since the 1980s, Ethiopia has been highly impacted by the erratic nature of rainfall as a result of climate change (raising average temperatures and droughts), thus leading to increased crop failures and reducing agricultural production by 21%, which led to a 9.7% fall in the GDP (DFID, 2012). Similarly, during the period 1991–2008, Ethiopia lost 13%–40% of its agricultural output due to climate change, making it more challenging to produce sufficient food for the growing population (Bekele *et al.*, 2020).

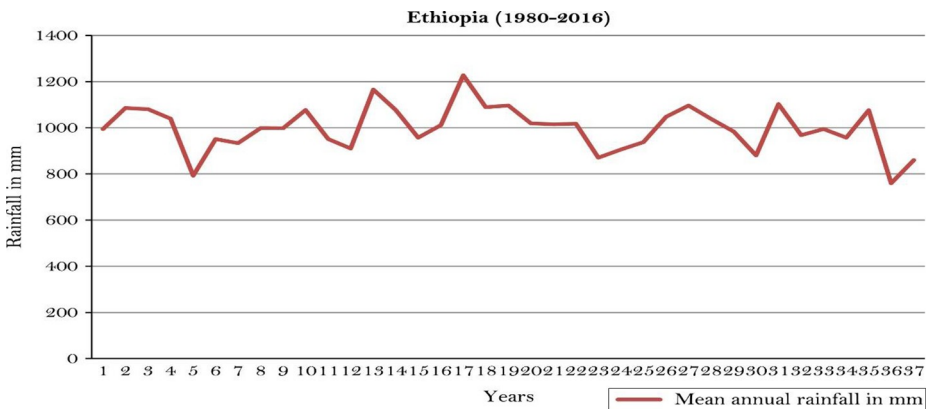
More recently, the country experienced a drought between 2015 and 2016, which resulted in the worst famine in the country’s history and left over ten million people in need of urgent food relief assistance (Ogola, 2021). Moreover, it is estimated that due to climate change impacts, Ethiopia will lose more than 6% of its agricultural output each year and also reduce 8%–10% of its GDP by mid-century (USAID, 2020). As shown in Figure 1, the trend of temperature change in Ethiopia from 1993 to 2021. Similarly, Figure 2 also revealed the mean annual rainfall pattern from 1980 to 2016.

As shown in Table 1, previous studies have found that erratic climatic circumstances coupled with a lack of essential resources negatively and significantly influence agricultural



Source: Abebe (2017)

Figure 1. Temperature change from 1993–2021, in Ethiopia



Source: Abebe (2017)

Figure 2. Mean annual rainfall of Ethiopia

Table 1. Impact of climate change in agriculture production in Ethiopia (impact model result)

Climate change	Impact of climate change on crop in percent (%)	Analysis model	Source
Water stress	35% decline in maize yield	Process-based crop model (DSSAT)	Yang <i>et al.</i> (2023)
	25.4%, 21.8% and 25.2% teff, maize and sorghum decline, respectively	Dynamic computable general equilibrium model	Solomon <i>et al.</i> (2021)
	28.3%, 30.9%, 28.5% and 34.6% of teff, wheat, barley and maize, declined, correspondingly	Pearson correlation coefficient. drought index	Adunya and Benti (2020)
Heat stress	6.9% of 2015 barley, 96% of 2017 sorghum yield declined	NDVI, Dev-NDVI and SPI index	Eze <i>et al.</i> (2022)
	79%, 81%, 79% and 0.83% for teff, maize, sorghum and barley, respectively	Hadley Centre Coupled Model v3	Evangelista <i>et al.</i> (2013)
	50% crop failure	Descriptive statistics	Singh (2019)
Other climate-related stress	20% maize yield will decrease in 2050	Centre Coupled Model Version3	Kassie (2014)
	(1981–2010) 14% cereal failed	sIMulator (APSIM) model	Araya <i>et al.</i> (2020)
	18.1%, 13.2%, of sorghum and wheat decline	Climate models (UQAM_CRCM5 and SMHI_RCA4)	Kassaye <i>et al.</i> (2021)
Other climate-related stress	1,228,352 in Orommia, 1,026,132 Somalia and 843,241 quintals of cereal crops decline in Tigray regions in 2020 production year	Critical review analysis	Demem (2023)
	36 to 40% reduction in wheat yield by 2050	Multi-model ensemble	Rettie <i>et al.</i> (2022)

Source: Own summary (2023)

crop production in Ethiopia. Previous literature indicates a long-run relationship between cereal crop production and climate change variables in Ethiopia (Gemetchu *et al.*, 2016; Asfew and Bedemo, 2022).

