

A Synthesis of Climate Change Adaptation and Mitigation Research Findings at the Africa Center of Excellence for Climate Smart Agriculture and Biodiversity Conservation

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Abstract

Climate change is posing challenges to the survival of mankind and sustainable development in the world. Its impacts are more pronounced in Africa, particularly the sub-Saharan Africa where the people's livelihoods are over-dependent on the climate sensitive sectors like rainfed agriculture. Several researches have been conducted to evaluate the possible impacts of climate change on livelihoods and to study the performances of different climate smart technologies and practices in addressing the impacts. As part of these efforts, masters and doctoral students at the Africa Center of Excellence for Climate Smart Agriculture and Biodiversity Conservation at Haramaya University in Ethiopia conducted studies under five thematic areas namely, Climate smart production and management of crops and livestock, soil and water management; policy, institutions and innovations; and Biodiversity conservation. The findings revealed that smallholder farmers need to use climate smart agriculture (CSA) technologies and practices to increase their resilience to climate change through enhancing the productivity of crops and livestock and reducing GHG emissions. Hence, there is a need for a policy support to the farmers in adopting the CSA Technologies through implementing policies that focus on the poorer segments of the farming society to alleviate differences in the adoption of such agricultural technologies and embracing Indigenous Knowledge (IK) and Local Institutions (LI) in climate change adaptation.

Key words: Adaptation, Adoption, Climate change, climate smart agriculture, Haramaya University, Smallholder farmers, Vulnerability

Résumé

Le changement climatique pose des défis à la survie de l'humanité et au développement durable dans le monde. Ses impacts sont plus prononcés en Afrique, en particulier en Afrique subsaharienne où les moyens de subsistance des populations dépendent fortement des secteurs sensibles au climat, comme l'agriculture pluviale. De nombreuses recherches ont été menées pour évaluer les impacts possibles du changement climatique sur les moyens de subsistance et pour étudier les performances de différentes technologies et pratiques agricoles intelligentes face au climat dans la lutte contre les impacts. Dans le cadre de ces efforts, des étudiants en maîtrise

et doctorat du Centre d'Excellence Africain pour l'Agriculture Intelligente face au Climat et la Conservation de la Biodiversité à l'Université de Haramaya en Éthiopie ont mené des études sous cinq thèmes : production intelligente et gestion des cultures et du bétail, gestion des sols et de l'eau ; politiques, institutions et innovations ; et conservation de la biodiversité. Les résultats ont révélé que les petits exploitants agricoles doivent utiliser des technologies et des pratiques agricoles intelligentes face au climat (CSA) pour accroître leur résilience au changement climatique en améliorant la productivité des cultures et du bétail et en réduisant les émissions de gaz à effet de serre. Il est donc nécessaire de soutenir les agriculteurs dans l'adoption des technologies CSA en mettant en œuvre des politiques qui se concentrent sur les segments les plus pauvres de la société agricole pour pallier les différences dans l'adoption de telles technologies agricoles et en intégrant les connaissances indigènes (IK) et les institutions locales (LI) dans l'adaptation au changement climatique.

Mots-clés: Adaptation, Adoption, Changement climatique, Agriculture intelligente face au climat, Université de Haramaya, Petits exploitants agricoles, Vulnérabilité

Introduction

Climate change is a worldwide problem posing challenges to the survival of mankind and sustainable development. Particularly, Africa is likely to warm during this century at a rate faster than the global average, with the drier subtropical regions warming more than the moist tropics (IPCC, 2007) whereby the combination of increasing temperature and changing rainfall patterns could make annual production of food crops on an increasingly eroded land and scarce water resource base, even more risky and largely unpredictable (FAO, 2006). Moreover, climate change is already imposing a significant challenge to countries in Sub-Saharan Africa (SSA) by causing degradation of natural resources and biodiversity subsequently affecting food security, water and energy supply, poverty reduction and sustainable development. While contributing the least to the problem of climate change, SSA countries remain highly susceptible to the impacts of climate change. They are also the least to cope up with climate change and the associated problems, since the adaptive capacity of their socio-economic systems is lower compared to other African regions (Umesh *et al.*, 2015).

