

Climate-Smart Agriculture and Poverty Among Rural Households in Developing Countries: A Review

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ABSTRACT

Climate change is a major global challenge, and climate-smart agriculture (CSA) offers a solution by aiming to reduce emissions while increasing production and resilience. With most of the world's poor living in rural areas and depending on agriculture, the sector is closely tied to poverty. This raises a critical question: in developing nations, especially in Africa, is agriculture a cause or an effect of poverty traps? Climate extremes worsen agricultural outcomes and deepen rural poverty, but CSA has the potential to improve food security and lift incomes. This systematic review examines how rural households in developing countries are affected by climate change, their adoption of CSA practices, and the measurable impacts of CSA on food security and poverty reduction. Hence, this review paper demonstrates that climate-smart agriculture can directly impact output levels, food security, earnings, and general socioeconomic well-being, thereby reducing poverty.

Keywords: Climate-smart agriculture, poverty, rural households, Food security, developing countries

INTRODUCTION

Climate change, food and nutrition insecurity have become two of the greatest development challenges of our time. Yet a more sustainable food system can not only heal the planet but also ensure food security for all citizens (Food and Agriculture Organization [FAO], 2017). The concept of 'climate-smart agriculture' (CSA) expresses a desire to better integrate agricultural development and climate responsiveness in light of a changing environment and rising food demand; it seeks to meet both food security and more general development goals. production, adaptation, and mitigation are pillars of CSA efforts that sustainably raise production, improve resilience, and reduce or eliminate greenhouse gases (GHGs). This requires planning to handle tradeoffs and synergies between these three pillars (FAO, 2010).

Currently, the global agricultural food system alone emits at least one-third of all total emissions from greenhouse gases. The total global food demand is estimated to increase to feed a projected global population of 9.7 billion people by 2050, which is around the corner (United Nations [UN], 2019). The increase in food production has been linked to rural agricultural expansion, and unsustainable use of locally available land and also available resource inputs. This creates a vicious circle, leading to an increase in total emissions of carbon gases to our environment (Akaniyene & Dimitrios, 2023). Moreover, agriculture remains the most vital to the economy of most developing African countries. Its development has a significant role in food security and drastic abject poverty reduction in this sub-region. The increase in agricultural production over the past few decades has mainly been due to land area expansion in the rural household farmers' domain, with very little change in production techniques and limited improvement in their total yields per total output. At present, one in four people remains malnourished in most of the African developing countries (Timothy, Marloes, Olufuke, James, Rebert, George & Bruce, 2015).

Rural poverty remains the most prevalent in most of the African developing countries, despite continued efforts to improve farmers' living standards or their welfare (Barrett, Christiansen, Sheahan & Shimeles, 2017; Hansen, Hellin, Rosenstock, Fisher & Campbell, 2019). Rural household farmers in particular make up a significant proportion of the population that is caught up in a web of abject poverty yearly, mainly because of low turnout

in agricultural productivity. Currently, about 48% of Africa's population, or approximately 450 million people, live in extreme poverty, on less than US\$1.25 per day, with 63% of the continent's poor living in rural areas depending on agriculture for their livelihoods (World Bank, 2015). At the same time, the continent is experiencing a rapid increase in population and urbanization. Half of the 2.4 billion increase in global population that will occur between 2013 and 2050 will occur in sub-Saharan Africa (SSA), and 56% of Africa's population is projected to live in urban areas by 2025 (United Nations Department of Economic and Social Affairs [UNDESA], 2013 & 2014).

The agricultural sector in most of the developing African countries continues to be less productive due to farmers' reliance on poor and unsustainable farming practices that lead to land degradation and poor soil fertility, aside from the insecurity faced by the rural farmers themselves, most of them cannot go to the farm freely again for any tangible production because, of the fear of herder farmers clashes, bandits, kidnappers kidnapping them on daily basis (Grabowski, Kerr, Hahhblade & Kabwe, 2016). Climate change appears to be a major source of risk for agricultural production in most of the African developing countries or SSA (Intergovernmental Panel on Climate Change [IPCC], 2014; Jayne, Sitko, Mason & Skole, 2018). In most cases, agricultural household farmers pay the heaviest price or bear the brunt since their livelihood is dependent on rain-fed agriculture and they operate in environments characterized by weak institutions, political instability, and poor agricultural policies and programs (Kassie, Teklewold, Marennya, Jaleta & Erenstein, 2015; Hansen et al., 2019).

Climate-induced risks also bring about a great threat to agricultural productivity by making worse production risks and altering agricultural households' farmer's incentives to innovate and invest in remunerative activities of rural household farmers (Emerick, Dejanvry, Sadoulet & Dar, 2016). Low and completely erratic continuous rainfall yearly also leads to soil moisture stress, which is another important constraint to agricultural production in most arid and semi-arid regions of developing countries in Africa (Thierfelder, Chivenge, Mupangqa, Rosenstock, Lamanna & Eyre, 2017). Farmers facing climate variability and extreme weather, which can lead to soils with low moisture content, which could also lead to low crop yields per total output and crop failure at any point in time that, would promote or introduce rural abject poverty (Dzanku, Jirstrom & Marstorp, 2015; Asfaw, McCarthy, Lipper, Arslan & Cattaneo, 2016b). Due to these increasing challenges of climate change, shrinking agricultural frontiers and declining soil fertility feeding an already surging population (that is expected to double to 2 billion by 2050) and alleviating rural poverty are the main challenges in the current agricultural development policies and programmes (Grabowski et al., 2016).

The accurate solution to address these intertwined challenges requires a new paradigm for transforming African agriculture. Since the farming systems in most developing countries are capital-deficient, soil degradation, prone to weather extremes and have poor quality soils, political instability, inconsistencies in policies and programmes formulation (Kassie et al., 2015), the development and promotion of technologies and practices that could help to improve soil quality and increase crop yields per unit effort or inputs have no parallels correlation in the process of African agricultural transformation in their developing countries (Dzanku et al., 2015).

