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Climate-Smart Agriculture for Zambia's Smallholder Farmers: Review Paper

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Abstract: Most developing country's governments in Sub Sahara African countries' including Zambia's and international organizations have committed major resources to promote Climate-Smart Agriculture (CSA) as a means of increasing resilience to the effects of climate change. Zambia has made significant progress in expanding CSA and is now regarded as a regional leader in this file. This research is of great importance in ascertaining adopted practices impacts among rural farming households and contributions to soil physicochemical properties (agroecosystem). The study's findings will aid in the improvement of CSA activities and have an impact on policy regarding the development of future intervention approaches. Hopefully, CSA activities in Zambia will be scaled up, resulting in more effective resource use and CSA project execution. Therefore, an inclusive study is needed to quantify the effects of CSATs on soil physicochemical properties across different (selected) technologies and household consumption among smallholder farmers. The inclusive study will conduct a statistical analysis with a holistic econometric approach.

Keywords: Agriculture, Climate, Impacts, Household, Smallholder

Introduction

Poverty and vulnerability are mostly rural phenomena in Zambia, with the rain-fed smallholder farming system being the primary cause(Kalaba *et al*., 2010; Mbilinyi, and Kazi, 2013; Kuntashula *et al*., 2015;). The smallholder rural farmer faces several constraints that limit productivity and profitability, trapping the family in a cycle of poverty(Kuyah *et al.*, 2020). According to the Ministry of Agriculture and the Ministry of Fisheries and Livestock's Second National Agriculture Policy, the agricultural industry generates about 10% of Zambia's GDP and employs more than 70% of the population. Despite the significant contribution of agriculture to Zambia's gross domestic product (GDP), experiences threats by climatic change and variability(White *et al*., 2016). Climate change affects 80% of the rural agrarian farming households (i.e. minimizing the industry contribution to real poverty reduction, particularly in rural areas).

Therefore, the study by Mcsweeney *et al*., (2010) alluded that climate change to harming Zambia's rural poor farming households. Additionally, in the year 1960 and 2006, the average annual temperature in Zambia rose by 1.3 degrees Celsius. However, according to the Zambian Meteorological Department, extremely high temperatures ranging from 30 to 38 degrees Celsius were recorded around the country in 2004. Temperature extremes have also been reported, with clear detrimental consequences for plant and animal physiology, growth, and productivity. Climate change will almost certainly have a significant impact on the average yields of Zambia's major crops (maize, wheat, and sorghum), because agronomic conditions for these crops may worsen in large parts of the country. Extreme weather events such as drought and flooding, on the other hand, are expected to have a higher impact on crop production(Arslan *et al.*, 2015). Reduced crop production exacerbates food insecurity and nutrition, likely to have an impact on human life. Therefore,(CIAT and World Bank, 2017) reported in Zambia on climate change-related agricultural losses anticipated to total of US$2.2–3.13 billion over the next 10–20 years. With the complexity of the socio-economic character of agricultural systems in Sub-Saharan Africa, integrated CSA approaches have been promoted to maximize the benefits of CSA technologies as well as adoption by smallholder farmers(Makate, 2019; Mizik, 2021).

The government of Zambia is conducting multiple CSA measures to repair degraded landscapes and improve farmers' resilience to climate change in conjunction with national and international research and development partners(Lufumpa, 1991). It's worth noting that technologies and practices for reducing or eliminating the negative effects of climate change have been developed over time (Fischer *et al.*, 2002;Zougmoré *et al.*, 2018). Adaptation, mitigation, and resilience measures are the terms used to describe these technologies and practices. These technologies combat loss of soil fertility, and folder shortage of which governments and non-governmental organizations have stimulated smallholder farmers to adopt them (Ajayi *et al*., 2003;Miller *et al.*, 2020). Climate-smart agriculture technologies (e.g. organic farming, agroforestry, conservation agriculture, multi-cropping) are tailored to increase household income, agriculture productivity, climate change resilience, and mitigation through incorporating tree crops in farming systems and less of synthetic fertilizer usage(Tadesse *et a*l., 2021). The implementation of CSA technologies and practices in highly degraded landscapes across various developing countries, such as Malawi, Ethiopia, Tanzania, Kenya, Nigeria, and Uganda, is based on this premise; soil and water conservation, grazing management, crop rotation, crop residue incorporation, and perennial-crop based agroforestry systems are all examples of CSA practices in these areas(Mizik, 2021). In terms of crop productivity; CSATs focuses on improving soil health and recovery from depleted nutrients(Sosthenes *et al*, 2012).