Sub-Saharan Africa is 'highly vulnerable' to the impacts of climate change because of the over-dependence on climate sensitive sectors such as, rain-fed agriculture, forestry and water resources (Slingo *et al.* 2005). Agriculture is a major contributor to the national economies and is predominantly practiced by smallholder farmers, and the agricultural productivity is lower than that in other developing regions and far below its own potential (Rosen and Shapouri, 2012). Climate change has contributed to the cycle of poverty and recurrence of food shortages in SSA for several decades in the past. Burdened with growing weather variability, smallholder farm households are under further threat of becoming the most food-insecure, undernourished, and poverty-stricken sector of the African society (AGRA, 2014).

There is clear evidence that the conventional agricultural production system in SSA failed to cope up with the impact of climate change on livelihoods, food security and biodiversity which is aggravated by anthropogenic factors. This calls for the need to implement Climate Smart Agriculture (CSA) practices and technologies to adapt to the change and mitigate it. CSA is an approach to develop the technical, policy and investment

conditions to achieve sustainable agricultural development for food security under climate change. This approach can strengthen livelihoods and food security, especially of smallholders, by improving the management and use of natural resources and adopting appropriate methods and technologies for the production, processing, and marketing of agricultural goods. CSA supports countries in putting in place the necessary policy, technical and financial means to mainstream climate change considerations into agricultural sectors and provide a basis for operationalizing sustainable agricultural development under changing conditions (FAO, 2013). However, there is shortage of educated human capital and quality research in SSA to evaluate the effectiveness and adoption levels of the CSA practices under specific conditions. Hence, to contribute to filling this gap in the educated human capacity and quality research in the SSA region particularly in the areas of Climate Smart Agriculture and Biodiversity conservation, the Africa Center of Excellence for Climate Smart Agriculture and Biodiversity Conservation (ACE Climate SABC) of Haramaya University, Ethiopia, was established through the World bank's loan grant as a regional hub for the Eastern and Southern African region to train postgraduate students and conduct quality research. Although the Center was originally established to train students from the Eastern and Southern Africa region, it has now expanded its scope to other parts of Africa due to its selection to host PhD students sponsored by the Regional Scholarship Innovation Fund. The PhD and MSc students at the Center conduct research in five thematic areas. Several research findings have been generated from students' research since the start of the program in 2017. Although the some of the research findings have been published in various journals or just shelved in the form of thesis or dissertation, they have not been synthesized for possible policy action. The objective of this paper is to present a synthesis of major findings of the ACE Climate SABC students' research with emphasis on the published reports.

Methodology

ACE Climate SABC students normally conduct their research under five thematic areas namely, climate smart crop production and management; climate smart livestock production and management; climate smart soil and water management; policy, institutions, and innovations; and Biodiversity conservation within selected specific focus areas indicated in Figure 2 based on their interest. This paper presents a synthesis of major findings from publications of the researches conducted by the doctoral or masters students of the Africa Center of Excellence for Climate Smart Agriculture and Biodiversity Conservation. Major findings from published papers between the years 2019-2023 by the ACE Climate SABC students, have been categorized and synthesized (Figure 1).

Major Findings

Predictions/Simulations/Trends Analysis. In a study conducted in Sub humid Uganda, climate projections revealed increases in mean temperature of 0.5 °C and 1.0 °C under RCP4.5 and RCP8.5, respectively (Zizinga *et al.*, 2020a) in 30 years period while the annual averages rainfall showed decrease (4.7%) and increase (2%) in the future under RCP4.5 and RCP8.5, respectively. Similarly, Woldeselassie *et al.* (2021) reported an increase in the mean annual temperature and a decrease in the mean annual rainfall during 30-years period in Kersa, Eastern Ethiopia and showed that climate change markedly affected potato production. Habte *et al.* (2022) also reported declining trends of annual (-4.7 mm/year), autumn (-4.5 mm) and winter (-0.54 mm) rainfalls in Southern range-lands of Ethiopia. According to this study, Rainfall Anomaly Index identified 13 drought years over the past 32