Sustainable intensification is uniquely positioned as a way forward for African developing countries' agricultural transformation (Godfray & Garnett, 2014). One of the options for promoting sustainable agricultural production is the utilization of 'climate-smart' agricultural technologies and practices that could support agricultural production and enhance adaptive capacity by cushioning the effects of climate change in the sub-region (Lipper, Thornton, Campbell, Baedeker, Bwalya, Caron, Garrity & Tibu, 2014; Asfaw et al., 2016b). As such, climate-smart agricultural practices are receiving greater attention in agricultural development policy-making these days to harmonize economic and environmental predicaments (Kpadonou, Owiyo, Barbier, Denton, Rutabingwa & Kiema, 2017; Jayne et al., 2018). Conservation agriculture is also well known as, an example of a group of climate-smart agricultural practices that promote sustainable production and can improve households' resilience to weather shocks or unforeseen circumstances (Pittelkow Liang, Linquist, Vangrienigen, Lee, Lundy, Vnagestel, Six and Vankessel, 2015).

To create more efficient, effective and equitable food systems that address issues in the environmental, social and economic dimensions across productive natural environments, different countries' and stakeholders' interests are taken into consideration. Many of the strategies that make up CSA already exist globally and are utilized by farmers to manage a variety of production risks even though the concept is new and continually evolving (FAO,2013).

The Food and Agriculture Organization defined climate-smart agriculture as “that sustainably increases productivity, resilience (adaptation), reduces/removes GHGs (mitigation), and enhances achievement of national food security and development goals” (FAO, 2010). CSA has three main objectives/pillars in which site-specific efforts should be applied:

1. higher agricultural productivity and income in a sustainable way;
2. higher (adapted and built) resilience to climate change;
3. efforts towards GHG reduction.

The successful implementation of these objectives accomplishes the so-called “triple win” when the implementation of different innovative practices results in higher yields, climate change mitigation, as well as lower GHG emissions (FAO, 2013). In 2021, Siedenburb, Martin and McGuire in their work, concluded that CSA practices seem to be able to provide a solid win-win outcome in developing countries.

Due to rapidly developing technology, there are many new CSA items on the verge of commercialization related to the Internet of Things, Conventional agriculture, and Precision agriculture among others. Climate change directly impacts the whole agricultural sector, which can be either positive (e.g., agricultural production zones expand) or negative (e.g., more frequent natural disasters such as heat stress). The developing countries are particularly affected due to the higher share of agriculture in their national gross domestic product. In addition, they are typically more vulnerable to such changes compared to developed countries (Long, Block & Coninx, 2016).

METHODOLOGY

This review was informed by a structured literature search rather than an unsystematic reading of the field. Because full access to subscription databases such as Scopus, Web of Science, CAB Abstracts, and AGRICOLA was not available at the time this search was carried out, the search reported here was conducted over Google-indexed sources journal pages, PMC, and institutional repositories by a single reviewer in one session on 14 September 2026. This is disclosed here as a limitation rather than presented as a full multi-database systematic review; it should be read as a documented, traceable scoping search that establishes the current evidence base and identifies gaps, with the extensions needed for full PRISMA rigor set out at the end of this section.

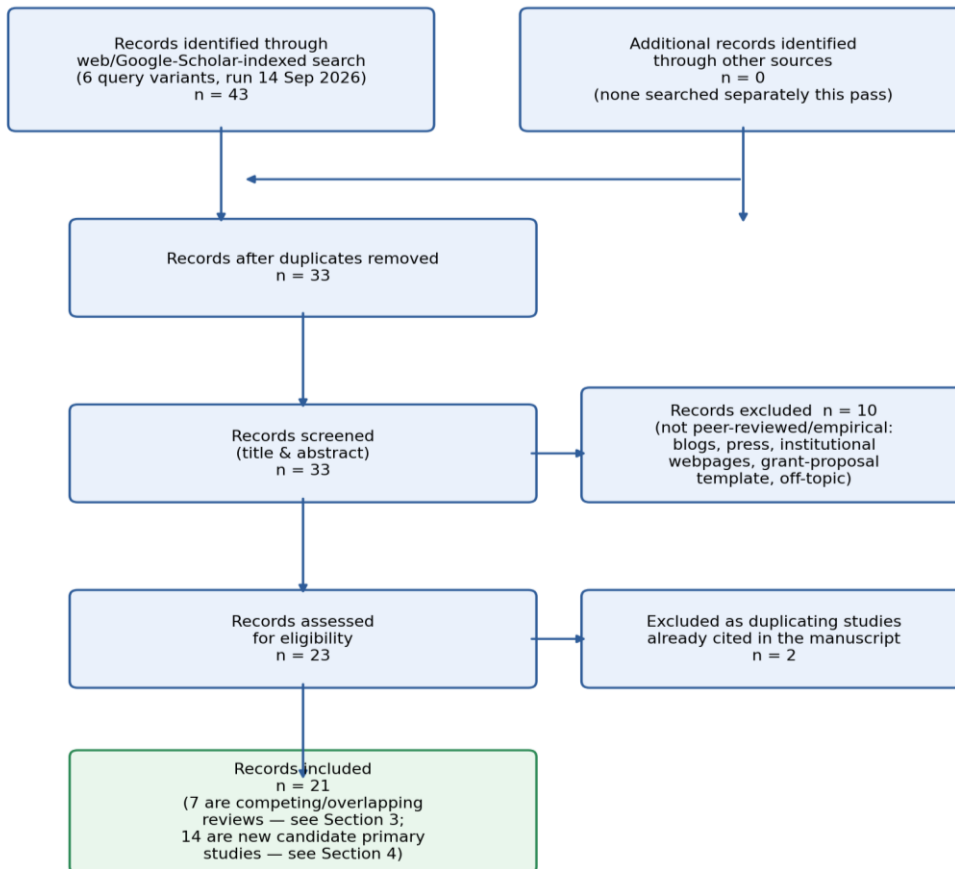
Search strategy. Six query variants were run in place of a single combined Boolean string, since the search tool used did not reliably support complex Boolean operators: “climate-smart agriculture poverty rural households review”; “climate-smart agriculture food security developing countries systematic review”; “climate-smart agriculture adoption smallholder farmers income impact Asia”; “climate-smart agriculture poverty Latin America rural households”; “climate-smart agriculture adoption poverty meta-analysis Africa”; and “climate-smart agriculture poverty Nigeria rural households.” The search covered the period 2010–2025, reflecting the formalization of the CSA concept by the FAO around 2010 and the range of this manuscript’s own reference list, and was restricted to English-language records. The six queries returned 43 raw results, which were reduced to 33 after duplicates were removed.

