EFFECT OF CLIMATE SMART TECHNOLOGIES ON SMALL HOLDER FARMERS' RESILIENCE TO CLIMATE CHANGE
CASE STUDY: NAKASEKE DISTRICT, UGANDA

BY

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Dedication

This research work is dedicated to my family; my husband Mr. Kamubona Naboth, Children Joel Josiah and Joylyn, who missed my quality time as I hassled with the course. This was a hard journey to accomplish but I finally overcame the major obstacles.

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Abbreviations

AEBIOM:	European Business Association
ATAAS:	The Agricultural Technology and Agribusiness Advisory Services
CH_4:	Methane
CIAR:	Australian Centre for International Agricultural Research
CLUSA:	Cooperative League of the United States
CO_2:	Carbon dioxide
COMESA:	Common Market for Eastern and Southern Africa
CSA:	Climate Smart Agriculture
CSATs:	Climate Smart Agriculture Technologies
DFID:	Department for International Development
EPIC:	Economic and Policy Innovations for Climate Smart Agriculture
EU:	European Union
FANRPAN:	Food Agriculture and Natural Resources Policy Analysis Network
FAO:	Food and Agricultural Organization
GHG:	Green House Gases
Ha	Hectares
IFDC:	International Fertilizer Development Center
IRRI:	International Rice Research Institute
IRWH:	In-Field Rain Water Harvesting
LWG:	Live Weight Gain
MAAIF:	Ministry of Agriculture Animal Industry and Fisheries
N_2O:	Nitrous oxide
NAADS:	National Agricultural Advisory Services
NEPAD:	New Partnership for Africa's Development
OWC:	Operation Wealth Creation
REDS:	Rural Enterprise Development Services
SDG:	Sustainable Development Goal
SES:	Social Ecological System
SLM:	Sustainable Land Management

SRFSI:	Sustainable and Resilient Farming Systems Intensification
UDP:	Urea Deep Placement
UNDP:	United Nations Development Programme
UNISDR	United Nations office for Disaster Risk Reduction.
USAID:	United States Agency for International Development
WB/ GEF:	World Bank’s Global Environment Facility

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Abstract

The study examined the Effect of Climate Smart Technologies on Small Holder Farmers' Resilience to Climate Change in Nakaseke District in Uganda. A descriptive cross sectional survey design was adopted where both quantitative and qualitative approaches were used. Data was collected from 196 farmers, using questionnaires and analyzed using Statistical Package for Social scientists (SPSS) scientific package.

Findings revealed that farmers were using several climate smart technologies in the three sub counties visited. Main technologies used included; improved crop varieties like drought and disease tolerant varieties, fertilizers and planting basins use. Use of organic manure, mulching, seed priming, timely planting and crop rotation were among the indigenous practices mentioned. Other technologies included construction of physical soil conservation structures like bunds and ridges, mixed cropping, agro forestry and irrigation. These technologies were majorly implemented by Sasakawa Global 2000 (45%), NARO (25.8%), and local Government (18.4%).

To analyze the effect of the CSATs on crop output, a paired sample test was used to determine the statistical significance between the two periods i.e. Period 1(before CSATs) and Period 2(After CSATs). The periods were analysed at a confidence interval of 95% with 5% standard error. Results generated by the test confirmed that there was statistical mean difference in the output of maize, beans, cassava, sweet potatoes, coffee, and soya bean ($P<0.05$). There was however no significant increase in yields of rice and ground nuts ($P>0.05$) as a result of these CSATs.

The general perception of the respondents was that climate smart technologies mainly fertilizer use and drought resistant varieties were important for increasing their crop yields. Farmers attributed non up take of some technologies to the challenges associated with them. These challenges included lack of credit access, inadequate extension services, labour intensiveness of some technologies, land tenure system, and longtime taken for some technologies to show impact, a case of agro forestry.

In view of the farmers' perceptions and the highlighted challenges involved in adoption of the climate smart technologies, there is need for the government and other stakeholders to disseminate the climate smart technologies to more farmers at affordable costs. This will allow the farmers to easily adopt the technologies and in turn increase their crop and livestock productivity.