Table 2 reveals the impact of climate change on four dimensions of food security (food availability, food accessibility, food utilization and food stability). Ensuring the food security status of the household necessitates focus on reducing climate shocks and enhancing families' access to fundamental infrastructural services and amenities (Mekonnen, 2022; Ayinu *et al.*, 2022).

2.2 Climate-smart agriculture in Ethiopia

Table 3 shows that in Ethiopia, the major CSA practices that were implemented by smallholder farmers include mulching, intercropping, conservation agriculture, crop rotation, integrated crop and livestock management, agroforestry, improved grazing and improved water management. Moreover, CSA also comprises innovative practices such as improved weather forecasting, early warning systems and climate risk insurance (FAO, 2016).

3. Review methodology

An article review is undertaken by conducting document analysis through an in-depth review of related literature from a different source (Albore, 2018). In this article review, a systematic

Table 2. Potential impacts of climate change on food security dimensions

Climate-induced hazards	Impact on food security outcomes			
	Food availability	Food accessibility	Food utilization	Food stability
Increase in temperatures	Reduced crops and livestock products and effect on local markets	Impacts incomes, prices affordability and changes in preference	Dehydration and illness from eating spoiled food	Higher cost for storing grain and perishable products
Incidences of drought	Declines in production, wild foods, decrease in food exports/increase imports and increased need for food aid	Increase in food prices, decline income and preferred foods not available or too costly	Dietary adjustments and inability of body to process food due to diseases	Greater instability of food supply, prices and based incomes
Changes in precipitation (timing, location and amount)	Some local losses virtually certain, but distribution is unknown	Full-cost pricing for water may cause food prices to rise		Greater instability of food supply
Incidence high wind, storm and floods	Decrease surplus production and increase emergency food distribution	Increase in food prices and possible loss of farm income and non-farm employment	Food safety is decline and inability of body to process food due to diseases	

Source: Authors' own summary (2016)

method was used, starting with the process of searching using online databases. The data were collected from previously published materials, like books, research articles, reports from national and international organizations, policy briefs and other indexed scholarly materials, that are related to the topic of this review's research. The search was carried out from June 2022 until May 2023.

3.1 Literature search technique

The literature search was conducted systematically using Google Scholar, Science Direct and AGORA sources. The search criteria included the literature published in reputable journals starting from 2015 up to the current year 2023. The search of the literature's study area is limited to Ethiopia or studies that comprise Ethiopia. The studies were identified using keywords such as the adoption of CSA practices, food security, resilience and livelihood risk management, the impact of climate change, the effect of SCA practices and Ethiopia.

3.2 Screening the literature (inclusion and exclusion criteria)

As shown in [Table 4](#), the literature inclusion and exclusion criteria were established by considering different criteria that assure the relevance of literature to achieve the review objectives.

3.2.1 PRISMA flow diagram. [Figure 3](#) displays the overall literature selection process of this systematic review by using PRISMA flow diagram. In the first stage, a total of 1,243 online materials were identified through databases using various keywords and titles. Then after, in the second stage, 486 duplicates were deleted, remains a total of 757 papers. In the