Eligibility criteria. Records were included if they were empirical studies, systematic reviews, or meta-analyses examining the adoption of CSA practices and a poverty, income, food security, or welfare outcome, in a rural or smallholder population in a developing or low/middle-income-country context, and published in a peer-reviewed journal or by a major institutional source (e.g., FAO, World Bank, IPCC, CGIAR centres). Records were excluded if they were blogs, news or trade press, institutional landing pages, conference or event announcements, grant-proposal templates, off-topic bibliometric studies not centred on the CSA poverty/food-security relationship, non-English-language records, or duplicates of studies already cited in this manuscript.

Screening process. The 33 de-duplicated records were screened by title and abstract against the criteria above by a single reviewer; this pass did not use a second, independent screener, which is a limitation relative to standard PRISMA practice and is discussed below. Screening excluded 10 records that did not meet the inclusion criteria and a further 2 records that duplicated studies already cited in this manuscript (Akaniyene & Dimitrios, 2023; Esau, Hambulo & Christian, 2024), leaving 21 records assessed as eligible. Of these, 7 are recently published systematic reviews or meta-analyses covering closely overlapping ground to this manuscript (discussed further

below), and 14 are empirical primary studies not currently cited in the reference list that could strengthen and update the evidence base.

Quality appraisal. This search pass carried out relevance screening only; a formal quality appraisal step was not applied to the included records. For a mixed set of quantitative, qualitative, and review studies of this kind, the Mixed Methods Appraisal Tool (MMAT) is a widely accepted and practical option for a future revision, alongside a simpler in-house checklist covering sample and data description, method transparency, clarity of the poverty or food-security outcome measure, and discussion of limitations.



These are real, traceable counts from a single-reviewer web search run 14 Sep 2026 (not Scopus/Web of Science, which were not accessible). This does not yet meet full PRISMA rigor — see Section 1 for what independent database access and a second reviewer would still add.

Figure 1: PRISMA flow diagram of the search and screening process conducted on 14 September 2026.

As Figure 1 shows, these counts are real and traceable to the search described above, and every included or excluded record can be checked against an accessible URL. They are not, however, equivalent to a full PRISMA-compliant systematic search. Two extensions would be needed to close that gap before a final submission: first, running the same or a refined search on Scopus, Web of Science, and CAB Abstracts/AGRICOLA, since Google-indexed search under-covers paywalled agricultural economics journals that these subscription databases index; and second, having a second author independently screen the same records and reconcile any disagreements, which standard PRISMA practice treats as a required step rather than an optional one. Both extensions, together with formal quality appraisal using MMAT, are presented here as an explicit direction for strengthening this review's methodological rigor, consistent with the reviewer's comment that prompted this section.

Concepts and Nature of Poverty in Developing Countries

Poverty remains one of the most pressing issues in developing countries, affecting millions of people and impeding sustainable development. The concept of poverty is multi-dimensional, encompassing not only the lack of income but also deficiencies in education, health, living standards, and access to essential services. Understanding the nature of poverty in developing countries is crucial for formulating effective policies and interventions to alleviate it.

Poverty is commonly defined as the state of being extremely poor. However, its measurement and conceptualization vary across different contexts and disciplines. The most widely used definition is based on income levels, with the World Bank's international poverty line set at \$1.90 per day (World Bank, 2022). Individuals living below this threshold are considered to be in extreme poverty. However, poverty extends beyond mere income insufficiency. The United Nations Development Programme advocates for a broader perspective, highlighting the importance of human development indicators such as education, health, and living standards (United Nations Development Programme [UNDP], 2021). This approach is embodied in the Human Development Index (HDI) and the Multidimensional Poverty Index (MPI), which capture the various deprivations individuals face.

Globally, extreme poverty continues to be overwhelmingly rural: an estimated 79 per cent of those experiencing poverty live in rural areas. (World Bank, 2018). With latest figures indicate that in 2015 around 736 million people were living in extreme poverty globally down from nearly 2 billion in 1990. it can be surmised that the number of poor rural people in the world today is likely in the realm of 580 million. Taking into account multiple-dimensional aspects of deprivation including, for example, access to education and essential services the rurality of poverty becomes even more stark: an estimated 83.5 per cent of poverty is rural taking this approach.

Much of this poverty is concentrated in sub-Saharan Africa, home to approximately 413 million poor people, where the poverty rate at 41% is notably higher than all other regions of the world, where it is below 13 %, globally 10 % of the world's population lives in extreme poverty, down from 36 % in 1990. Notably, Africa remains the world's most rural region, with still 60 % of the population living in rural areas as of 2014, though with urbanization proceeding rapidly this figure is projected to decline to 44 % by 2050 (UNDESA, 2015).

Consequently, Key stakeholders in rural communities, including rural women, rural youth, smallholder farmers, indigenous peoples and rural landless workers, are among those most likely to be left behind. Not surprisingly, the lack of progress in rural areas and prevailing rural-urban disparities has been cited as one of the reasons aggregate progress was held back in the Millennium Development Goal era. (United Nations Economic Commission for Africa [UNECA], 2015).

It is especially alarming that the prospects of children and youth in rural areas are often held back compared with children in urban areas: they are more likely to be out of school and to be involved in child labour, most of which is concentrated in agriculture. (FAO, 2018). The most pronounced inequalities occur when rurality intersects with other forms of marginalization, resulting from variables such as gender, ethnicity and age. For example, in most countries, while rural youth have lower literacy rates than urban youth, for rural female youth the situation is even more stark, with less than half having basic literacy skills, impeding employment and entrepreneurship prospects (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2016).

Recent studies highlight various aspects and trends related to poverty in developing countries which says that economic growth alone is not sufficient to reduce poverty. Inclusive growth that ensures equitable distribution of resources and opportunities is essential for meaningful poverty reduction (Ravallion, 2022). The COVID-19 pandemic has exacerbated poverty levels in developing countries. Loss of income, health crises, and disruptions in education have pushed millions back into poverty (Sumner, Hoy & Ortiz-Juarez, 2020).