Climate change (i.e. false start of the rain, increased alternate cooling and cooling) increases soil degradation associated with a decrease in soil aggregate stability. According to Ukaegbu and Nnawuihe (2020),and Azuka (2013), a decrease in water-stable aggregates renders soils more susceptible to raindrop impact, resulting in increased disintegration and slaking. Mbagwu (2003) espoused that the soil environment is one of the factors that influence aggregate stability. In addition, the structure of tilled soil, and its hydraulic qualities are altered with time and space (Pinheiro *et al*., 2004; Bhattacharyya *et al.*, 2009; Ukaegbu and Nnawuihe, 2020). The greatest threat to ecological stability, residential environment, and local economic development has been soil deterioration (Pinheiro *et al.*, 2004). Long-term tillage substantially limits agricultural yield due to soil degradation, including soil erosion and nutrient depletion (Nkhuwa *et al.*, 2020). The latter can be solely addressed by climate-smart agricultural technologies and practices activity implementation.

Agreeing to Anuga *et al*. (2019) climate-smart agriculture (CSA) has been touted as a key technique for increasing agricultural production in a changing climate, ensuring farmers' climate resilience, and lowering greenhouse gas emissions. CSA technologies have been identified and their importance in tackling food security issues (i.e. enhance soil fertility, fodder availability, water availability among others). Therein, CSA technologies and practices include minimum tillage, crop residue management, soil and water conservation, conservation agriculture, and agroforestry to a landscape (McCarthy and Brubaker, 2014). According to Anuga *et al. (*2019), CSA projects have been directed towards the most vulnerable farming communities in the world. Despite the potential and promotion of CSATs, its adoption is still low (Mizik, 2021). The diffusion of CSATs practices has also remained low and its impact(United Nations, n.d.; Ajayi and Catacutan, 2012). Empirical studies in Zambia by Neubert *et al*. (2011), Arslan *et al*.(2015), Kayula (2017), CIAT and World Bank (2017), Branca *et al*.(2019), Mulungu *et al.(*2019), Odubote and Ajayi (2020) and Swisha (2020), and have attempted to investigate socio-economic impacts of CSATs adoption among smallholder farmers in Zambia.

Literature Review

In this chapter, variety of literature is reviewed related to impacts of CSA technologies on farmland and adoption among smallholder farmers, and successes of CSA across Sub-Sahara Africa countries.

Definitions of Key Terms

Climate Smart Agriculture Definition

Achouri *et al*. (2010) and FAO (2010) defined “CSA” as agriculture adaptation approaches that raise production, resilience, reduce/remove greenhouse gas emissions (mitigation), and improve national food security and development goals in a sustainable way.

Climate

According to NASA (2011) the average weather conditions of an area or location over a long period, generally 30 years, are referred to as climate.

Climate change

Climate change is defined as any change in climate over time, whether caused by natural variability or human activity (UNFCCC, 2011;IPCC, 2018). A large change in the atmosphere's mean state and event frequency is often referred to as a big shift.

Climate variability

Climate variability encompasses changes in the climate's mean state and other statistics (such as standard deviations and the incidence of extremes) on all temporal and geographical scales beyond individual weather occurrences (IPCC, 2018). Internal variability (internal variability) and external variability (external variability) are two sources of variability in the climate system (IPCC, 2007).

Adaptation to climate change

According to IPCC (2018), adaptation to climate change refers to changes in natural and human systems because of current or anticipated climatic occurrences and their consequences, to minimize harm and maximize benefits.

Adaptive capacity

IPCC report (2014) and (UNFCCC, 2011)described adaptive capacity as a system's ability to adapt to climate change, including climate variability and change, to mitigate possible harms, seize opportunities, or respond to climate change's effects

Resilience to climate change

GACSA (2016) defined resilience as how well a community affected by climate change bounces back or recovers.

Vulnerability

WFP (2015) and Padgham (2009) explained vulnerability to a population's, system's, or location's sensitivity to harm from hazard exposure, and has a direct impact on the capacity to plan for, respond to, and recover from hazards and catastrophes.

