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Review Article

Climate-smart Agriculture and Agricultural Diversification Effects on Productivity and Resilience of Smallholder Farmers in Ethiopia

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Abstract

Climate-smart agriculture is the term for adaptations aimed at boosting agricultural production to support higher incomes and food security while lowering greenhouse gas emissions and enhancing farmers' resilience to climate change. Mulching, intercropping, conservation agriculture, crop rotation, integrated crop-livestock management, agroforestry, better grazing, and enhanced water management are examples of effective CSA techniques used in Ethiopia. To minimize vulnerability, marketing risks, income, and biological instability, farmers grow multiple crops on a given plot of land each year. This practice is known as agricultural diversification, and it is an important part of the decision-making process a farmer uses to minimize the risk of agricultural production. This review analysis was based on a thorough examination of published works that were retrieved from Google Scholar and several online resources. Numerous studies have demonstrated that age, gender, family size, wealth, membership in agricultural organizations, land ownership, and educational attainment all have a common impact on smallholder farmers' adoption of climate-smart farming techniques. Conversely, impediments or contributing elements that hinder the implementation of climate-smart agriculture have been noted. These obstacles might be either non-physical (software) or tangible (hardware). Infrastructure, funds, equipment, land, and people resources are some of the physical impediments. In addition, the institutional, cultural, policy, and regulatory contexts; information, knowledge, and skills; technologies and innovations; and governance are some of the non-physical or software impediments. Lastly, it was strongly advised to promote CSA techniques that are affordable cost and easily implement for larger smallholder farmers. The policy supportive strategies ought to focus on design in Climate Smart practices that are environmental and economically easily implemented at smallholder farmers conditions.

Keywords

Climate-Smart Agriculture, Agricultural Diversification, Smallholder Farmers

1. Introduction

The agricultural sectors of the majority of emerging African nations rely heavily on rainfall, and they are also impacted by climate change and other variables such seasonal dynamics, drought, high temperatures, extremely low humidity, and precipitation. Thus, some of the major issues that continue to threaten the food security status of households are low crop

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yields, deteriorating soil fertility, high environmental degradation, and rising agricultural hazards [17, 43]. According to a variety of scientific data, climatic variability will have a significant impact on the food security of the impoverished in SSA. The Intergovernmental Panel on Climate Change (IPCC) predicted that climate change and variability might cut agricultural production and income in Sub-Saharan Africa by 50% and 90%, respectively, in 2020 and 2100 [29]. It is anticipated that by 2050, the average yields of rice, wheat, and maize in this region will drop by 5%, 22%, and 14%, respectively, while sorghum, millet, and groundnut yields will also drop by 27–32% [37].

Ethiopia's low smallholder agricultural production, especially for cereal crops, is caused by rainwater that degrades the soil, farmers' inefficient use of agricultural resources like soil amendments, and unpredictable and unpredictable rainfall. Inadequately resourced agricultural extension systems and the restricted use of better seed and fertilizers are additional contributing factors. In addition, the arid lowlands suffer from unpredictable rainfall and occasionally extreme droughts. These factors, along with land degradation, population increase, and climate change, have significantly hampered the nation's social and economic advancement as well as its food security situation [51].

Reducing susceptibility and preparing for climate change adaptation are two benefits of managing climatic variability. In order to address the effects of climatic variability and change on issues related to resource management and development, climate knowledge and policies are essential. Understanding systems and clients would be taken into account in a climate-smart agriculture (CSA) production system in order to improve institutional capacity for the adoption and expansion of CSA practices and approaches. Mulching, intercropping, conservation agriculture, crop rotation, integrated crop-livestock management, agroforestry, better grazing, and better water management are examples of tried-and-true, useful CSA practices in Ethiopia. Innovative methods including enhanced weather forecasting, early-warning systems, and climate-risk insurance are also a part of CSA [37].

Several empirical studies have shown that implementing climate-smart agricultural practices can greatly mitigate the economic effects of climate change on agriculture. Adaptations that aim to boost agricultural output to promote higher incomes and food security while enhancing farmers' resistance to climate change and lowering greenhouse gas emissions are referred to as climate-smart agriculture [22]. Numerous research has looked at the data about climate-induced decisions about crop varieties, animal choices, mixed farming, and irrigation decisions [63].

Smallholder farmers in Ethiopia fight to reduce poverty via agricultural diversification and achieve food and nutritional security [23, 49]. Although diversification is prevalent in all societies, its impact and scope differ from one place to another and even within a single home. Farmers are being forced to diversify their businesses as a hedge against the growing risks of crop failure brought on by unpredictable rainfall and crop disease [2]. Crop variety is therefore essential to a farmer's decision-making process in order to reduce the risk associated with agricultural output. Agricultural diversification is the process by which farmers plant multiple crops on a single plot of land annually in order to lessen vulnerability [50].