years, of which 53.85% occurred between 2007- 2017. The rise in temperature and decrease of rainfall resulted in decrease in soil moisture and biodiversity as well as yields of crops like potato and maize (Woldeselassie *et al.*, 2021). A study on the effect of climate change on sweet potato virus disease in Kenya indicated that the geographical extent of areas at risk of sweet potato virus disease will increase for Kenya under future climate change scenarios from a current 36,736.09 km² to about 63,179.76 km² by 2085 under RCP 8.5. Increase in temperature and moisture variables will enhance niche suitability for sweet potato viruses and vectors. Therefore, the situation calls for climate smart practices such as better crop timing, better cultivar choice and management, integrated pest management and sustainable cropping systems to enhance sustainable production of sweet potato crop (Quinter *et al.*, 2022).

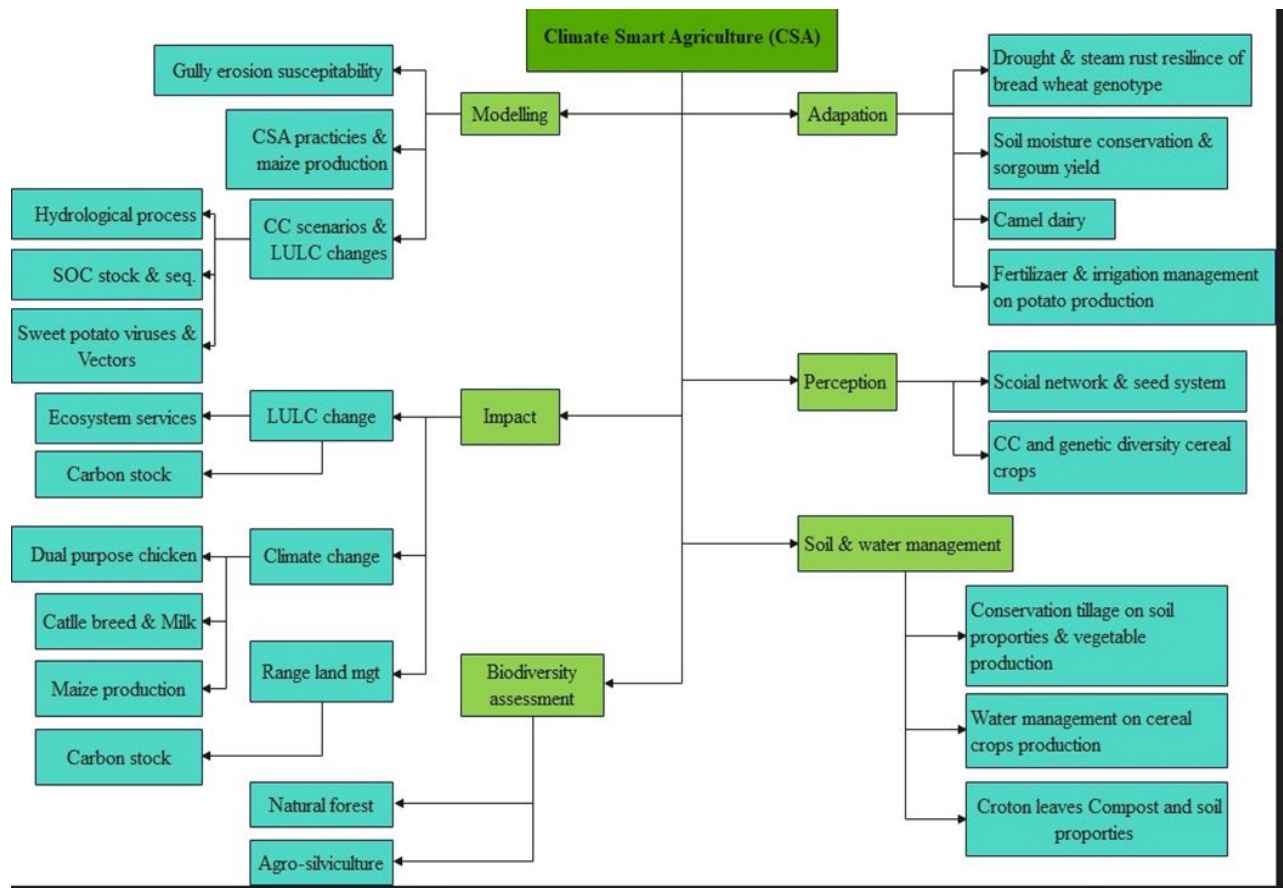


Figure 1. Major areas of students' research at ACE Climate SABC

Another study that evaluated the Regional Climate Models (RCMs) for simulating precipitation and temperature over the Guder sub-basin of Upper Blue Nile Basin in Ethiopia, indicated that there is no best model for all conditions. For instance, Fetene *et al.* (2023) reported that the best model for rainfall simulation had a poor performance for temperature. Therefore, this justifies the need for evaluation RCMs model to choose the most realistic model for a localized climate impact study. According to a study conducted in the subhumid parts of Uganda, AquaCrop model is recommended as a reliable tool for assessing the effectiveness of the selected CSA practices for sustainable and improved maize production (Zizinga *et al.*, 2020c).