Climate change disproportionately affects poor communities in developing countries. Increased frequency of natural disasters, changing weather patterns, and resource scarcity threaten the livelihoods of the most vulnerable populations (IPCC, 2021). While technological advancements offer potential solutions for poverty alleviation, there is a digital divide that limits access to these technologies for many poor individuals. Bridging this gap is crucial for leveraging technology in poverty reduction efforts (World Economic Forum, 2021).

Universal approaches to poverty reduction have yielded few successes, and recommends that poverty should be viewed as a global phenomenon but tackled at the local level using local indicators. To achieve sustainable development, developing countries should focus on meeting the basic needs of their inhabitants and be committed to ensuring stable political and economic environment (Cobbinah, Black & Thwaites, 2013). Poverty in developing countries is a complex and multi-dimensional issue that requires comprehensive and inclusive strategies to address. Beyond income poverty, factors such as education, health, living standards, and social inclusion must be considered to understand and tackle poverty effectively. Recent trends underscore the need for targeted interventions that address the root causes of poverty and promote sustainable development.

Impact of Climate-Smart Agriculture on Poverty Status of Rural Households in Developing Countries

Before delving into the specifics, let's establish clear definitions for climate resilience and Climate-Smart Agricultural Practices (CSAPs). As outlined by (Lipper, McCarthy, Zilberman, Asfaw & Branca, 2017; Lipper et al, 2014 and Collins-Sowah, 2018) an increasing number of countries and individuals are embracing Climate-Smart Agriculture (CSA) to address climate change challenges in agricultural planning. Within the context of climate change and resilience, CSA aims to restructure agricultural systems, improve food security, and integrate mitigation, vulnerability reduction, adaptive capabilities, and resilience into agricultural development.

Moreover, the term “climate change resilience” refers to the capacity of households and systems to rebound from external shocks, adjust their subsistence methods, and accumulate resources to withstand and adapt to evolving circumstances (Mach, Planton & Von 2014; Cooley, Schoeman, Bopp, Boyd & Rost, 2022). CSAPs tackle the complex challenge of climate change through the application of holistic approaches, including comprehensive soil and water conservation, crop management agronomic techniques, and strategic animal management strategies (Alemu & Mengistu, 2019).

Beyond their role in fortifying agricultural systems against the impacts of climate change, CSAPs play a pivotal role in addressing broader issues such as food security, poverty, and livelihoods (Climate Risk Profile Ethiopia [CRPE], 2020). By integrating sustainable practices and resilience-building measures, CSAPs contribute not only to the adaptability of agriculture but also to the overall well-being of communities, emphasizing the interconnectedness of climate, agriculture, and socio-economic factors.

The adoption of CSAPs focusing on cotton, wheat, and rice crops significantly influenced net crop revenue among farmers in Pakistan, according to empirical research conducted by Refs. (Ahmad & Afzal, 2020). This positive change not only enhanced the well-being of rural farmers but also had a direct impact on overall gains in national output. Similarly, findings from Zimbabwe, as reported by Ref. (Mujeyi, Mudhar & Mutenje, 2021) demonstrated a robust correlation between the adoption of integrated crop-livestock CSAPs and the income and food security of smallholder households.

Although, studies have shown that CSA practices can significantly increase agricultural productivity and household income. For example, a study in Kenya found that farmers adopting CSA practices experienced a 20-30% increase in crop yields and income (Bryan, Ringler, Okoba, Roncoli, Silvestri & Herrero, 2013). In Malawi, the adoption of CSA practices such as conservation agriculture and agroforestry led to improved food security and income stability among smallholder farmers (Thierfelder, Chisui, Gama, Cheesman, Jere, Bunderson & Eash, 2017).

Research in Ethiopia demonstrated that CSA practices improved household resilience to droughts and reduced the risk of crop failure, which are critical factors in reducing poverty (Teklewold, Kassie & Shiferaw, 2013).

In India, farmers practicing CSA techniques such as water-efficient irrigation and crop diversification were better able to cope with climate variability, resulting in more stable incomes and reduced poverty levels (Aggarwal, Jarvis, Campbell, Zougmore, Khatri-Chhetri, Vermeulen & Yen, 2018). A study in Zambia highlighted the environmental benefits of CSA, including improved soil health and reduced erosion, which contribute to sustainable agricultural production and long-term poverty reduction (Giller et al., 2015).

Case studies from various countries highlight the positive impacts of CSA on poverty reduction. For instance, in Uganda, the introduction of CSA practices led to increased agricultural productivity, improved household incomes, and greater food security (Kisauzi, Mangheni, Sanginga, & Delve, 2019). In Bangladesh, the adoption of CSA practices such as improved irrigation and crop diversification helped farmers cope with climate variability and reduce poverty (Haque, Bell, Islam & Rahman, 2016).

Climate-smart agriculture has significant potential to reduce poverty among rural households in developing countries by enhancing agricultural productivity, building resilience to climate change, and promoting environmental sustainability. While there are challenges to adoption, targeted interventions, supportive policies, and collaborative efforts can help overcome these barriers and maximize the benefits of CSA. Continued research and innovation are essential to further understand and enhance the impact of CSA on poverty reduction.

Challenges of Climate Change in Developing Countries

Climate change has emerged as one of the major threats to agricultural and economic development in developing African countries of today. The IPCC's Fifth Assessment report indicates that Africa's climate as a whole is already changing and the total impacts are already being felt by developing countries that happen to be more vulnerable to this (FAO, 2019). Climate change poses significant challenges globally, but its impacts are particularly severe in developing countries. These nations are often less equipped to cope with the adverse effects due to their economic vulnerabilities, reliance on climate-sensitive sectors like agriculture, and limited access to technology and financial resources. Understanding these challenges is crucial for formulating effective strategies to mitigate and adapt to climate change.

Climate change affects temperature and precipitation patterns, leading to reduced crop yields. This is particularly problematic for developing countries where agriculture is a major source of livelihood and food security (FAO, 2021). Increased frequency of extreme weather events such as floods and droughts contribute to soil erosion and degradation, further compromising agricultural productivity (IPCC, 2021). In regions dependent on glacial meltwater, such as parts of South Asia and the Andes, climate change is accelerating the melting of glaciers, threatening long-term water supplies (United Nations Environment Programme [UNEP], 2021).