Table 3. Summary of some common CSA practices in Ethiopia

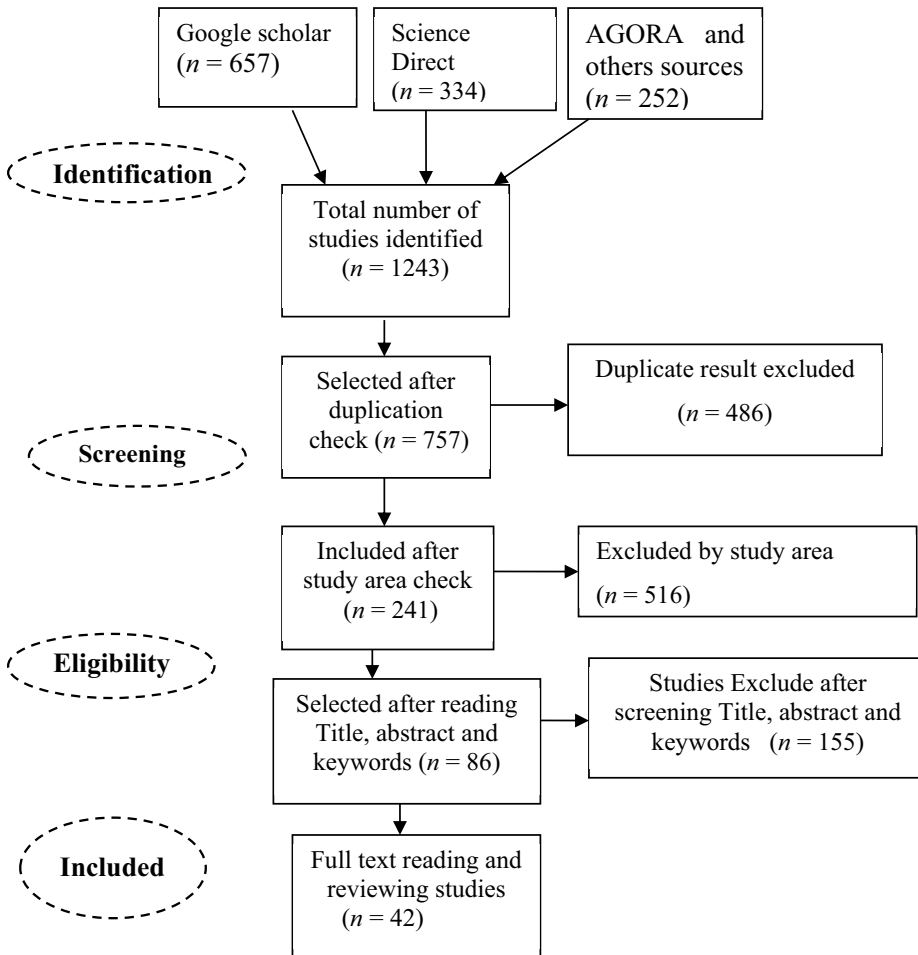
CSA practice	Components	Why it is climate smart
Integrated soil fertility management	<ul style="list-style-type: none"> • Reduced tillage • Cropresidue management and mulching • Crop rotation/ intercropping with cereals and legumes 	<ul style="list-style-type: none"> • Carbon sequestration • Reduce existing emission • Resilience to dry and hot spells
Small-scale irrigation	<ul style="list-style-type: none"> • Compost and manure management, including green manure • Efficient fertilizer application techniques (time, method, amount) 	<ul style="list-style-type: none"> • Reduce emission of nitrous oxide and CH₄ • Improved soil productivity
Agroforestry	<ul style="list-style-type: none"> • Tree-based conservation agriculture • Practiced both traditionally and as improved practice • Farmer managed natural regeneration 	<ul style="list-style-type: none"> • Trees store large quantities of CO₂ • Can support resilience and improved productivity of agriculture
Crop diversification	<ul style="list-style-type: none"> • Popularization of new crops and crop varieties • Pest resistance, high yielding, drought tolerant, short season 	<ul style="list-style-type: none"> • Ensuring food security • Resilience to weather variability • Alternative livelihoods and improved incomes
Improved livestock feed and feeding practices	<ul style="list-style-type: none"> • Reduced open grazing/zero grazing • Forage development and rangeland management • Feed improvement • Livestock breed improvement 	<ul style="list-style-type: none"> • Improved livestock productivity • GHG reduction • CH₄ reduction
Others	<ul style="list-style-type: none"> • Water conservation and harvesting • Early-warning and weather information • Support to alternative energy sources • Crop and livestock insurance • Livelihoods diversification • Post-harvest technologies 	<ul style="list-style-type: none"> • Resilience of agriculture • Improved incomes • Reduced emissions • Reduced deforestation • Reduced climate risk