Land Use/Land Cover Change. A study on landscape transformations in Central highlands of Ethiopia indicated that Forests, wetlands, grazing lands, shrub-bush-woodlands, and water bodies were reduced by 9755 ha (37%), 4092 ha (38.4%), 21,263 ha (81%), 63,161 ha (25.7%), and 905 ha (1%), respectively, between 1986 and 2021 (Biratu *et al.*, 2022). Meanwhile, cultivated lands, bare-lands, and built-up areas will experience an increase between 1986 and 2051. The estimated total ecosystem service values were reduced by US\$58.3 and 85.4 million in the period 1986–2021 and 1986–2051. A similar study on land Use land cover analysis in the southeastern range-land of Ethiopia revealed transition of land use/cover from grassland, woody and forest vegetation cover to bush/shrub and cropland in the study areas. The study indicated that in 32 years, potential grazing resources had declined with a resultant increase in the proportion of bush/shrub feed resources available for livestock (Habte *et al.*, 2021). A study in Northern highlands of Ethiopia also indicated that LULC changes and slope gradient had a major impact on SOC stock and C sequestration rate over 30 years in a highly populated watershed (Bethel *et al.*, 2023). Conversion of cultivated land to grass land resulted in higher SOC stock (72.03 Mg ha^{-1}) and SOC sequestration rate ($3.00 \text{ Mg ha}^{-1} \text{ year}^{-1}$), while lower SOC stock (8.87 Mg ha^{-1}) and sequestration rate ($0.77 \text{ Mg ha}^{-1} \text{ year}^{-1}$) were recorded when land use changed from cultivation to a plantation forest.

Farmers' Perceptions and Factors Affecting Adoption Decisions. A study on perception of pastoralists on climate change in southern Ethiopia revealed that pastoralists in Ethiopia perceive increasing patterns of temperature (82.8%) and drought intensity (84.8%) as well as decreasing trends of rainfall and feed availability (Habte *et al.*, 2022). Chinasho *et al.* (2022) also reported that the farmers' understanding of the roles of irrigation in climate change adaptation is good but their perception of practices for improving WUE- is poor due to poor water distribution systems and low education levels.