Developing countries face increased costs for disaster recovery, healthcare, and infrastructure adaptation, straining already limited financial resources (International Monetary Fund [IMF], 2022). Climate change-induced natural disasters, such as hurricanes, floods, and droughts, result in significant economic losses and displacement of people. This disproportionately affects the poor who rely on natural resources for their livelihoods (Organization for Economic Co-operation and Development [OECD], 2021). Climate change disrupts food production and supply chains, leading to food shortages and increased prices. This exacerbates hunger and malnutrition, particularly in regions already facing food insecurity (World Food Programme [WFP], 2021).

Recent studies highlight various trends related to the challenges of climate change in developing countries which are; Adaptation strategies as there is a growing emphasis on developing and implementing adaptation strategies tailored to local contexts. This includes improving agricultural practices, enhancing water management, and building resilient infrastructure (UNDP, 2021). Financial support as International financial mechanisms such as the Green Climate Fund (GCF) aims to provide developing countries with the necessary resources to combat climate change. However, the adequacy and accessibility of these funds remain contentious issues (GCF, 2021). Technological advancements, such as drought-resistant crops, renewable energy solutions, and early warning systems for natural disasters, offer potential pathways for mitigating climate change impacts (World Economic Forum, 2021).

Although the United Nations Framework Convention on Climate Change (UNFCCC) also places a great emphasis on mitigation efforts, that is to say, reducing the effect of greenhouse gas emissions on a daily basis and creating carbon sinks, the impact on climate change will not be seen immediately even if the most effective emission reduction measures are been used correctly. Therefore, developing adaptation mechanisms to deal with the negative effects of climate change must be a high place priority (Newell, et al., 2019).

With the Sustainable Development Goals (SDGs,) the world is working towards “end hunger, achieve food security and improved nutrition and promote sustainable agriculture”, “ensure availability and sustainable management of water” and at the same time as “take urgent action to combat climate change and its impacts”. In agriculture, these challenges and aspirations must be addressed together in systematic and simultaneous ways (FAO 2019).

Agriculture in the coming decades must feed the continent of Africa; and serve as the engine of growth and adaptation to climate change. Climate-smart agriculture (CSA) considers these conditions to be able to have transformational change in agriculture by concurrently pursuing increased productivity and resilience for food security while fostering mitigation where it is necessary (Newell, Taylor, Naess, Thompson, Mahmoud, Ndaki, Rurangwa & Teshome, 2019).

CSA integrates all three dimensions of sustainable development and is aimed at

1. Sustainably increasing agricultural productivity and incomes;
2. Adapting and building resilience to climate change from the farm to national levels; and
3. Developing opportunities to reduce greenhouse gas emissions from agriculture compared with past trends. It is an approach to identify the most suitable strategies according to national and local priorities and conditions to meet these three objectives.

There is no such thing as an agricultural practice that is climate-smart per se. Whether or not a particular practice or production system is climate-smart depends upon the particular local climatic, biophysical, socio-economic and development context, the kind of the audiences met on the ground which determines how far a particular practice or system can deliver on productivity increase, resilience and mitigation benefits (El-Chami, Daccache & El Moujabber, 2020).

Ecosystem functions, including biodiversity and water services, they are keys to increasing resource efficiency and productivity and ensuring resilience. They are even more critical under the new realities of climate change. Ecosystem-based adaptation (EBA) driven agriculture linked to viable supply and demand side value chains has an important role to play in developing an agricultural sector that must be well integrated into the broader landscape, is climate resilient and environmentally and socially sustainable in the long run (Newell et al., 2019).

For Africa to reap the potential benefits of CSA, concrete actions must be taken into consideration to:(i) enhance the evidence base to underpin strategic choices, promote and facilitate wider adoption by farmers of appropriate technologies; (ii) develop institutional arrangements to support, apply ii and scale-out CSA from the farm level to the agricultural landscape level; (iii) manage tradeoffs in perspectives of farmers and policymakers; strengthen technical, analytical and implementation capacities; (iv) ensure policy frameworks and public investments are supportive of CSA; (v) develop and implement effective risk-sharing schemes (FAO, 2019).