*Key words: Climate change, Climate smart technologies, Output, Resilience.

CHAPTER 1: INTRODUCTION

1.1 Introduction

Agriculture is the mainstay of Uganda's economy and the primary driver of economic growth and poverty alleviation. It supports livelihoods of 73 percent of the households, provides employment to about 33.8 % of the economically active population, and over 80 percent of the poorest of the population and contributes 20.9 percent to the Gross Domestic Product- GDP (UBOS, 2016).

The sector is most important in terms of food security, employment, household income, raw materials for local industry and exports to regional and international markets. It accounts for 90 percent of the country's export earnings (UBOS, 2016). Much of the agricultural production in Uganda can be described as small scale i.e. takes place at household level essentially using household labour and is mainly rain-fed. The current agriculture and food system, focuses largely on production increases and economies of scale, destroys natural resources and agro-biodiversity in unprecedented dimensions, while at the same time leaving many people without sufficient access to adequate and nutritious food. This has put the future of production at stake (Johannes *et al*., 2016). Its constraints and shortcomings are increasingly becoming obvious in the light of climate change.

In view of this, Uganda's agriculture needs significant transformation in order to address the challenges likely to be faced in achieving food security and responding to climate change.

1.2 Background of the Study

The future of the country's agricultural sector remains uncertain, with declining agricultural productivity and low yields blamed majorly on the changing climatic patterns, weather variability, reduced soil fertility, occurrence of pests and diseases and use of poor agro inputs among other factors (MAAIF, 2010). However, there is potential to combat the challenges as the country strives to achieve sustainable development goals through Sustainable Land Management (SLM) and Climate Smart Agriculture (CSA) initiatives. Such initiatives include: (1) MAAIF-UNDP-GEF SLM project in the Cattle Corridor districts; (2) MAAIF- NARO- WB/ GEF SLM

ATAAS Project (3) COMESA, UNDP and FAO project being piloted in five districts in eastern Uganda and (4) the Cooperative league of the United States (CLUSA) in northern Uganda and by Rural Enterprise Development Services (REDS) with the support of development partners including Norway, DFID, EU and USAID. In addition, the country has in place a suite of enabling macro-economic and sectoral policies, strategies and action plans that aim at catalyzing agricultural sector development and growth in a changing climate.

Climate smart Agriculture (CSA) is one of the identified priority strategies to Uganda's agricultural development and growth in the changing climate. It encompasses sustainable agricultural technologies and practices (Climate Smart Technologies-CST) that contribute to adaptation of farmers to the effects of climate change and enhance productivity. CSA programs in Uganda stem from the concerted efforts by the government to mainstream climate change considerations into the national development planning and budgeting, sectorial policies, strategies and plans. The CSA approach was designed to identify and operationalize sustainable agricultural development within the explicit parameters of climate change (MAAIF, 2010). A multi-stakeholder/multi-disciplinary National CSA task force was formed, cutting across ministries of Agriculture, Animal Industry and Fisheries (MAAIF) and Water and Environment, parastatals, civil society organization (CSOs), non-governmental organizations (NGOs), community-based organized (CBOs), private sector, researchers, academia and individuals (MAAIF and Ministry of Water and Environment,2015).

On the ground, CSA is based on a mix of climate-resilient technologies and practices for integrated farming systems and landscape management (Mwongera *et al*., 2017). The evidence base and knowledge to determine the practices that work best in a given context continue to be expanded through the testing and implementation of a broad range of practices. This work is creating a better understanding about the trade-offs that may need to be made when striving to meet the interconnected goals of food security, climate change adaptation and climate change mitigation, and about the synergies that exist between these (Ampaire *et al*., 2015).

1.3 Problem Statement

Climate change is one of the greatest challenges affecting the world today and increasingly becoming a primary determinant of agricultural production in Uganda. It affects agriculture in several ways, one of which is its direct impact on crop productivity and sustainability. Some of its effects include unpredictable rainfall sequences characterized by unusual hailstorms and floods, droughts, increased insect pests' pressures and disease incidences, soil degradation and reduced crop yields.