Concerning factors affecting adoption of CSA practices by small holder farmers, a study conducted in Zimbabwe by Makate *et al.* (2020b) reveals mainly pro-rich inequalities in the adoption of CSA technologies (e.g., minimum tillage, planting pits, and improved maize varieties), access to complementary inputs (e.g., fertilizer), infrastructure (e.g., use of improved granary), and access to institutional services (e.g., extension and local institutions). Heterogeneity in asset wealth, farm household characteristics, and sociopolitical factors chiefly explain observed inequalities in access to Climate-Smart Agriculture technologies, infrastructure, and institutional services in Africa. Multiple adoption of innovations is mostly explained by access to key resources (credit, income and information), level of education and size of land owned by the farmer. More so, the concurrent adoption of conservation agriculture, stress adapted legume varieties and drought tolerant maize has far greater dividends on productivity and income than when considered individually. However, impacts of multiple adoption of the practices are not entirely uniform across different geographic regions and gender. Effective institutional and policy efforts targeted towards reducing resource constraints that inhibit farmers' capacity to adopt complementary climate-smart agriculture packages such as conservation agriculture, drought tolerant maize and improved legume varieties must be gender sensitive and context specific (Makate *et al.*, 2019a). Results show enhanced collective impact of simultaneous access to credit and extension on CSA technology adoption. Further, joint impacts of credit and extension on adoption were found to be less pronounced in youth and women farmer groups compared to their old and male farmer group counterparts respectively (Makate *et al.*, 2019b). Hence, the need for prudent policy and institutional strategies in improving access to credit and extension services especially

to youth and women in Malawian and Zimbabwean smallholder farming in order to improve adoption and up-scaling of CSA technologies. A similar study in Zimbabwe by Makate *et al.* (2019c) reported presence of a wider gap between the rich and the poor in adopting CSA technologies. Hence, decision makers need to consider implementing policies that focus on the poorer segments of the farming society to alleviate differences in the adoption of such agricultural technologies. For example, subsidizing the uptake of improved maize varieties including DTM and prioritizing equitable land distribution, coupled with specialized extension services for the poor in a cereal-based CA farming system, could reduce the observed gap between rich and poor in the uptake of these innovations and consequently improve food security. It has also been indicated that embracing Indigenous Knowledge (IK) and Local Institutions (LI) in climate change adaptation projects can enhance adoption and scaling success of climate-smart agriculture innovations in smallholder farming (Makate *et al.*, 2020a)

Effects of Climate Smart Agriculture Practices. Different studies evaluated the effects of CSA practices on crop and livestock productivity; improvement of farm households livelihoods and mitigation to climate change. Commonly used major adaptation practices include adjusting planting dates, using improved varieties, intercropping, recommended mineral fertilizers, supplementary irrigation, area enclosures, soil and water conservation measures. In a study conducted in Uganda, CSA practices such as permanent planting basins, halfmoon, mulching (Zizinga *et al.*, 2022b,d) increased maize grain yield and water use efficiency in sub humid regions of Uganda as compared to the conventional farming practices. Another study in Tanzania reported that evaluation of water productivity and agronomic performance of paddy rice through water saving irrigation and nitrogen fertilization revealed that less water can be used to produce more crops under alternative rice growing practices. The results are important for water-scarce areas, providing useful information to policy makers, farmers, agricultural departments, and water management boards in devising future climate-smart adaptation and mitigation strategies (Mboyerwa *et al.*, 2021). It was also indicated that Rice grain yield and higher NUE could be achieved at low N inputs under sustainable rice intensification (Mboyerwa *et al.*, 2022). Woldeeslassie *et al.* (2021) also reported that farmers in Eastern highlands of Ethiopia practiced different CSA practices like supplemental irrigation, mineral fertilizers and organic fertilizers to alleviate problems of soil degradation and nutrient depletion so as to improve potato production. Similarly, Mumme *et al.* (2023) also reported that Small-scale irrigation significantly improves farm households' livelihoods and mitigates the effects of climate change by enhancing their ability to respond to erratic weather events, which builds their resilience. In another study conducted in semiarid pastoral ecosystem of eastern Ethiopia, area enclosure and browsing management practices were found to have the highest levels of soil organic carbon stocks, differing only in terms of the amount of woody and herbaceous biomass (Gebremedhin *et al.*, 2022).

Vulnerability to Climate Change, and Adaptation Strategies

Vulnerability of Smallholder Farmers. A study on vulnerability of smallholder farmers to climate change-induced shocks in East Hararghe zone of Ethiopia revealed that 73% of households were vulnerable to climate-induced shocks. Households with better farm experience, land size, livestock ownership, access to credit, access to extension service, social capital, access to climate information, non-farm income, and headed by a male were not vulnerable to climate change; whereas households who were living in low and midland

agro-ecologies, far from the market, and participating in productive safety-net programs were vulnerable to climate change (Zelege *et al.*, 2021).