Numerous studies have also shown that agricultural diversification benefits most smallholder farmers and ecosystems by reducing agricultural losses to pests and wildlife, increasing soil fertility and biodiversity, and promoting yield stability and diversity in nutrition [38]. Moreover, [1]. asserted that the goal of food security requires agricultural diversification. Similarly, agricultural diversity is critical to economic growth through raising household incomes, productivity, soil health, and sustainable intensification of agriculture [50]. However, many farmers are unwilling or unable to diversify their operations because of things like land type, elevation, soil quality, irrigation infrastructure, and system placement [11, 17].

Studies in Ethiopia and different literature on climate change adaptation have mostly concentrated on identifying the factors that influence the selection of a single adaptation practice [18]. However, some have taken a group of adaptation practices into consideration as a single entity empirical study on farmers' decision-making processes for adaptation when presented with several possible combinations of tactics are scarce. Likewise, little is known about how adaptation techniques might work together to increase farm income and agricultural output [20].

CSA and environmentally sustainable farming methods are thought to be essential for guaranteeing food security by guaranteeing calorie availability, adequate production, universal accessibility, and appropriate use in the appropriate variety and stability. According to numerous study, there is a dearth of empirical data on climate-smart agriculture practices in Ethiopia, and there is also little data on the factors that influence smallholder farmers' decision to diversify their businesses in order to increase profits and lower the risk of crop failures. This review paper assessed associations of climate-smart agriculture and agricultural diversification its implications for production and resilience on smallholder farmers' in Ethiopia.

2. Material and Methods

Method of assessing article review was majorly based on a rigorous literature review of a published paper that was accessed from Google scholars like journal and review articles, online books and other published academic documents. The review Literature of available from local and international literature on climate-smart agriculture was majorly used. Documents used were retrieved through online available sources which included reports and documents on specifically related to widely practice of climate change adaptation through Climate Smart Agricultural and agricultural diversification in Ethiopia and some African countries.

3. Results and Discussion

3.1. Concepts and Definition

The term "agriculture" is used to refer to the production of crops, animals, fisheries, and forests. A technique to help direct efforts to change and reorient agricultural systems in order to effectively and sustainably promote food security and development in the face of a changing climate is called climate-smart agriculture. In order to preserve and improve agriculture's ability to sustainably support food security, climate-smart agriculture aims to determine which production systems and supporting organizations are most appropriate for addressing the challenges posed by climate change in particular regions. As a result, climate-smart agriculture encompasses tried-and-true practical methods including crop rotation, mulching, intercropping, conservation agriculture, integrated crop-livestock management, agroforestry, better grazing, and better water management. It encompasses cutting-edge techniques including improved weather forecasting, risk insurance, and early-warning systems. In order to meet the needs of the changing climate, it is important to create new technologies, such as crops that can withstand drought or floods, and to get existing technologies off the shelf and into the hands of farmers [51].

3.2. Climate Smart Agriculture Main Goal and Objectives

FAO introduced the concept of "Climate-Smart" agriculture in 2010 as a background paper for the Hague Conference on Agriculture, Food Security, and Climate Change (FAO, Climate-Smart" Agriculture Policies, Practices and Financing for Food Security, Adaptation and Mitigation. 2010) [22]. The paper addressed three primary goals: Increasing agricultural incomes and production to sustainably increase food security; fostering climate change adaptation and resilience; and creating chances to cut greenhouse gas emissions relative to anticipated trends.

3.2.1. Sustainably Increasing Agricultural Productivity and Incomes

Agriculture is the primary source of income for about 75% of the world's impoverished, who reside in rural areas. Experience has demonstrated that in nations where a sizable portion of the population depends on agriculture, expansion of the agricultural sector is very beneficial in lowering poverty and boosting food security. Agricultural expansion can be achieved in part by increasing productivity and lowering costs through improved resource-use efficiency. Smallholder farmers in developing nations have significant "yield gaps," which are the discrepancies between the yields they achieve on their farms and the maximum yield that is physically possible [23]. In a similar vein, livestock productivity is frequently much below its potential. Reducing these disparities by improving agro-ecosystem productivity and the efficiency of soil, water, fertilizer, livestock feed, and other agricultural inputs provides greater returns to farmers, lowering poverty and expanding access to and availability of food. When compared to historical trends, these identical actions can frequently lead to lower greenhouse gas emissions.