The Government of Uganda through the Ministry of Agriculture Animal Industry and Fisheries (MAAIF) has partnered with non- government organizations (NGOs), research and private sector to intervene by developing and promoting climate smart technologies and innovations to build resilience of farmers. The concept of Climate-Smart Agriculture (CSA) was put forward as a solution to the interrelated challenges of climate change and food security. Yet it is focused heavily on food production and increasing yields through input-based, technical "solutions".

Despite the efforts, it appears that for many small holder farmers, climate smart technological advancement never materialized for reasons not clearly understood. Until now, farmers including those that have been taught about technical solutions still continue to alarm on seasonal failures due to harsh weather in form of prolonged dry spells, hailstorms and floods, pests and diseases resulting into very low yields. Food crises, water shortages and disease outbreaks are on the raise due to prolonged dry spells and droughts.

These pose questions on whether the climate smart technologies are not reaching farmers in rural areas, whether the farmers are not adopting them, whether the technologies are too difficult to be taken up, or they may not be the right technologies for farmers? The above scenarios pose questions to the existing systems. Yet, not much linkage has been done empirically to demystify the proposition surrounding the impact of selected climate smart technologies on resilience to climate change and this has created a knowledge gap. It is against this background that this work sought to examine the impact of selected climate smart technologies on resilience to climate change among small holder farmers in Nakaseke district, Uganda.

1.4 Main Objective of the Study

The main objective of the study was to evaluate the effect of selected climate smart technologies on resilience to climate change among small holder farmers in Uganda.

1.4.1 Specific objectives of the study

The specific objectives of the study are:

a) To establish the various (indigenous and introduced) Climate Smart Technologies being practiced by small holder farmers.
b) To analyze the effect of Climate Smart Technology packages on small holder farmers' output.
c) To examine small holder farmers' perception on the introduced climate smart technologies towards climate resilience
d) To establish the challenges small holder farmers face in adoption and sustainable use of key climate smart technologies in the area of study

1.4.2 Research questions

This study sought to answer the following questions:

a) What climate smart technologies are being practiced by farmers in Nakaseke district?
b) What impact do climate smart technologies have on small holder farmers' output?
c) What is the perception of small holder farmers on climate smart technologies? Are the technologies smart or not?
d) What challenges do small holder farmers in Nakaseke District encounter when adopting / implementing climate smart technologies?

1.5 Conceptual Framework

This sub section illustrates the conceptual framework of the study and provides a discussion of the main areas of focus in the conceptual review. It sought to delineate the palpable and crucial link between the issues and as a final point it seeks to summarize the conceptual framework for the study.