Source: [FAO \(2016\)](#)

Table 4. Criteria for literatures inclusion and exclusion in the review

Criteria	Included	Excluded	Justification for criteria
Publication date	2015 to 2023	Papers before 2015	To examine the recent CSA adoption status and their implication
Country or papers study area	Studies conducted in Ethiopia or comprise Ethiopia	Non-Ethiopian papers	To maintain the scope of the review
Publication language	Papers in English language	Papers not written in English language	Easily readability of the papers
Publication theme	CSA adoption, its implication in food security, resilience, livelihood risk management, climate change impact	Papers outside climate change, CSA practices and their implication	To keep the main aim of the systematic review
Papers availability	Fully available papers	Incomplete papers	Some papers requiring purchasing or not open access

Source: Authors' own summary (2023)



Source: Created by Author (2023)

Figure 3. Graphic presentation of the literature screening

third stage, 241 materials were selected, while 516 materials were excluded because of studies were outside Ethiopia. In the fourth stage, 86 materials were included after reading the title, abstract and keywords, while 155 materials were excluded. Finally, 42 materials were selected for full reading.

3.3 Data extraction

After a detailed reading of the selected studies, the data was extracted for each study into a matrix, which was divided into different sections. The sections were: authors and year of publication; title; study area (location) objectives; analysis; findings; and conclusion about CSA practices.

4. Results and discussions

4.1 *Determinants of smallholder farmers' adoption of climate-smart agriculture practice in Ethiopia*

Most CSA practices and technologies have low to medium farm adoption rates in various parts of Ethiopia. The key determining factors of adoption have been generalized into five categories, including institutional factors, economic factors, demographic factors, environmental factors and social and human capital factors (Table 5).

4.1.1 *Factors influencing the adoption of integrated soil fertility management (ISFM).* Soil fertility management has received the emphasis of the Ministry of Agriculture in Ethiopia to increase agricultural productivity and overcome the challenges of food insecurity, but its application at the smallholder level was hampered by different factors. The study by Tekeste (2021) examined the factors that influence farmers' adoption of CSA practices and found that farmers' income (on-farm and non-farm income) significantly influenced the adoption of integrated soil fertility management (ISFM) as a component of CSA. This result is due to the fact that farmers' income level had a significant influence on their adoption of farm technologies.

Likewise, the study by Kifle *et al.* (2022) assured that the adoption of ISFM was positively and significantly influenced by household income. This implies that households with a higher annual income had more likely opportunity to adopt new farm technologies. This could be obvious because farmers who have better incomes can purchase different agricultural inputs.

Studies by Jafer and Aman (2014), Yibekal *et al.* (2018) and Ahmed (2019) have also found that farmers' access to resources like, farmland, the availability of family labor and access to weather information has made great contribution to farmers' adoption of ISFM. These studies commonly found that lack of resources was the foremost barrier for farmers to adopt the CSA components. Moreover, the adoption of soil fertility management was also influenced by inadequate agricultural extension services, an open grazing system, a lack of credit and scarce agricultural input facilities (FAO, 2016).

The other study also analyzed the adoption of multiple ISFM technologies, and the result noted that several factors, including land ownership, input market distance, farmers' access to credit and agro-ecological zones, strongly affected the adoption of the various ISFM technologies (Guteta and Abegaz, 2015; Kwadzo and Quayson, 2021).

4.1.2 *Factors influencing the adoption of small-scale irrigation (SSI).* Studies conducted by Leta *et al.* (2018), Natnael (2020) and Solomon (2020) found that farmers' decision to use small-scale irrigation (SSI) was significantly influenced by their access to extension services and the availability of irrigation-related training. Enhancing farmers' extension contact and training access was a critical option to help the farmers' adoption of irrigation agriculture.

Landholding size, access to credit services, extension services, market distance, household head's age, proximity to the nearest farm site, livestock ownership, farming experience, access to irrigation and good health have a significant effect on farmers' decisions to adopt SSI as CSA practice (Abegunde *et al.*, 2019; Bedeke *et al.*, 2019; Bojago and Abrham, 2023).