3.2.2. Building Resilience to Climate Change

The Intergovernmental Panel on Climate Change (IPCC) recently released its fifth assessment report, which states that the effects of climate change on crop and food production are already noticeable in a number of global locations, with negative effects outnumbering positive ones and developing nations being particularly vulnerable to even more detrimental effects on agriculture [30]. It is anticipated that average and seasonal maximum temperatures will continue to rise in the medium and long term, which will raise average rainfall. However, these effects will not be distributed equally. Globally, wet regions and seasons are becoming wetter, while dry regions and seasons are becoming dryer [55]. Increased exposure to these climatic risks, which are already occurring in many regions of the world, threatens to significantly reduce poverty and boost food security among low-income groups that depend on agriculture. These detrimental effects of climate change can be lessened or even avoided, but doing so will require developing and putting into practice efficient adaptation plans. The best adaptation techniques will differ even within nations due to the site-specific impacts of climate change, as well as the great diversity in agro-ecologies and farming, livestock, and fishing systems. There are currently a number of potential adaptation measures that might serve as a solid foundation for creating adaptation plans that work for every given location. Increasing ecosystem services by applying agroecology concepts and landscape techniques is one way to improve the resilience of agro-ecosystems. Examples of adaptation strategies that can boost resilience include diversifying production or incomes to reduce risk exposure, as well as establishing input supply networks and extension services that facilitate timely and effective use of inputs, such as stress-tolerant crop varieties, livestock breeds, and fish and forestry species [55].

3.2.3. Developing Opportunities to Reduce Greenhouse Gases Emissions Compared to Expected Trends

Approximately 25% of all anthropogenic greenhouse gas emissions are caused by agriculture, which includes land-use change. In addition to being a primary cause of deforestation and the deterioration of peatlands, agriculture also adds to emissions mostly through the management of crops and animals. As a result of anticipated agricultural expansion under business-as-usual growth strategies, non-CO_2 emissions from agriculture are predicted to rise. The greenhouse gas emissions from agriculture can be decreased in a number of ways. One important tactic for agricultural mitigation is sustainable intensification, which lowers emission intensity (such as the CO_2 eq/unit product). In order for the increase in agricultural output to outpace the increase in emissions, the process entails putting new practices into place that improve the efficiency of input utilization Increasing agriculture's ability to sequester carbon is another crucial strategy to reduce emissions. Carbon sequestration is the process by which plants and soils absorb CO_2 from the atmosphere and store it in their biomass. Two strategies for sequestering carbon in agricultural systems are lowering soil disturbance (e.g., through reduced tillage) and increasing tree cover in crop and animal systems (e.g., through agroforestry). This method of reducing emissions might not last forever, though, as the stored CO_2 is released if the trees are felled or the ground is ploughed. Notwithstanding these obstacles, increasing carbon sequestration offers a significant potential mitigation source, particularly given that the agricultural methods that produce sequestration are also critical for food security and adaptability [61].

3.3. The Analytical Framework for Climate-smart Agriculture

The goal of climate-smart agriculture (CSA) is to minimize any potential negative trade-offs while fostering synergies among food security, adaptation, and mitigation of climate change—all of which are directly tied to agriculture. By integrating the need for adaptation and the possibility of mitigation into development initiatives, CSA aims to increase the agriculture sector's ability to sustainably support food security. Opportunities and obstacles to implementation, and hence policy choices, will be determined by the unique situations, circumstances, and capacities within nations [23, 37]. There is no set model for CSA; instead, its final implementation will depend on the unique circumstances of each nation and community. Accordingly, climate-smart agricultural production methods can provide substantial co-benefits for climate change adaptation and mitigation while also optimizing the benefits for food security [10].

3.4. Climate-Smart Agriculture Technologies and Practices

The implementation of climate-smart agriculture (CSA) practices and technologies in Ethiopia is taking place within the framework of integrated watershed management, which includes a variety of crop and livestock production practices such as agroforestry, crop rotation, and intercropping, as well as soil and water conservation measures like tie ridges, terracing, soil/stone bunds, and infiltration ditches, among others [51]. Despite their potential advantages for adaptation, productivity gains, and mitigation efforts, the majority of the climate-smart agriculture techniques and technology identified have low to medium on-farm adoption rates. Numerous major obstacles to broad adoption include restricted or nonexistent access to productive inputs (better seeds and fertilizer), insufficient credit availability, inadequate equipment and technology, limited availability of formal markets for produce sales, and poor quality and accessibility of extension services, especially with regard to climate-smart agriculture [39, 51].

There is disagreement over which practices and technology should be taken into account in CSA. There are many who contend that any agricultural method that increases output or resource efficiency qualifies as climate smart. According to [31]. some view CSA as an adjunct to sustainable intensification of agricultural production systems. Since little is known about the connection between conservation agriculture and CSA, any practice that falls under conservation agriculture may be categorized as CSA. Crop yields, water and nutrient use efficiency, and greenhouse gas emissions from agricultural fields can all be improved by implementing conservation agricultural practices like minimum tillage, various crop establishment techniques, nutrient and irrigation management, and residue incorporation. Similar to this, academics view the adoption of better seeds, rainwater collection devices, and agricultural insurance as climate-smart since they help mitigate the effects of extreme weather occurrences [28]. Numerous agricultural techniques and methods are already available in the field that can help boost output while maintaining an emphasis on environmental sustainability. These technology and practices play a critical role in lowering the intensity of greenhouse gas emissions and the current and future effects of climate change on agriculture [42].