Climate-Smart Agriculture overview

Climate-Smart Agriculture is a method for guiding agricultural management in the face of the changing climate(FANRPAN, 2018). The concept was first introduced in 2009, and it has since been reshaped based on feedback and interactions from a variety of parties involved in its development and implementation. CSA aims to develop globally applicable principles for managing agriculture for food security in the face of climate change(GACSA, 2016). CSA therefore could serve as a foundation for policy support and recommendations from multilateral organizations such as the United Nations (e.g. FAO, WFP,UNEP). The key components of the CSA approach were established in response to discussions and conflicts surrounding climate change and agricultural policy for long-term development.

Climate Change Impacts on Agriculture in Zambia

The Intergovernmental Panel on Climate Change (IPCC) has released its Fifth Assessment, which shows that global climate change is already causing agricultural damage and reducing food production capability, particularly in poorer nations (IPCC, 2014). The vulnerability of SSA countries, including Zambia to climate change is exacerbated by reliance on rain-fed agriculture and natural resources. CC has contributed to high levels of poverty, low human capital due to inadequate readiness for climate disasters, and poor rural infrastructure.

Flaig (2021)established that temperatures in SSA are already beyond the threshold at which additional warming effects yield challenges. According to Zambia's National Communication to the United Nations Framework Convention on Climate Change (UNFCCC), the mean annual temperature rose by 1.3 degrees Celsius between 1960 and 2003, with an increasing trend continuing. Agricultural yields in Zambia will continue to fall in the absence of any action. Both formal specialists and rural masses are already feeling climate change impacts across Eastern and Southern Africa, including Zambia, according to a comparative evaluation by FANRPAN (2018).

Zambia is already facing climate-related risks (e.g. droughts, dry spells, seasonal, flash floods, and severe temperatures). Some of these hazards, particularly droughts and floods, have become more frequent and severe in recent decades (CIAT and World Bank, 2017).These risks pose a threat to people's food, water security, water quality, energy, and livelihoods, particularly in rural areas. Zambia has a population of 17.6 million people, with 69 per cent of the population living in rural areas (Central Statistical Office, 2011). Moreover, 60% of Zambians live in poverty (CIAT and World Bank, 2017). For the majority of rural households, agriculture remains one of the most effective roads out of poverty. Additionally, the(CIAT and World Bank, 2017) reported that agriculture currently accounts for less than 10% of Zambia's GDP. Agriculture-driven GDP growth is around four times as effective in eliminating poverty than GDP growth from other industries inorder to attain Sustainable Development Goals number one and number two [i.e. ‘no poverty’ and ‘zero hunger’] (Bank and Bank, 2008;UN, 2015). Zambian agriculture sector composes of 82% of smallholder farmers. The agriculture sector employs about 70% of women and youths reported by (FAO, IFAD, UNICEF, WFP, 2020).

Zambian farmers have made adjustments to their agricultural operations to adapt to changing climate conditions and other problems(Mwanamwenge and Cook, 2019). Changes in agricultural methods are aimed at both crop and livestock production (i.e. introduction of new crop varieties, improved animal breeds, enhanced soil management, water conservation technology, and increased fodder production). Climate-Smart Agriculture technologies and practices are intended to improve resource-poor smallholder farming systems in Zambia, as well as contribute to climate change adaptation and mitigation(Ajayi *et al*., 2003; Ajayi *et al*., 2011; Kiptot *et al*., 2014; Arslan *et al*., 2015).

Climate Smart Agriculture Empirical Studies in Zambia

The empirical study conducted by (Odubote and Ajayi, 2020) evaluated the variety of multilayer CSA treatment activities, trying to strengthen smallholder farmers’ resilience to climatic shocks. Increased access and use of stress-tolerant maize seeds by connecting farmers and agro-dealers with stress-tolerant seed suppliers, increased access and use of ICT-enabled weather information services by farmers. In addition, increased and sustained private sector investment in weather index insurance (WII) and farmer uptake, and promotion of integrated crop-livestock farming systems are among the initiatives. However, (Odubote and Ajayi, 2020) underlined the importance of a market facilitation approach in private sector investments in CSA and smallholder farmer uptake. Additionally, preliminary findings indicated that farmers are willing to embrace CSA solutions, which will aid in the development of CSA solution platforms.