Petros and Yishak (2017) and Natnael (2020) also analyzed farmers' decisions to use SSI was significantly influenced by environmental factors such as the terrain of their farmland and its proximity to a water source. These studies assure that farmers were more likely to use SSI if their land has a suitable topography, and they are also more likely to do so if their field is close to a water supply.

Farmers' educational status and income level have a positive and significant effect on farmers' adoption of irrigation farming. In contrast, age of the farmers and the dependency

Table 5. Summary of the systematic review for determinate of CSA adoption and its implications

Authors name and year	Title and study area	Result of the studies		
		CSA practice	Determinants of CSA adoption	Implication on food security, resiliency and risk management
Tekeste (2021)	Climate-smart agricultural practices and its implications to food security in Siyadebrina Wayu District, Ethiopia	Conservation, agriculture, ISFM, irrigation, improved feed	Household size, farming system, income, irrigated farm, distance to market, farm size and access to credit	Found CSA have the potential to alleviate food insecurity among small-scale farmers
Tsige et al. (2020)	Gendered constraints for adopting climate-smart agriculture amongst smallholder Ethiopian women farmers	Comprehensive CSA study	Access to credit, extension services, membership in cooperatives, land, training and information	Not addressed
Belay et al. (2023)	Determinants of climate-smart agricultural practices in smallholder plots: in Wadla district, northeast Ethiopia	Improved crop varieties, intercropping, improved livestock breeds and rainwater harvesting	Sex, education, livestock holding, access to credit, farm distance, market distance and training	Not addressed
Sertse et al. (2021)	Farm households' perceptions and adaptation strategies to climate change risks from Raya Azebo district, Ethiopia	Crop diversification, mulching, SWC, and improved seed	Household head's age, literacy level, utilization of credit service, extension services	Improving CSA practice adoption had significant effect livelihood resilience
Ali et al. (2022)	Impact of climate-smart agriculture adoption on food security, poverty of rural farm households in Rift Valley Ethiopia	Conservation, soil fertility management, crop diversification, irrigation	Monthly income, access to extension, access to credit and dependency ratio	Improve food security and reducing risk of crop failure
Beyene (2018)	Adoption of Climate-Smart Agricultural Practices: Determinants and Challenges in Gerar Jarso Woreda of Oromia Regional State, Ethiopia	Agroforestry, compost adoption, mulching	Sex, education, income, livestock, knowledge, extension services organizations membership	Not addressed
Tesfaye et al. (2019)	Climate-smart Innovations and rural poverty: exploring impacts and pathways in Ethiopia	Minimum tillage, cereal-legume intercropping	Not addressed	CSA practices reduce the depth of poverty via risk mitigation role
Fentie and Beyene (2019)	Climate-smart agricultural practices and welfare of rural smallholders in Ethiopia: Does planting method matter?	Row planting technology	Not addressed	Positive and significant impact on per capita consumption and on crop income per hectare

(continued)

Table 5. Continued

Authors name and year	Title and study area	CSA practice	Result of the studies	
			Determinants of CSA adoption	Implication on food security, resiliency and risk management
Negeera et al. (2022)	Determinants of adoption of climate smart agricultural practices among farmers in Bale-Eco region, Ethiopia	Multiple CSA practices	Age, education, land size, household asset value, extension contacts, awareness to climate change and farmer experience with climatic shocks	Not addressed
Diro et al. (2022)	Determinants of adoption of climate-smart agricultural technologies and practices in the coffee-based farming system of Ethiopia	Applied minimum tillage (36%), intercropping (45%), improved forage (19%), SWM (47%)	Participation on field days, education, extension, ownership of communication devices (radio)	Improving livelihoods, economic growth and sustainable development in the region of Ethiopia
Sisay et al. (2023)	Climate-Smart Agriculture Technologies and Determinants of Farmers' Adoption Decisions in the Great Rift Valley of Ethiopia	Crop diversification, agroforestry, integrated soil fertility management	Age, sex, education, farmland size, livestock ownership, income, access to credit, access to climate information, training and extension contact	Not addressed
Adamseged and Kebede (2023)	Are farmers' climate change adaptation strategies understated? Evidence from two communities in Northern Ethiopian Highlands	Short maturing crop and irrigation, soil conservation	Sex, age, household size, membership of associations	Not addressed
Amare and Simane (2017)	Determinants of smallholder farmers' decision to adopt adaptation options to climate change and variability in the Muger Sub basin of the Upper Blue Nile basin of Ethiopia	Small-scale irrigation, agronomic practices, livelihood diversification, SWC measures	Credit access, social capital, educational status, farmland size, gender, livestock, distance to marketplace and exposure to early warning	Not addressed
Belay et al. (2023)	Does climate-smart agriculture improve household income and food security? Evidence in Ethiopia	Multiple CSA practices	Extension services, climate services and subsidies	Positive effect on farm income and food security