A wide range of CSA solutions have been put out to mitigate the adverse effects of climate change, create agricultural production systems that are climate resilient, and capitalize on the advantages of global warming, according to [36]. These choices range from making minor adjustments to crop management procedures (such as modifying the time of sowing, water and fertilizer application, tillage techniques, and intercultural operations) to altering agricultural production systems (such as altering cropping systems and land uses) in order to adapt to new climatic conditions in a specific area. Crop yields, net farm incomes, and input use efficiency can all be greatly increased by these options, which can also, whenever feasible, lower greenhouse gas emissions. An overview of CSA practices in Ethiopia is provided below:

Table 1. *Summary of some common CSA practices in Ethiopia.*

CSA Practice	Components	Why it is Climate Smart?
Conservation Agriculture	1. Reduced tillage 2. Crop residue management-mulching, intercropping 3. Crop rotation/intercropping with cereals and legumes	1. Carbon sequestration 2. Reduce existing emissions 3. Resilience to dry and hot spells
Integrated Soil Fertility Management	1. Compost and manure management, including green manuring 2. Efficient fertilizer application techniques (time, method, amount)	1. Reduced emission of nitrous oxide and CH_4 2. Improved soil productivity
Small-Scale Irrigation	1. Year-round cropping 2. Efficient water utilization	1. Creating carbon sink 2. Improved yields 3. Improved food security
Agroforestry	1. Tree-based conservation agriculture 2. Practiced both traditionally and as improved practice 3. Farmer managed natural regeneration	1. Trees store large quantities of CO_2 2. Can support resilience and improved productivity of agriculture
Crop Diversification	1. Popularization of new crops and crop varieties 2. Pest resistance, high yielding, tolerant to drought, short season	1. Ensuring food security 2. Resilience to weather variability 3. Alternative livelihoods and improved incomes
Improved Livestock Feed and Feeding Practices	1. Reduced open grazing/zero grazing 2. Forage development and rangeland management 3. Feed improvement 4. Livestock breed 5. improvement and diversification	1. Improved livestock productivity 2. GHG reduction 3. CH4 reduction
Other	1. In situ water conservation/ harvesting 2. Early warning systems and improved weather information 3. Support to alternative energy fuel-efficient stoves, biofuels 4. Crop and livestock insurance 5. Livelihood's diversification 6. Post-harvest technologies (agro-processing, storage)	1. Resilience of agriculture 2. Improved incomes 3. Reduced emissions 4. Reduced deforestation 5. Reduced climate risk

Source: [37].

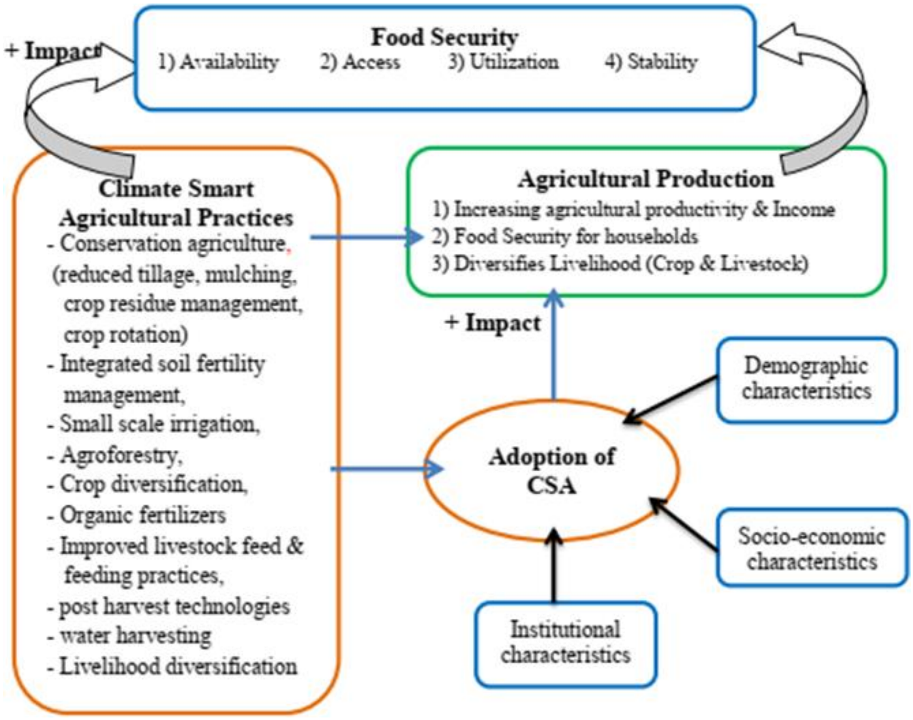
3.5. Climate Smart Agriculture Related Policies and Strategies in Ethiopia

The United Nations Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD), and the United Nations Convention to Combat Desertification (UNCCD) are just a few of the international conventions and protocols pertaining to climate change and land degradation that Ethiopia has ratified and signed. Policies and strategies that are pertinent to CSA include the Climate-Resilient Green Economy Strategy (CRGES), the Ethiopian Program of Adaptation to Climate Change (EPACC), the National Adaptation Program of Action (NAPA), the Ethiopian Program of Adaptation to Climate Change (EPACC), the National Appropriate Mitigation Actions (NAMA), the Agricultural Sector Policy and Investment Framework (PIF), the Environmental Impact Assessment Proclamation (EIA), and the Environmental Policy of Ethiopia (EPE) [37].