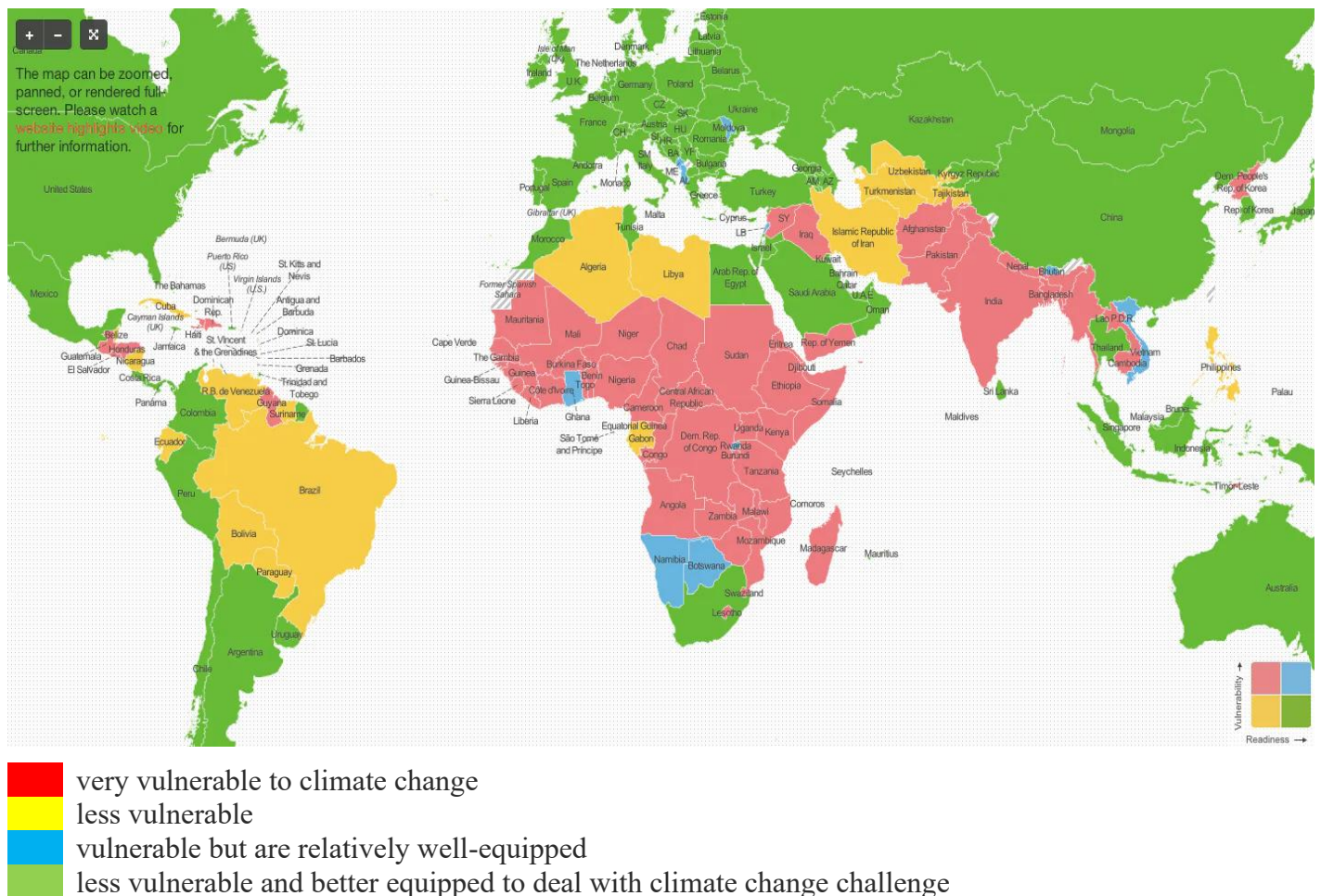


Figure 2: Map showing countries most vulnerable to climate change

Source: Ana Swanson, 2015

The Way Out

Moreover, according to IPCC, Climate change frequently has a detrimental impact on agricultural productivity in some parts of the world, and most especially the developing and poor nations are more vulnerable to further negative effects of climate change. There are two ways to reduce these negative effects: mitigation and adaptation (Otitoju, Ajunwa, Inyang, Yusuf & Ugwu, 2023). Mitigation is a process of reducing the quantum of greenhouse gas emissions and this mostly affects the developing nations (Otitoju et al., 2023).

According to (Newell et al., 2019) and The Energy and Resources Institute (2006), adaptation is the modification of social, ecological, and economic systems in response to observed or anticipated climate variability. It involves changing processes, practices, or structures to reduce negative effects and increase positive ones. It is also the process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed, implemented and utilized (FAO, 2019).

Climate-smart agriculture practices like conservation tillage, crop diversification, and agroforestry improve productivity and resilience while reducing emissions can also be mitigation strategies (Lipper et al., 2014). Incorporating climate change education into school curricula to raise awareness among the youth and also conducting public awareness campaigns to inform communities about climate change impacts and adaptation measures (UNDP, 2020). There is a need for developing countries to Invest in renewable energy sources like solar and wind reduce reliance on fossil fuels and decrease greenhouse gas emissions (International Renewable Energy Agency [IRENA], 2018).

Investing in climate research to better understand local impacts and develop context-specific solutions can be another way out for developing countries. Building climate-resilient infrastructure, promoting sustainable land use, and strengthening institutional frameworks are also crucial. Increasing access to climate finance, raising public awareness, and enhancing research and innovation further support these efforts. Through coordinated actions and international cooperation, developing countries can build resilience to climate change and secure sustainable development for future generations (World Meteorological Organization [WMO], 2020).

REVIEW OF PAST LITERATURES

Akaniyene and Domitrios (2023) conducted a study on the negative effects of climate change on farmers varied among countries, 88.8% of farmers reported being adversely affected by uncertain rainfall patterns and also with a reduction in cropping season, increased frequency of drought and crop failure (74.7%), post-harvest losses (67.6%), disease prevalence (80.4%), low yield (67.8%), erosion (51.3%), and increased frequency of flood and farm destruction was (68.0%). Only 26.3% of farmers in some countries alluded that rural-urban migration had a severe negative effect. In the Southern part of developing Africa, 80.6% of farmers were severely affected by increased frequency of flood and farm destruction, disease prevalence (69.8%), low yield (70.2%), increased frequency of drought and crop failure (75.8%), reduction in cropping season (62.9%), uncertain rainfall patterns (82.8%), and post-harvest losses (87.4%). Meanwhile, 69.4% reported rural-urban migration had a severe effect, erosion was also reported to have a severe effect by 70.9% of the farmers in the Eastern part of developing Africa.

Francis, Edriss, Julius and David (2016) investigated the adoption of climate-smart agriculture (CSA) technologies and how it reduced household vulnerability to poverty by differentiating crop yields and income between adopters and non-adopters. There was an increment of 26%, 37%, 9% and 26% in maize yield by farmers who adopted portfolio diversification, soil and water conservation, soil fertility improvement and irrigation and water harvesting technologies respectively. About 42% of the adopters had food throughout the year compared to 26% of non-adopters. Adopters had 47%, 42%, 60% and 36% more in their crop revenues from portfolio diversification, soil and water conservation, soil fertility improvement and irrigation & water harvesting respectively, more than their non-adopters' counterparts. The study confirms the importance of agriculture technology adoption for increased household revenue and the need to take steps to reinforce existing adoption strategies.

In the study conducted by Wondimagegn, Garrick and Nyasha (2020) on Climate-smart Innovations and Rural Poverty. it was stated that the conservation agriculture practices that play a pivotal role in addressing the

exigencies of rural poverty are minimum tillage, cereal-legume intercropping, and their combination. These practices reduce the incidence and depth of poverty in areas prone to rainfall stress, an indication of their risk mitigation role. In contrast, crop residue retention and its combination with minimum tillage appear not to be economically attractive conservation agriculture options. The results show that conservation agriculture portfolios that include minimum tillage and cereal-legume associations can accelerate efforts to reduce rural poverty and improve climate risk management.