Mulungu *et al*. (2019) examined how rainfall and temperature affect maize and bean production, and variability at the national and subnational levels using 30 years of yield and weather data from Zambia (1981–2011) using the Just and Pope model. Above the existing mean values, the results demonstrated a negative influence of temperature rise on yield and a positive impact of rainfall rise on yield. The findings varied depending on the agro-ecological region. By 2050, the worst-case scenario estimated impacts using the HadGEM-ES2 global circulation model suggest that large yield declines (25 percent for maize and 34% for beans) will be in area II, with temperature increases countering the positive gains from increased rainfall. The model primarily underestimated maize production and overestimated bean yield. Therefore, Mulungu *et al*. (2019) recommended making agriculture more robust to climate change, urging for agro-ecological region-specific adaptation techniques and well-planned policy initiatives.

FANRPAN (2017) espoused that climate change is already being felt by both formal specialists and rural masses in Eastern and Southern Africa, including Zambia, according to a comparative evaluation. FANRPAN in the year 2017 commissioned CSA Policy scoping studies, which assessed the responsiveness of policy frameworks in fifteen (15) Eastern and Southern African nations, with aid of national consultants (i.e. Botswana, Democratic Republic of Congo, Kenya, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, South Africa, Swaziland, Uganda, Tanzania, Zambia and Zimbabwe). The study reviewed existing literature and interviews with key informants from a variety of organizations in the research process. In some countries, national policy dialogues were held in all countries to (a) share the draft CSA scoping study report results with stakeholders, (b) evaluate the draft CSA scoping study report outputs, and (c) solicit policy recommendations from stakeholders. External reviewers assessed the draft reports, and both national conversation recommendations and external reviewers' recommendations were incorporated into the CSA scoping study's final findings.

The investigation by Branca *et al.* (2019)compared the benefits and costs of CSA systems to those of traditional systems in several agro-ecologies (i.e. including opportunity costs of switching from one system to another). On agricultural households in Zambia, primary data acquired through ad hoc household and community surveys were used. Zambian smallholder farmers use a wide range of land management strategies, which they apply to a variety of crops. Meanwhile, the adoption of numerous combinations of practices made it difficult to isolate the productivity effect of each practice. Nonetheless, Branca *et al*. (2019) also investigated how SLM technology packages boost crop output and net incomes on Zambian smallholder farms. As a result, for essential food and cash crops, Minimum Soil Disturbance (MSD) systems were chosen as the main distinguishing element to compare with "conventional tillage systems" (maize, groundnuts and cotton). Minimum soil disturbance has shown promising results in terms of land, capital, and labour productivity in arid areas of Zambia. It could be a viable CSA option if appropriate choices are made in terms of labour source (manual versus animal draft power), specific practice (planting basins/potholes versus ripping, legume inclusion in crop rotations, and residue retention), crop (maize versus groundnut), and access to water(Branca et al., 2019). SLM technology alternatives can also help the environment by reducing carbon emissions. A marginal abatement costs curve was created to better understand mitigation potential. The study's findings revealed that all MSD options have negative marginal abatement costs, implying synergies between increased farm incomes and climate change mitigation, and represent a means of generating "win-win" solutions to address poverty and food insecurity while also benefiting the environment (climate change mitigation). According to Branca *et al.* (2016), the cost-effectiveness of various land, management strategies is offered as a synergetic choice criterion that would allow policymakers to prioritize support interventions based on the economic efficiency of GHG abatement.

An inclusive study by Arslan *et al*. (2015) investigated the consequences of a range of potentially climate-smart agricultural technologies in Zambia (i.e. reduced tillage, crop rotation, and legume intercropping, as well as the use of better seeds and inorganic fertilizer). The study investigated the shifting effects of these practices with climatic circumstances. Wherein, Arslan *et al*. (2015) combined panel data from the Rural Incomes and Livelihoods Surveys with a novel collection of meteorological variables based on geo-referenced historical rainfall and temperature data. While controlling for family characteristics, estimates on influences of maize yields due to occurrence of extremely low yields and yield shortfalls from typical values. The study, therefore, evidenced that minimal soil disturbance and crop rotation have no effect on these yield outcomes, but legume intercropping considerably enhances yields and reduces the likelihood of low yields. Furthermore, climatic conditions also have a considerable impact on the average favourable effects of current input utilization (seeds and fertilizers). Purposively Arslan *et al*. (2015) further alluded that one of the most reliable predictors of yields and their resilience appears to be timely fertilizer access. Findings have policy implications for targeted measures to boost smallholder agriculture's productivity and resilience in the face of climate change in Zambia.