Conceptual framework

The conceptual framework provides a graphic representation of the productivity and adoption of climate-smart agricultural practices. Climate-smart farming practices, agricultural production, and food security are all intertwined factors contributing to climate change. Additionally, the conceptual framework identifies the socio-economic, demographic, and institutional elements that impact the adoption of CSA as well as climate-smart agriculture methods. The CSA is closely related to agricultural output, which raises agricultural income and productivity, provides households with food security, and diversifies sources of income. CSA and agricultural production are clearly related, and they should be crucial to raising agricultural productivity and ensuring food security (figure 1).

The adoption of climate-smart agricultural methods is influenced by a number of factors, including institutional, demographic, and socioeconomic ones. Demographic characteristics such as age, household size, sex, and educational level of household; socioeconomic characteristics such as land and income of household affect farmer decision to adopt climate-smart agricultural practices. Access to climate change knowledge, agricultural extension agents, and loan availability are some of the institutional elements that influence farmers' decisions to use climate-smart agricultural practices.



Source: Adapted from [29, 40].

Figure 1. *Variable effects climate smart agriculture practices.*

3.6. Empirical Evidence on Adoptions of Climate-smart Agriculture

A number of empirical researches have been conducted to understand factors that affect farmer adoption of Climate Smart Agriculture [62]. These studies identified common variables that affect the smallholder farmers' adoption of climate-smart agricultural practices. The farmer's age, gender, family size, wealth, membership in agricultural organizations, land ownership, and education level influence the adoption of sustainable practices. Adoption rate is also determined by subjective variables such as farmer 's awareness of new practices, personal willingness, and overall concern for the problem the practices aim to address [18].

According to [39] the commonly described barriers to the adoption of climate-smart practices are financial constraints, shortages of labor, land, and water. Farmers may be generally willing to adopt new practices, but perceive a specific practice to be inadequate, unnecessary, or difficult to incorporate into existing management systems. Two broad categories of barriers or factors that prevent the adoption of climate-smart agriculture were identified. These are physical or hardware and non-physical or software barriers. The physical barriers are inputs such as land, human resources, equipment, infrastructure, and finances. And the non-physical or software barriers relate to the institutional, cultural, policy, and regulatory environments; information, knowledge and skills; technologies and innovations; and governance among others [39].

Effects of agricultural input and output markets on the adoption of CSA: The decisions farmers make about the type of technologies and practices they adopt are determined by the benefits and costs associated with them, which in turn is affected by the ability of producers to access input supply and output market chains. Improved market access that raises the returns to land and labor is, therefore, a critical force for the adoption of new climate-smart practices in agriculture. However, many smallholder farmers in vulnerable areas continue to face complex challenges in the adoption of CSA options. There is still inadequate understanding of the market, policy, and institutional failures that shape and structure farmer incentives and investment decisions [12].

Effects of information on the adoption of CSA: Information on the types of options, particularly those well suited to local conditions, is often scarce. For instance, this lack of information can increase the risk of planting expensive seeds that may not survive or otherwise do poorly. The information available to farmers on the types of CSA options that are well-adapted to the locality is likely to be an important determinant for adoption. Information may come from several sources, including government extension programs and non-governmental organization (NGO)/donor programs [37]. Climate change, by increasing uncertainty, as well as the value of rapid and accurate response increases the value of information. [16]. These include institutions engaged in agricultural research, extension, agricultural production and marketing statistics, and the provision of climate-related information. Adopting CSA requires farmers to make both short- and long-term planning decisions and technology choices. Agricultural extension systems are the main conduit for disseminating information required to make such changes. Difficulty in communicating the information and lack of user participation in the development of information systems is a problem [37].

Effects of credit facilities on the adoption of CSA: Credit service is an important factor that influences the adoption of agricultural technologies, especially for poor farmers who often have limited financial resources for purchasing agricultural inputs and implements [37].

3.7. Agricultural and Crop Diversification

Diversification in agriculture commonly means growing different crops instead of concentrating under a single crop. However, Pingali and Rosengrant [54] defined diversification as "change in product (or enterprise) choice and input use decisions based on market forces and the principles of profit maximization". Conversely, [33]. have defined "agricultural diversification as the movement of production-portfolio from a low-value commodity mix (crop and livestock) to high-value commodity-mix (crops and livestock)" making a shift from the traditional definition. However, to encompass all the agricultural and allied sectors, diversification should be considered as a strategy of changing crop or enterprise-mix with a more equivalent distributive share for each sector. But the rationale to select agricultural diversification as a strategy connects different logic viz. risk minimization, sustainability, or high production depending on the intention of the farmer.