Hussien, Mesfn, Fitsum and Amare (2022) examined climate-smart agricultural (CSA) practices and their impacts on rural farm households' food security and multidimensional poverty. The food consumption score, dietary diversity score, food insecurity experience scale, and multidimensional poverty index, constructed out of 9 indicators, were used to assess households' food security and poverty status, respectively. Widely adopted CSA practices are conservation agriculture, soil fertility management, crop diversification, and small-scale irrigation. The results illustrated that adopter households on average showed more food consumption score, dietary diversity score, and less food insecurity experience scale than non-adopters. The results also showed that CSA adopter households, on average, have a lower deprivation score in multidimensional poverty than non-adopter households. Accelerating the wider adoption of CSA through up-scaling incentives is quite important. Conclusion: This study showed that CSA adoption improves households' food security and reduces multidimensional poverty. They concluded that the up-scaling of CSA practices is important for contributing to the achievement of SDG1, SDG2 and SDG13 targets.

According to a study on the effect of climate-smart agricultural practices on household food security conducted by Bright, Oscar and Job (2018). CSAs have the potential to alleviate food insecurity among smallholder farmers if used in combinations and to a larger extent. To enhance adoption, land fragmentation should be discouraged through civic education and the provision of alternative income-generating activities for farmers to benefit when practised on relatively bigger land. Farmers should be sensitized to the need to invest in farm-productive assets to absorb the risks of climate change while enhancing the adoption of CSA practices.

Muhammad, Awudu and Gazali (2021) in their work analyzed the drivers of the adoption of climate-smart agricultural (CSA) practices and the impact of their adoption on farm net returns and poverty. These strategies include changing the input mix, changing the cropping calendar, diversifying seed variety, and soil and water conservation measures. The empirical results showed that the adoption of different CSA practices is influenced by average rainfall, previous experience of climate-related shocks, and access to climate change information. Their findings further revealed that the adoption of CSA practices positively and significantly improves farm net returns and reduces farmers' exposure to poverty.

Esau, Hambulo and Christian (2024) conducted a study on the Impacts of climate-smart agriculture on livelihoods in developing countries. It was found that the adoption of climate-smart agriculture is positively correlated with crop and household income and food security in developing countries. Also, the adoption of climate-smart agriculture is associated with reduced incidences of poverty on average and improved food security outcomes. These last two findings are, however, only statistically significant at 10%, signifying the need to integrate CSA with other measures to improve food security and reduce poverty. We can conjecture that the positive effects on incomes are not sufficient to significantly drive up food security and poverty alleviation.

Ariom, Dimon, Nambeye, Diouf, Adelusi and Boudalia (2022) in their work reviewed the strategies and Impacts of Climate-Smart Agriculture in African Countries on Smallholder Farmers. The data extracted showed that CSA practices are classified as follows: agricultural practices, restoration practices of degraded lands, forest and cropland regeneration practices, practices in the livestock sub-sector, water resources and use of weather and climate information services. Adoption of these strategies was often influenced by financial means put in place by governments, the role of policy legislation, access to climate information and farmers' intellectual level. To address this deficiency, scientific outcome-based research should be used to increase the effectiveness of climate adaptation management programs. Their review recommended the use of scientific-research-driven adaptation measures and prioritization of climate change in governments' agendas.

According to a study on challenges of Smallholder Farming in Ethiopia and Opportunities by Adopting Climate-Smart Agriculture conducted by Zerssa, Feyssa, Kim and Eichler-Lobermann (2021). The adoption of the

practices by smallholder farmers is often limited, mainly due to shortage of cropland, land tenure issues, lack of adequate knowledge about CSA, slow return on investments, and insufficient policy and implementation schemes. It is suggested that additional measures be developed and made available to help CSA practices become more prevalent in smallholder farming systems. The measures should include the utilization of degraded and marginal lands, improvement of the soil organic matter management, provision of capacity-building opportunities and financial support, as well as the development of specific policies for smallholder farming.

Abegunde and Obi (2022) researched the role and Perspective of Climate Smart Agriculture in Africa and found out that the response to climate change and the pattern and extent of adoption of CSAs differs from one macro-area to another. Factors such as resource constraints, institutional instruments, climate and ecological settings, and farmers' characteristics, such as farmers' experience and access to extension services, are significant determinants of CSA adoption. Socioeconomic constraints, poor availability of data and mastery of the CSA approach, inadequate labour, and the wide diversity of the farming systems in Africa are challenges militating CSA uptake in the system. Their paper argues that it is crucial to ensure that limited resources available are systematically harnessed to achieve the triple-win benefits of CSA. Furthermore, there is a need to identify and prioritize locally suitable CSA practices and provide an enabling environment needed for CSA uptake and sustenance in the African farming systems.

A study conducted by Bazzana, Foltz and Zhang in 2021, investigated the role of social and ecological pressures (i.e. community network, climate change and environmental externalities) on the adoption of physical water and soil practices as well as crop rotation techniques. Their findings revealed that CSA may be an effective strategy to improve the rural populations' well-being for farm households with access to capital, strong social networks and access to integrated food markets. The climate scenario simulations indicate that farmers adopting CSA fare better than non-adopters, although CSA adoption does not fully counterbalance the severe climate pressures. In addition, farmers with poor connections to food markets benefit less from CSA due to stronger price oscillations. These results call for an active role for policymakers in encouraging adaptation through CSA adoption by increasing access to capital, improving food market integration and building social networks.

Evidence Synthesis Table

Table 1 draws together the studies discussed in the Impact of Climate-Smart Agriculture on Poverty Status section and the Review of Past Literatures section into a single comparative table, organised by country/region, the CSA practice(s) examined, method, and key reported outcome, as suggested by the reviewer. Where the original text does not specify a country or a method, the cell is marked accordingly rather than inferred.