(continued)

Table 5. Continued

Authors name and year	Title and study area	CSA practice	Determinants of CSA adoption	Result of the studies	Implication on food security, resiliency and risk management
Tesfaye and Nayak (2023)	Climate Change Adaptation Measures by Farm Households in Gedee Zone, Ethiopia: An Application of Multivariate Analysis Approach	Agro-forestry, irrigation, soil conservation, adjusting planting and crop diversification	Gender, age, family size, farming experience, income land size; agro-ecology, soil fertility, land slope, market distance, extension contact	Not addressed	Not addressed
Mekonnen (2022)	The Climate Change-Agriculture Nexus in Drylands of Ethiopia	Conservation agriculture, grazing land management, crop rotation, crop residue	Not addressed	Maintain agricultural productivity, reduces GHGs emission, minimize impact of climate change	Positive effect on welfare improvement of farmers
Moges and Ayen (2023)	The effects of climate change adaptation strategies on the welfare of rural farm households in Ethiopia	Combination of crop rotation and improved seed	Temperature and rainfall pattern	Not addressed	Helps to build a resilient agricultural system and improve the well-being of farm households
Asmare et al. (2018)	The effect of climate change adaptation strategy on farm households' welfare in the Nile basin of Ethiopia	Crop diversification	Not addressed		

Source: Own summary (2023)

ratio have a negative and significant effect on farmers' adoption to SSI. This is because aged farmers are less likely to accept new practices. After all, they are conservative to change. In contrast, younger farmers are more likely to have formal education or training in agriculture and have a tendency to be risk-takers. They are more willing to adopt CSA practices as a result (Mango *et al.*, 2018; Eliyas, 2019).

4.1.3 Factors influencing the adoption of crop diversification and agroforestry practices. Farmers' access to extension services, education level, livestock ownership, membership status, market information, soil fertility, training access, climate change information, perceptions of farmers on land degradation and climate change perception have a positive and significant effect on farmers adoption, whereas slopes of farmland, road distance and gender of the household head have a negative and significant effect on farmers decision to apply crop diversification (CD) and agroforestry practice (Ahmed *et al.*, 2023).

The adoption of CD is positively and significantly determined by farmers' age, household income and financing, farmers' knowledge of climate change and level of training, while, adoption of agroforestry practice was significantly and positively influenced by the sex of farmers, livestock ownership and training access (Sisay *et al.*, 2023). In contrast with this study, the adoption of improved agronomy, drought-tolerant high-yielding crop varieties and integrated pest management was significantly and negatively affected by the age of the household head (Belay *et al.*, 2023a and Ayenew *et al.*, 2020).

Similarly, Kifle *et al.* (2022) revealed that family size, farming system, on-farm income, access to extension service, distance to market and access to weather information had a significant influence on the adoption of agro-forestry practices, while the result also shows that CD was significantly influenced by access to credit services.

Kom *et al.* (2020) also point out that farm land size has statistically and positively affected the probability of adoption of CSA technologies among smallholder farmers. The study implies that, farmers with vast farmlands adopted more CSA technologies than farmers with smaller farmlands. This is because land is a vital resource in agricultural output and farmer households that have access to land and other resources will be able to easily adopt new farming practices.

The finding by Kassa and Abdi (2022) shows that the adoption of CSA by farmers was statistically influenced by factors like education, household income, how seriously they took climate change and the amount of their acreage. The level of CSA adoption, however, was negatively and significantly affected by the distance between the farm and the farmhouse.