Agricultural diversification can be categorized as 1) shift of resources from farming activities to non-farming activities; 2) resource reallocation within the farming activities such as from less profitable crop (enterprise) to more profitable crop (enterprise); 3) resource use in diverse but complimentary activities. According to the different authors, agricultural diversification involves a shift from a regional dominant crop to another crop, from one enterprise (e.g., crop) to another (livestock) or to be involved in other complementary activities (including crop, livestock, and non-farm). A study also [33] also described diversification as (i) undertaking a mix of diverse and complementary activities within the agricultural sector; (ii) reallocation of resources from low-value activities/commodities to high-value activities/commodities; and (iii) resource shifting from farming to non-farming activities. Accordingly, agricultural diversification can be analyzed as 1) crop diversification, 2) livestock diversification, and 3) income diversification (crop, livestock, and non-farm) [57].

Different scholars define crop diversification in various ways. Crop diversification can be considered as the re-allocation of farm resources, such as land, capital, labor, and farm equipment to new or different crops of relatively high value or more stress-tolerant crop species from susceptible crop species. Crop diversification has also been used as an adaptation strategy by an individual household or groups to reduce the level of vulnerability deriving from adverse policy and climatic impacts. Ethiopian smallholders also grow crop species that are genetically diverse to meet the diverse socioeconomic needs as well as to withstand risks of the market and climatic variability [60].

Ethiopian smallholders undertake their livelihood activities under complex, diverse, and risky environmental conditions. Adverse events because of unpredictable weather conditions and periodic droughts, declining landholding and fragmentation, lack of institutional services, the fluctuation of input and output prices, and population pressure significantly impact household welfare. Declining farm size and soil fertility, erratic rainfall distribution, and recurrent drought are the main contributors to food insecurity and vulnerability of smallholders in the country [64]. These challenges can be the push factors towards diversification while the ongoing infrastructures (roads, telecommunication, electricity, and so on) development and expansion can be considered as pull factors [60].

3.8. Empirical Evidence Crop Diversification vs. Smallholder Farmers' Productivity

Earlier studies confirmed that diversification from staple food crops towards cash crops and/ or varieties with a desired agronomic and market attributes is triggered by the diversity that exists among the farming households. A variable that explains crop diversification and intensity include farming experience, the sex of a farmer, area of a plot owned, access to extension and credit services, social-capital of the household, and agroecology. The empirical analysis was explained as follows.

The study investigated the pattern, trend, and covariates of crop diversification in eastern Ethiopia based on data collected from 167 households randomly and proportionately selected. To manage risks of drought, pests and diseases, soil fertility decline, and input price variations, farmers in the study areas employ crop diversification as a self-insuring strategy. The farmers are becoming risk-averse which has implications on technology adoption. Tobit model result indicated that farmers with more extension contacts and larger livestock size are likely to specialize whereas those who have access to market information and irrigation, those who own machinery, and more farm plots are more likely to diversify. The extension system should include risk-minimization as a strategy [48].

A study by [16] examined the determinants of income diversification among rural households using cross-sectional data collected from the Fedis District of Eastern Hararghe, Ethiopia. The multinational logit model was used to identify factors influencing households' participation in non-farm activities while the determinants of non-farm income were analyzed by the Tobit model. Factors related to human capital (gender and age of the household head, number of economically active family members, household head's education level, and presence of children attending school), livelihood assets (livestock holding, size of cultivated land), livelihood diversifying strategy (crop-based diversification through several crops grown harvested), and infrastructure (proximity to market) are found to have an impact on participation in non-farm employment activities and the amount of income derived.

According to [6], a number of socioeconomic and institutional factors, including land size, age, education, farming experience, off-farm income, the distance between the farm and the main road and market, and farm machinery ownership, all have an impact on crop diversification. In addition, [15] discovered that the main determinants of crop selections in northern Ethiopia were proximity to a town, road accessibility, education, liquid wealth, and irrigation availability. Furthermore, [50] proved that the households' choices regarding crop diversification were greatly impacted by the size of the land, the amount of money they made from the sale of grain, the distance from the district, the walking time to the farm, the availability of all-weather conditions, market information, extension services, the proportion of fertile plots, and a number of other factors.

A study by [9]. found that the articles reported both non-significant and positive relationships between smallholders' adoption of innovations and agricultural experience. A cross-sectional and panel study from Uganda revealed a mixed (inverted-U-shaped) association between farming experience and the use of technology for maize, coffee, and bananas. Based on their experience, the authors claim that farmers can stop using the technologies, particularly if they require more labor and require an increase in farm area. The farming experience is anticipated to have a favorable or negative impact on crop diversity in this study as well.