In the study by Kaczan *et al*., (2013) in Malawi and Zambia as the two countries that are tailing interventions as part of a Climate-Smart Agriculture programme. To increase the productivity of their smallholder agricultural systems in the face of climate change, these countries are aggressively promoting the use of agroforestry and conservation agriculture. The study evidenced the utilization, yield, and socioeconomic implications of these technologies. Agroforestry is a potential choice for smallholder farmers, with well-documented productivity and profitability benefits, according to the studies. The evidence for conservation agricultural use in the target nations is likewise encouraging, but it is weaker(Kaczan *et al*., 2013). Despite the promotion than in other African countries, adoption rates are lower than one might expect considering the potential benefits and resources invested. Therefore, Kaczan *et al.*, (2013) made recommendations on further research on biophysical factors and farm profitability of adopting CA, and AF as main limits.

Neubert *et al*. (2011) study findings demonstrated that in Zambia, there are no one-size-fits-all approaches to agricultural development. As a result, the strategies and policies are adjusted for individual regions and target groups. As a result, they strive to promote pro-poor development for the most vulnerable farmers, as well as building resilience to economic shocks and climate change. Neubert *et al.* (2011) recommended that it is critical to put these measures in place to accomplish development and mitigate the detrimental effects of future external shocks. Furthermore, it became evident that additional prioritization or sequencing of the proposed solutions was not appropriate. They are all important for development and resilience, and they're all intertwined (e.g. without animal traction, smallholder productivity would not grow significantly, and conservation farming would not be conceivable). The same may be said about market creation. Almost all of the suggested strategies, such as conservation farming, diversity, and irrigation, require functioning markets to be successful (Neubert *et al.*, 2011). In conclusion, focusing solely on one or two measures would be a mistake; a multidimensional strategy with parallel interrelated policies is required.

Conceptual framework

To meet the growing and interconnected challenges of crop failure, animal diseases, pasture shortages, and climate change, agriculture in developing countries must undergo a significant transformation (Lang and Barling, 2012;Patel *et al.*, 2016). These issues are evident in Sub-Saharan African countries like Zambia, where the population is expected to increase by one billion people by 2050, bringing the total population between 1.9 and 2.4 billion (UNDESA, 2012).

Climate smart agriculture technologies must be introduced to help smallholder farmers overcome these issues. CSA technologies are tailored to address agricultural production and productivity challenges faced by smallholder farmers in developing countries such as Zambia (e.g. yield variability, soil fertility loss, and a variety of climatic conditions) (Arslan *et al*., 2013). Agroforestry is one of the CSA technologies that has been advocated around the world(Ghattas and FAO, 2014).Despite the development and marketing of CSA projects, smallholder farmers have been slow to accept them. According to reviewed empirical studies, smallholder farmers' low rate of CSA adoption is driven by a number of factors and the outcomes (Tsige, 2019). Below is an illustration in figure 1.