Vulnerability of Livestock to Climate Change. A study on vulnerability of Fogera cattle calves to heat stress during different seasons in Sub-Humid part of Ethiopia revealed higher AT and Temperature Humidity Index (THI) during dry and short seasons while higher relative humidity (RH) was observed during the long rainy season. Physiological parameters (except rectal temperature), Hematological parameters (except for packed cell volume) and Biochemical and growth parameters were significantly affected by the seasons. THI was positively related with physiological but negatively with growth parameters. Thus, the THI value of 66 can be considered as optimum for high weight gain and normal physiological response to heat stress in Fogera cattle calves under their current production system (Abera *et al.*, 2021a). More specifically, increase in weather variables such as Temperature Humidity Index (THI) decreased the growth parameters (birth weight and weaning weight) of Fogera cattle calves (Abera *et al.*, 2021b).

Another study on the effects of climate variability on livestock productivity in Southeastern Ethiopia, has reported that significantly higher ($p < 0.01$) cattle and small ruminants than camel per household died during the disastrous drought occurred in 2008/9 and 2015/16. Nonetheless, the result indicated significantly higher ($p < 0.01$) amounts of milk yield (3.32 litre/day) of dairying camel during dry periods than cattle and small ruminants. Camel and goats are perceived as drought-resistant livestock species and cattle keepers shifting to have more camel and goat in response to prevailing drought in the study area (Habte *et al.*, 2022). Camel and Goats are more resilient to climate change than Cattle. Hence, it is recommendable to choose camel and goat more likely than cattle and sheep raising with increasing temperature and decreasing pattern of rainfall that favour bush/shrub feed resources.

Adaptation Strategies. Smallholder farmers use different techniques to adapt to climate change. For instance, Zelege *et al.* (2021b) indicated that smallholder farmers in Eastern Hareghe zone of Ethiopia use practices like improved varieties of crops, crop diversification, adjusting planting dates, soil and water conservation practices, reducing livestock holdings, planting trees and small-scale irrigation adaptation strategies. Moreover, this study indicated that sex of the household head, landholding size, livestock ownership, access to extension, access to credit, social capital, market distance, access to climate change-related training, nonfarm income, agroecological setting and poverty status of the households significantly influence farmers' choice of adaptation strategies.

Climate Change Mitigation. A few students conduct their studies in the areas of climate change mitigation. It has been reported that soil organic carbon increases in some of the watershed where soil conservation is practiced and decrease otherwise. A study conducted in Tanzania revealed that a treatment with sustainable Rice Intensification (SRI) with 90 kg N showed higher climate change mitigation potential (with lower GHG emissions) and reduced global warming potential (GWP) without compromising rice yield (Mboyerwa *et al.*, 2022).

Conclusion

Many climate projections revealed that there is a trend of increase in temperature and decrease in rainfall in many parts of Africa resulting in reduced productivity and affecting vulnerable organisms including humans, crops and livestock. Studies also indicated that changes in land use/cover are mostly from forest and grasslands to cultivated lands which results in lower soil organic carbon stock, lower carbon sequestration, reduced feed resources, and reduced ecosystem service values. Hence, there is a need to use climate smart agriculture practices that will reduce the vulnerability of smallholder farmers to climate change through enhancing the productivity of crops and livestock and reducing GHG emissions. However, farmers adoption of CSA practices is affected by several factors including access to CSA technologies, infrastructure, access to institutional services, level of education, land size, access to credit and extension services. Hence, there is a need for prudent policy and institutional strategies in improving access to credit and extension services especially to youth and women, consider implementing policies that focus on the poorer segments of the farming society to alleviate differences in the adoption of such agricultural technologies and embracing Indigenous Knowledge (IK) and Local Institutions (LI) in climate change adaptation.

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