The gender of the household head is another household attribute that is given more weight in studies of smallholders' decision behavior. A study carried out in Kenya revealed that households headed by men tend to be more diverse than those headed by women [34]. In most societies, female-headed households have less access to institutional services like land, education, agricultural extension, and other social services than male-headed households. This sociocultural factor is the reason behind the underlying assumption that female-headed households adopt less. In order to meet household food needs, it is therefore anticipated that households headed by men will diversify more, while households headed by women will concentrate on producing staple cereals. However, female-headed households can also participate in diversification practices, as it is a technique for adapting to the hazards of crop failure or price fluctuations [19].

Farm income diversification has also become one of the important determinants of farm household well-being. Households diversify their income in response to farm income risks by engaging in non-farm activities [31]. The study also suggested that farm income diversification is an important policy instrument towards income stabilization as an alternative risk management strategy. Another study in China shows that income diversification plays an important role in enhancing the resilience of smallholders to drought and stabilize livelihood systems. Diversification of income has a favorable correlation with household welfare in Nigeria. [3, 14]. The non-farm income also plays an important role to smoothen household consumption during agricultural shocks [55]. The study from Nigeria found that household income diversification can play both risk management and income enhancing role [60].

Crop diversity has been employed as an adaptation approach to increase household welfare, reduce income fluctuation risks, and explore opportunities [3]. The findings of specific studies, look at how crop and income diversity affect the welfare of particular households. Research on the effects of crop diversification on household welfare indicates that there is little correlation between the degree of crop diversification and the likelihood of living in poverty, though the effect diminishes beyond a certain threshold of diversification [8, 41]. In contrast to the rice-wheat system, the household's output and profitability significantly rose when potatoes, mung bean, clover, and rapeseed were introduced as part of agricultural diversification into a wheat-rice system. Crop diversification has produced lucrative returns, especially for smallholders in South East Asia and Thailand [35]. Using data from 500 respondents, [43]. calculated how crop diversification affected two significant outcomes: production and climate change adaption. The authors claim that diversity is a practical strategy for climate-smart agriculture, which greatly increases smallholders' resilience and production. Crop diversification was proven to have a positive impact on rural households' income and nutrition (dietary diversity) in eight developing nations [53]. Studies conducted in Ethiopia have demonstrated that diversification boosts productivity and reduces production fluctuations [20]. However, according to [7] diversification does not appear to lessen yield-related downside risks.

Additionally, diversification can support ecosystem services like effective nutrient cycling and biodiversity protection, as well as the production of crops and livestock [56].

Using panel data from Ethiopia, [49] found that, in contrast to specialization, cultivating a variety of crops lowers the likelihood of becoming poor, sliding into poverty, and staying poor. Additionally, crop diversification can boost crop sales volume and give smallholders the chance to find a crop or crops with greater market demand for production [53]. Generally speaking, specialization follows market size hitting a threshold, while diversification rises first as the market grows [21]. However, compared to specialization, diverse farming is less economically efficient and more environmentally sustainable [13]. According to another study, crop diversity significantly lowers technical efficiency [26]. These contradictory findings suggest that the impact of crop diversity on the agricultural output of smallholders varies by region. Furthermore, a small sample size, restricted geographic scope, and cross-sectional data were the foundations of the majority of earlier research [60].

3.9. Empirical Evidence on Crop Diversification and Food and Nutrition Security

According to the studies, the contribution of crop diversification to increased food security and nutrition in poor households is showed mostly positive. The result of examination found out that 89 out of 208 agricultural diversification projects, such as home garden intensification with vegetables or tree crops, the inclusion of vegetables on rice bunds, the introduction of fish ponds in paddy fields, or dairy cows and trees on farms, implemented in 52 developing countries contributed to an increase of food production in a per hectare basis [60]. For the successful projects, the impact of crop diversification on food production was very high, contributing, on average, to a 93% increase in food production per hectare. The authors assumed that food production and food security were directly related, and that the 89 diversification projects had a significant positive influence on food security. discovered that food diversity and crop diversification were positively correlated in Malawi. According to these authors, a 2% increase in the Household Dietary Diversity Score2 was linked to an increase of one unit in the average number of intercrops per maize farm, and a 1% increase in the Food Consumption Score was linked to an increase of one unit in the number of nonmaize crops grown on a farm.

Additionally, [43] found that crop diversification significantly improved food security, cereal crop productivity, and Zimbabwe's nutrition indices (Food Consumption Score and Household Dietary Diversity Score). A finding by [60] shows that adding more crops or animals did not significantly affect seasonal hunger and that an integrated agro-ecology-based approach was required. In Nicaragua, they confirmed the importance of mixing maize and beans, which Mesoamerican farmers have managed in their milpa production systems for thousands of years. Crop diversification patterns varied greatly within and between regions in Guatemala, according to evidence from a household survey that classified crop diversification patterns and food security "ex-post." Additionally, small farmers who switched from maize to potatoes were more likely to experience negative food insecurity and malnutrition than those who switched from maize to wheat and vegetables.