As shown in Table 5, most of the previous literature addresses the role of CSA practices and their adoption determinants in a single study. Most literature works consider multiple CSA practices, whereas only a pieces of literature focus on a single practice. Comprehensive CSA literature had a better scope by covering multiple climate-smart practices and being used for generalization of the results in specific areas. In addition, based on the results, the researchers indicate that the choice and application of CSA practices can vary from one place to another because of their appropriateness to the environmental and socioeconomic setup of the communities. The factors determining the adoption of CSA practices also varied between climate-smart practices and the location where they are implemented. Entirely, the synthesized result indicates that the previous authors acknowledged the significant role of different climate-smart practices in responding to the impact of climate change.

4.2 Role of climate-smart agriculture on household food security status

CSA has a multidimensional role in improving food security, reducing greenhouse gas (GHG) emissions and achieving sustainable agriculture in the face of climate change. Likewise, in the Amhara and Oromia regions of Ethiopia, the adoption of CSA has substantially correlated

with improved household income, a reduction in pre-harvest food insecurity and higher rates of primary school enrollment for children (Horner and Wollni, 2021).

A study by Ahmed *et al.* (2023) on “Impacts and adaptation extents of climate smart agricultural practices among smallholder farmers of Ethiopia” found that adoption of CSA practices had a positive impact on the food and nutritional security status of rural families. This study implies that adopter households had better dietary intake than non-adopter households.

According to Belay *et al.* (2023b), smallholder farmers who adopted CSA strategies improved their food security and earned much more farm revenue than non-adopters. Likewise, the study conducted on “Climate-smart agriculture and gender-differentiated nutrition outcomes” found a clear link between increased adoption of CSA practices and household food security. As a result, adopters of CSA practices had better per capita nutrition consumption and dietary diversification (Teklewold *et al.*, 2019).

The other study by Ali *et al.* (2022) revealed that the adoption of CSA practices had a positive and significant impact on households’ food consumption and dietary diversity while simultaneously lowering households’ multidimensional poverty. The study also demonstrated how CSA might increase food security by improving crop output and decreasing crop failure by lowering the effects of climate change.

The study conducted on “climate-smart innovations and rural poverty in Ethiopia” found that adoption of CSA packages can improve multidimensional poverty by responding to the impact of climate change on agriculture production. In other words, scaling up the adoption of CSA practices can reduce the multidimensional face of poverty among stallholder farmers (Tesfaye *et al.*, 2019).

4.3 Role of climate-smart agriculture on the livelihood resilience and risk management of smallholder farmers

Climate smart agriculture has been used in conjunction with integrated resource management to increase production, build resilience, and lower agricultural GHG emissions. Application of organic fertilizers, drought-resistant crop varieties, integrated pest management and improved livestock feeding were some of the CSA packages that were applied by the farmers to cope with changing climatic conditions (Eshete *et al.*, 2020; Asrat and Simane, 2017).

The study in the northern region of Ethiopia revealed that CSA practices have the potential to boost the well-being and resilience of farming communities. The study examines the long-term effects of the row planting technology and implies that the application of row planting with various combinations of CSA packages has a significant effect on the livelihood resilience of smallholder farmers (Fentie and Beyene, 2019).

Similarly, Bojago and Abrham (2023) reported that SSI has a decisive role in raise production and productivity by reducing the impact of unpredictable rainfall. Based on the result of the study, those who used SSI as CSA were able to make more money than those who did not. This implies that irrigation farming is a promising option to respond to the impact of climate change on agriculture production and household food security.

Adoption of CSA packages has various effects on households’ ability to cope with the impact of climate change. The adoption of CSA practices significantly improved food and feed production, reduced GHG emissions and improved economic performance by enhancing households’ resilience. Hence, scaling up CSA innovations may increase their positive effects on increasing the ability of household to cope with climate change related risks (Teklu *et al.*, 2023).

The study by Acevedo *et al.* (2020) indicates that farmers adoption of CSA packages directly increases agricultural productivity, thereby enhancing crop yields and reducing vulnerability to climate change. Likewise, a study conducted by Yitbarek and Tesfaye (2022)

points out that the implementation of CSA considerably improves the welfare and risk management capabilities of rural households in a nation like Ethiopia, where markets are incomplete and institutions are inadequate.