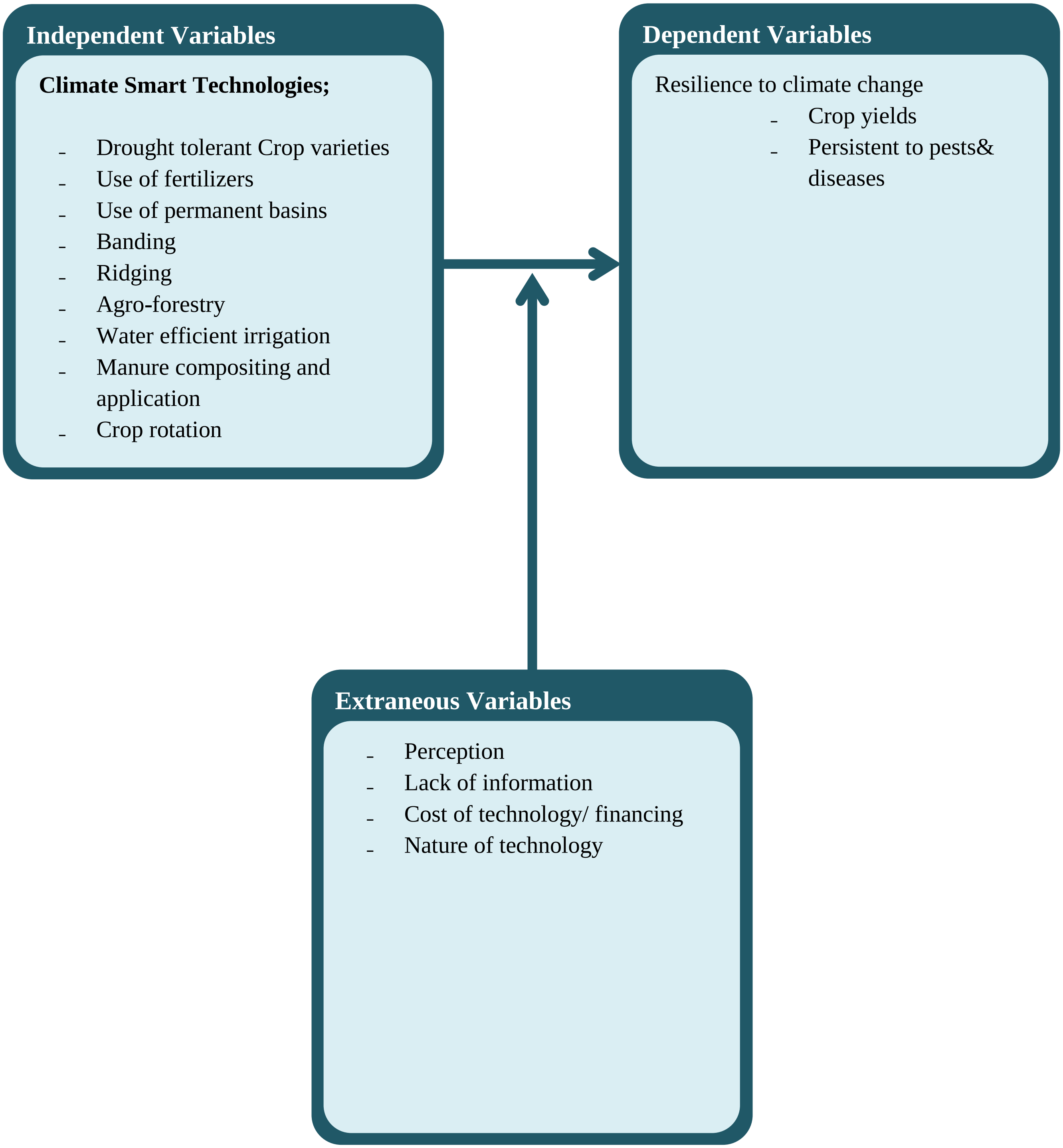

Figure 1: Conceptual framework illustrating the relationship between the study variables

A conceptual model developed above is intended to facilitate the understanding of elements of climate smart technologies that can contribute to farmers ‘resilience to climate change and enhance adaptive decision making. Climate Smart technologies have multiple entry points, ranging from the development of technologies and practices to the elaboration of climate change models and scenarios, information technologies, insurance schemes, value chains and the strengthening of institutional and political enabling environments. As such, it goes beyond single technologies at the farm level and includes the integration of multiple interventions at the food system, landscape, and value chain or policy level. To achieve food security goals and enhance resilience, government approaches must involve the poorest and most vulnerable groups. These groups often live on marginal lands which are most vulnerable to climate events and disasters like drought and floods. They are, thus, most likely to be affected by climate change. By involving all local, regional and national stakeholders in decision-making, it is possible to identify the most appropriate interventions and form the partnerships and alliances needed to enable sustainable development.

Smit *et al*., (2000) identify key factors that help to explain decisions regarding managing weather/climate risk, which include climate related stimuli, aspects of scale and responsibility, the form of adaptation, non-climatic factors/conditions, and finally evaluation of adaptation effects. The concept of climate-related stimuli refers to the form, timing, and severity of a given climate signal (Smit *et al*., 2000). Scale and responsibility refer to whom or what entity is adapting and at what scale, including the intent and purposefulness of the adaptation (autonomous or planned) as well as the timing and duration (anticipatory, concurrent, or reactive) (Smit and Skinner, 2002). The same authors identify four major forms of adaptation in the agricultural sector; technical development, government/insurance, farm production practices, and farm. In this case the most applicable is technical development, government/insurance and farm production practices.