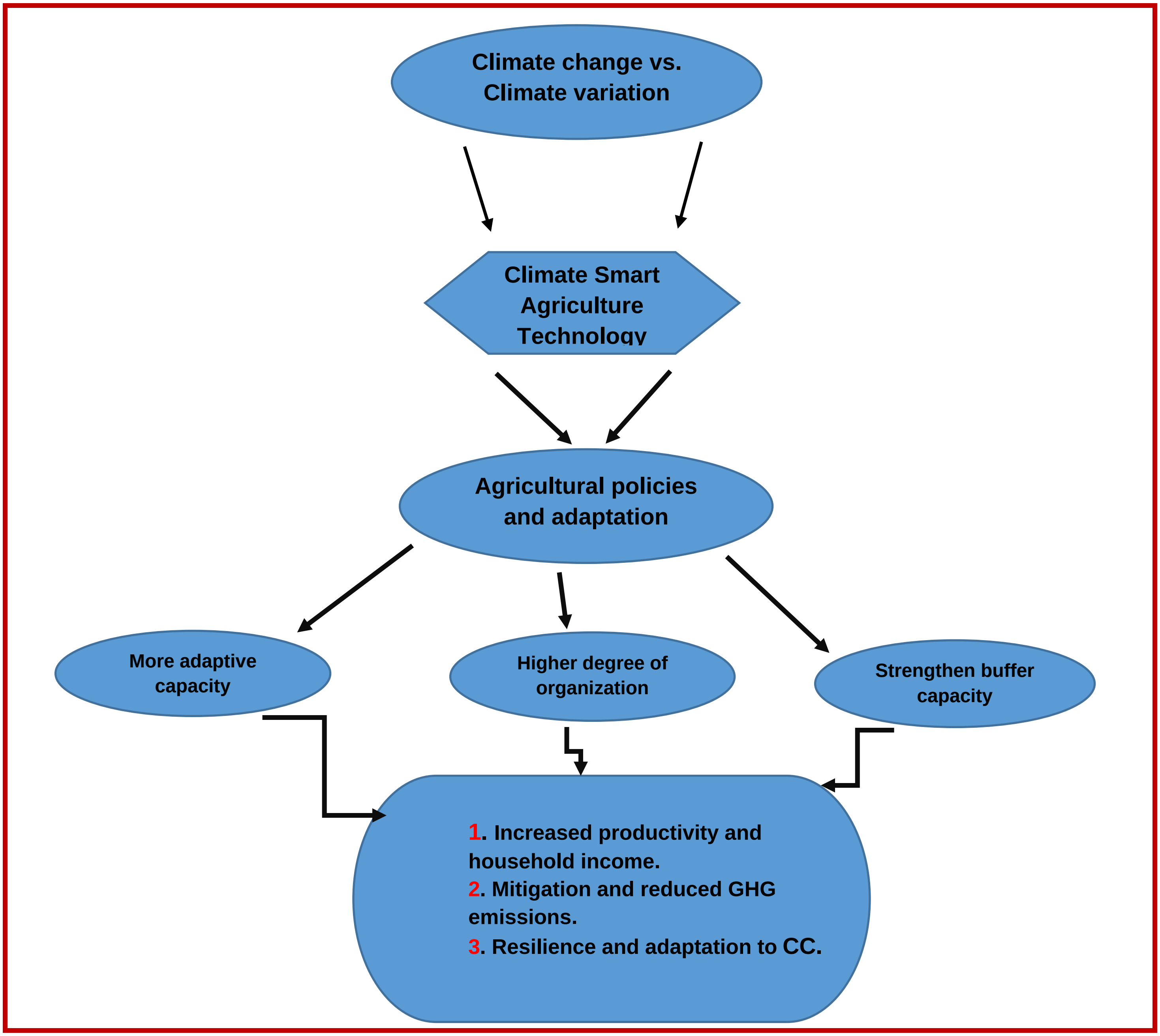

Figure 1: Conceptual framework of the study. Adopted and modified from Neubert 2011.

Conclusion and Recommendations

Climate-smart agriculture technologies are essential for optimizing agricultural operations' sustainability, resulting in increased productivity while lowering environmental impact. Climate change, global population growth, the need for food security, and the decline of human labour in agriculture, to name a few, are all pushing academics and policymakers to begin experimenting with novel agricultural practices. Therefore, research findings in this review addressed the three pillars of CSA, namely food security, adaptation, and mitigation. Because the majority of the agricultural systems that enable good CSA practices are not unique, smallholder farmers are sceptical when they are introduced. It is critical for African agricultural research and development players to properly characterize a technology or production practice as CSA-compliant technology when it qualifies. This classification is necessary to ensure that various bits of knowledge, technologies, and inventions disseminated under the CSA label are packaged properly. Partnerships between Sub-Sahara African countries could be explored for knowledge and technology exchange, as well as capacity development. Researchers, extension agents, policymakers, and other non-state actors in Zambia need to work together more effectively to promote the use of CSA-compliant technologies and production systems. If a concerted effort is not made to widely encourage access to and use of sustainable technologies in Zambia agriculture, the first and second Sustainable Development Goals (poor eradication and zero hunger) may not be accomplished by 2030. Good capacity building and youth empowerment are recommended as ways to promote CSA technology acceptance and use in the country. Farmers should also be equipped to adjust their mindsets regarding the effects of climate change and the best practices to follow per the three pillars of CSA.

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