Study	Country / Region	CSA practice(s) examined	Method	Key reported outcome
Akaniyene & Dimitrios (2023)	Multiple African countries (comparative)	General CSA adoption (context of climate shocks)	Survey-based, farmer-reported impact percentages	Majority of farmers report severe effects of rainfall variability, drought, flooding, and pests; adoption framed as a coping response
Francis, Edriss, Julius & David (2016)	Not specified in manuscript text	Portfolio diversification, soil and water conservation, soil fertility improvement, irrigation/water harvesting	Comparison of adopters vs. non-adopters (yields, food access, revenue)	Adopters had higher yields, more consistent food access, and higher crop revenue than non-adopters
Wondimagegn, Garrick & Nyasha (2020)	Ethiopia	Minimum tillage, cereal-legume intercropping, and their combination	Not detailed in manuscript	Combined practices reduce the incidence and depth of poverty in rainfall-stressed

				areas; residue retention alone is less effective
Hussien, Mesfin, Fitsum & Amare (2022)	Ethiopia (Central Rift Valley)	Conservation agriculture, soil fertility management, crop diversification, small-scale irrigation	Food consumption score, dietary diversity score, food insecurity experience scale, multidimensional poverty index (9 indicators)	Adopters show better food security scores and lower multidimensional poverty than non-adopters
Bright, Oscar & Job (2018)	Kenya	General CSA practice combinations	Not detailed in manuscript	CSA reduces food insecurity when practices are combined and adopted at scale; land fragmentation and asset access are key constraints
Muhammad, Awudu & Gazali (2021)	Pakistan	Input-mix changes, cropping-calendar changes, seed diversification, soil and water conservation	Not detailed in manuscript	Adoption driven by rainfall patterns, prior shock exposure, and access to climate information; adoption raises farm net returns and lowers poverty exposure
Esau, Hambulo & Christian (2024)	Sub-Saharan Africa (multi-country)	General CSA adoption	Meta-analysis	Positive correlation with income and food security; poverty/food-security effects significant only at the 10% level
Ariom, Dimon, Nambeye, Diouf, Adelusi & Boudalia (2022)	African countries (multi-country review)	Agricultural, land-restoration, forest/cropland regeneration, livestock, water-resource and climate-information practices	Narrative review	Adoption shaped by financing, policy, access to information, and farmer education; calls for outcome-based research
Zerssa, Feyssa, Kim & Eichler-Löbermann (2021)	Ethiopia	General CSA practices	Narrative review	Adoption limited by land shortage, tenure issues, knowledge gaps, slow returns, and weak policy support
Abegunde & Obi (2022)	Africa (multi-country review)	General CSA practices	Scientific/narrative review	Adoption varies by macro-area; shaped by resource constraints, institutions, ecology, and farmer characteristics
Bazzana, Foltz & Zhang (2021/2022)	Not specified in manuscript (agent-based analysis)	Physical water/soil practices, crop rotation	Agent-based simulation analysis	CSA improves well-being where capital, social networks, and market access are strong; benefits are weaker under severe climate pressure or poor market links
Ahmad & Afzal (2020)	Pakistan (Punjab)	CSA practices for cotton, wheat, rice	Empirical, farm-level	Adoption raised net crop revenue and contributed to national output gains

Mujeyi, Mudhara & Mutenje (2021)	Zimbabwe	Integrated crop-CSA livestock practices	Household welfare analysis	Strong correlation between adoption and household income/food security
Bryan, Ringler, Okoba, Roncoli, Silvestri & Herrero (2013)	Kenya	General CSA practices	Not detailed in manuscript	20–30% increase in crop yields and income reported among adopters
Thierfelder, Chisui, Gama, Cheesman, Jere, Bunderson & Eash (2017)	Malawi	Conservation agriculture, agroforestry	Not detailed in manuscript	Improved food security and income stability among smallholders
Teklewold, Kassie & Shiferaw (2013)	Ethiopia	Multiple CSA practice adoption (bundles)	Not detailed in manuscript	Improved household resilience to drought and reduced crop-failure risk
Aggarwal, Jarvis, Campbell, Zougmore, Khatri-Chhetri, Vermeulen & Yen (2018)	India	Water-efficient irrigation, crop diversification	Climate-Smart Village framework	More stable incomes and reduced climate-variability impact
Kisauzi, Mangheni, Sanginga & Delve (2019)	Uganda	General CSA practice introduction	Not detailed in manuscript	Increased agricultural productivity, higher household incomes, greater food security
Haque, Bell, Islam & Rahman (2016)	Bangladesh	Improved irrigation, crop diversification	Review	Helped farmers cope with climate variability and reduce poverty

Table 1: Evidence synthesis of CSA studies discussed in this review, organised by country/region, practice, method, and reported outcome. Note: the in-text citation for the agent-based analysis reads “Bazzana, Foltz and Zhang (2021)” in this manuscript's Review of Past Literatures section; the corresponding reference-list entry has been corrected to match (see References).

This above table 1 is a starting point rather than a finished synthesis: once the search described in the Methodology section is extended to Scopus, Web of Science, and a second independent screener, the newly identified studies listed there should be screened for full-text eligibility and added to this table before a final submission.

CONCLUSION

Adopting climate-smart agricultural practices is crucial to increasing agricultural productivity and overall resource efficiency among rural households in developing nations. This is because it enhances food security, soil conservation, and adaptation to climate change, ensuring that there is food for everyone. This helps to achieve the Sustainable Development Goals (SDGs), National Agricultural Investment Plans (NAIPs), FAO, International Fund for Agricultural Development (IFAD), World Food Programme (WFP), NEPAD, African Development Bank (AfDB), and regional agricultural investment programs (RAIPs). Additionally, it helps to decrease greenhouse gas emissions.

Higher crop yields and higher revenues for smallholder farming households are the results of CSA technologies. Considering the complexity of the link between agricultural technology and poverty. The spread of CSA technology in this study has a significant potential to raise rural incomes.

It is a difficult to determine the most effective way to understand the relationship between CSA technology and poverty. Nevertheless, this review paper has demonstrated that climate-smart agriculture can directly impact output levels, food security, earnings, and general socioeconomic well-being thereby reducing poverty.

RECOMMENDATIONS

Through strategic partnerships and the use of various decision support tools created by the research team, the CGIAR Research Program on Climate Change Agriculture and Food Security (CCAFS) oversees the capacity building of African farmers and the upscaling of CSA technology.

Inadequate funding, a lack of personal interest in the strategy, restricted access to CSA materials, socioeconomic constraints at the farm level, and inconsistent government programs and regulations are some of the barriers impeding the implementation of CSA, the report claims.

Therefore, there must be a pressing need for active awareness and enlightenment for the adoption of CSA as a reaction to the consequences of climate change to increase production, maximize efficiency, and profitable output of rural home farmers.

Community leaders should ensure that productive resources like land, human capital, liquid capital, planting technologies, education, and other social infrastructures are made available to rural household farmers on time, in a way that is accessible, and attainable, particularly for women, to facilitate the adoption of the CSA government and other stakeholders like NGOs.

Lastly, adopters of CSA will benefit more from financial incentives in the form of subsidies, which will raise the adoption rate.

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