3.10. Constraints to the Adoption of CSA Practices

Inadequate law enforcement. One obstacle to the adoption of CSA, according to respondents, is inadequate law enforcement to maintain conservation areas during the adoption process. Respondents asserted that neither rules nor enforcement procedures support the use of CSA. Cattle grazers are encroaching on confined spaces, leaving planted trees vulnerable to harm from both humans and animals. Furthermore, there is no legal protection for other conservation methods. Conservation agriculture, in the form of CSA practices, is not sufficiently integrated with agricultural extension services and strategies, and laws have not been sufficiently enforced, despite the establishment of certain norms and regulations. Focus group discussions revealed obstacles that aligned with the opinions of key informants: the widespread implementation of CSA and the absence of explicit legal directives to the community regarding conservation areas and constructed conservation infrastructure such as terraces, enclosed areas, and erosion checks.

In Ethiopia, NGOs and commercial sector organizations have used CSA techniques such integrated soil and watershed management and other conservation agriculture. For instance, an NGO manages the Safety Net Program, a significant step in soil and water conservation, with minimal government assistance [32]. However, strict laws and regulations have not backed the efforts of farmers, other private sectors, and non-governmental organizations. For CSA practices to be widely adopted, the government must provide sufficient assistance and follow-up to guarantee sustainability.

Lack of reliable climate information and incentives. One important factor in the target community's acceptance of CSA technology is information access. When farmers are given clear and accurate information about the technologies that are available and the potential implications of climate change in their area, they are more likely to use them. In order for farmers to adopt low-risk agricultural practices like planting drought-tolerant, early-maturity crops and modifying planting times based on available rainfall patterns, as well as to put existing soil and water conservation techniques and technology into practice, they need sufficient information about future climate conditions from a reliable source [24]. Furthermore, the research area's information sources are restricted to weather forecasting and extension services. The networks of weather stations, packaging, and distribution methods for users must therefore be expanded. For instance, all farmers and farming communities could have information at their fingertips if satellites and smartphones are used more frequently [66].

4. Conclusion

The studies revealed a low adoption rate of CSAs, with many farmers opting for low-capital alternatives, likely due to limited resources in smallholder farming. Crop management techniques were the most common choice, possibly because of their affordability. Food security was most affected by a broader package that included risk reduction techniques, crop management, field management, and particular soil management techniques. Because it handles a broader range of field and soil conditions and mitigates soil deterioration for production stability, this package is incredibly complete. Farmers must therefore integrate all CSAs as much as possible if they want to gain most from them. The results showed that gender, farm size, and farm assets all had a favorable impact on the likelihood of using CSA practices. Male-headed households with more farm assets were more inclined to utilize it on larger portions of their own plots. If used in combination and to a greater extent, CSAs have the potential to reduce food insecurity among smallholder farmersFinancial limitations, labor, land, and water shortages are the biggest obstacles to the adoption of climate-smart activities. Although farmers may be open to implementing new methods in general, they may believe that a particular technique is insufficient, superfluous, or challenging to integrate into current management systems. The adoption of climate-smart agriculture is hampered by two main types of obstacles. These include both non-physical (software) and physical (hardware) barriers. Inputs including land, labor, machinery, infrastructure, and money make up the physical obstacles. Additionally, the institutional, cultural, policy, and regulatory contexts; information, knowledge, and skills; innovations and technologies; and governance are all related to the non-physical or software barriers.

In Ethiopia, the diverse farming system continues to be a source of income, a technique for lowering risk, and a way to raise household incomes. Households also benefit greatly from crop diversification strategies, especially when it comes to income and ways to improve nutrition. In order to gain food and money from a variety of agricultural sources, it is also employed as a risk reduction method. However, the household's choice and level of crop diversification were influenced by a number of socioeconomic, demographic, and institutional factors.

5. Recommendations

The empirical review assessments shows that there is a research gap in Ethiopia specifically regarding climate-smart agriculture practices and the impact of agricultural diversification on smallholder farmers' resilience and productivity. Further study needs to be conducted to determine the influence of agricultural diversification and climate-smart agriculture practices on smallholder farmers.

In addition to strengthening and promoting the adoption of the priority climate-smart agriculture practices, research, policy, and supported programs should place a strong emphasis on the implementation of climate-smart agriculture practices, particularly which farmers have could practice in massively numbers.

Policy intervention very important to scale up to larger Climate Smart Agriculture packages which comprise a different list of activities: crop management, field management, risk reduction practices, and specific soil management practices, to have a higher effect on food security status. Finally, its Promote CSA practices that are cost-effective and easily conducted by wider smallholder farmers very important.

Abbreviations

CSA	Climate Smart Agriculture
IPCC	The Intergovernmental Panel on Climate Change
FAO	Food and Agricultural Organization

Author Contributions

Getu Mitiku Bekuma is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Fields

Getu Mitiku Bekuma: Rural development and agricultural extension, Commercialization and rural institution