Overall, the adoption of CSA has a crucial role in SSA countries to increase agricultural output, adapt to climate change, develop resilience and reduce GHG emissions. Hence, politicians in Africa must commit to supporting CSA and enacting legislation to boost agricultural growth, end hunger and protect the environment. They also need to provide chances for cooperation to scale up CSA practices at the local, national, regional and continental levels (Nyasimi *et al.*, 2014).

5. Conclusion and recommendation

Climate change remains a major threat for farm households; particularly, low-income nations like Ethiopia are affected by the global phenomenon of climate change, which is already having a detrimental influence on agricultural productivity globally. To mitigate the effects of climate change and adapt agriculture to it, a new paradigm known as “climate-smart agriculture” is emerging. Currently, CSA is seen as a successful tool to enhance resilience, improve food security and reduce emissions. Thus, this systematic review is intended to identify the factors that affect the adoption of CSA practices, their effects on household food security, livelihood resilience and risk management among farming households. The review’s findings showed that ISFM, SSI, agronomic practice and conservation agriculture (CD, crop rotation, high yield improved seed, crop residue incorporation, integrated pest management, drought tolerant seed) and agroforestry practices (interplantation) were the main CSA practices that were primarily adopted in different parts of Ethiopia.

Based on the results of this systematic review, the factors that influence the adoption of CSA practices can be categorized into five main categories. These include demographic factors, institutional factors, economic factors, environmental factors and social and human capital factors. The first factor is demographic factors (such as household head’s age, sex, family size, dependency ratio and educational status). Among these factors, household head age, sex and dependence ratio negatively and significantly influenced farmers’ adoption of the CSA practices, whereas family size and educational attainment had a positive impact on CSA adoption. Beside this, institutional factors, including access to extension contacts, training access, credit availability, market distance, access to climatic information and distance to input supply, were the significant determinants of CSA adoption by farmers. The review shows that access to extension contacts, training, credit and climatic information were the significant and positive determinants of adoption of CSA practices, but distance to markets and the supply of inputs was a negative determinant. In addition, economic factors such as farm land size, livestock ownership, on farm income, off-farm income, asset ownership was positive and significant determinant of CSA adoption by farmers. Environmental factors, such as farm distance, land sloppiness, farm land fertility, exposure to early warning systems and temperature and rainfall patterns, were the other key factor that significantly influencing the adoption of CSA practice. The adoption of CSA was also significantly influenced by the social and human capital, factors including cooperative membership, awareness of climate change, farmers’ perception, pair influence and experience with climatic shock.

This systematic review also revealed that the adoption of CSA has an indispensable role in improving household food security status, livelihood resilience, household risk management and poverty reduction. According to the results of a comprehensive evaluation of numerous studies, CSA adopter households on average had better food security status and experienced less food insecurity than non-adopter households. The results also showed that,

compared to non-adopters, the livelihoods of CSA adopter households were more resilient toward climatic shock by lowering the multidimensional impact of climate change on agriculture production.

According to the result of this review, we can infer that it is necessary to expand the adoption of CSA practices to promote the benefits of CSA in strengthening resilience and decreasing vulnerability, especially in low-income countries like Ethiopia. To do this, considering factors that affect farmers' adoption of CSA practices is the primary duty. Therefore, various interested stakeholders should enable and encourage hastening the wider implementation of CSA practice throughout the nation by improving the impediment factors.

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About the authors

Getasew Daru Tariku is a full-time Lecturer in the Department of Rural Development and Agricultural Extension at Mekdela Amba University, Ethiopia. He has an MSc in rural livelihood and food security from University of Gondar, Ethiopia. His research areas of interest are food security, climate change, rural livelihood, gender, rural development, agricultural technologies and extension. Getasew Daru Tariku is the corresponding author and can be contacted at: getasewdaru19@gmail.com

Sinkie Alemu Kebede is a full-time Lecturer in the Department of Rural Development and Agricultural Extension at Mekdela Amba University, Ethiopia. She has an MSc in rural development from Mekelle University, Ethiopia. Her research areas of interest are rural development, climate change, agriculture extension, gender, agricultural technologies adoption and agricultural economics.