1.6 Significance of the Study

The research findings will be of importance to a number of stakeholders. It is hoped that: It is hoped that the study will be used to develop a more comprehensive on climate smart technologies applications.

The study will give the researcher a more practical analytical insight relating theory to practice. In this regard, the study will broaden the researcher's knowledge on Climate Smart Technologies. The study will act as a reference point for researchers who will pursue further research on Climate Smart Technologies. The study may add value to the body of existing knowledge and perhaps lead to ventures in further research thus it will contribute to the existing literature. Through the resultant interaction between the researcher and the respondents, the researcher's knowledge, skills and understanding of research may improve.

1.7 Justification of the Study

Climate change is real and one of the greatest challenges affecting the world today and a primary determinant of agricultural production and development in many developing countries. It affects agriculture in several ways, one of which is its direct impact on crop productivity and sustainability (Ziervogel *et al*., 2014). In Uganda, it is already having an impact on agriculture and food security as a result of increased prevalence of extreme events and increased unpredictability of weather patterns with frequent episodes of unusual floods, droughts and hailstones which have had negative socio-economic impacts on agricultural production. It remains unclear whether there are gaps as far as the impact of selected climate smart technologies on resilience to climate change among small holder farmers in Uganda. Moreover, to date, not many studies have been done to examine the impact of selected climate smart technologies on resilience to climate change among small holder farmers in Uganda.

1.8 Scope of the Study

The study was conducted in three sub counties of Kikamulo, Semuto and Nakaseke in Nakaseke District (*See Fig: 3.1 and 3.2)*. It searched for the different climate smart technologies introduced to farmers by different organizations since 2012 to date. It addressed the afore-mentioned research questions with the aim of re-examining the climate smart technologies that have been promoted and are sustainably used by smallholder farmers. The study also examined the impact of those practices, looked into the challenges in adoption of such technologies and the strategies to address the challenges.

1.9 Operational Definition to Key Terms and Concepts

This sub section presents operational definitions to key terms and concepts which are:

Climate change:

Deviation from the average weather over time, characterised by long term changes in temperature, wind patterns and precipitation.

Climate Smart Agriculture

An applied set of farming principles and practices that increases productivity in an environmentally and socially sustainable way (*adaptation*); strengthens farmers' capacities to cope with the effects and impacts of climate change (*resilience*); conserves the natural resource base through maintaining and recycling organic matter in soils (*carbon storage*); and, as a result reduces greenhouse gas emissions (*mitigation*).

Resilience

The ability of a system to absorb disturbances and still retain its basic function and structure. Ability of a production landscape to absorb or recover, in terms of both ecosystem processes and socio-economic activity from various pressures and disturbances without lasting damage

Sustainable development

Development that meets the need of the present generation without compromising the ability of the future generation to meet their own needs

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter outlines the literature on the various variables of this study; these are presented in line with the study objectives. The literature is from Journals, text books and electronic materials both published and unpublished.

2.2 Climate Smart Agriculture Concept

Climate-Smart Agriculture (CSA) represents a set of strategies that can help to meet the challenges caused by climate change by increasing resilience to weather extremes, adapting to climate change and decreasing agriculture's greenhouse gas (GHG) emissions that contribute to global warming. It is an agricultural system that sustainably increases productivity, resilience and/or adaptation, reduces/removes greenhouse gases (mitigation) and enhances achievement of national food security and development goals (FAO, 2010; Lipper *et al*., 2014). The concept of CSA offers an integrated and systemic response to the combined challenges of food security, adaptation and adoption of smallholder farming practices, and natural resource conservation (FANRPAN, 2013). CSA centers on preparing small holder farmers for productive change and sustainability in their farming system and practices.

Globally, agricultural and forestry systems are expected to change significantly in response to future climate change, manifesting as major transitions in livelihoods and landscapes (Vermeulen*et al*., 2012). During the few past decades, crop yields have been reduced because of warming (Lobell*et al*., 2011), and the results of modeling studies suggest that climate change will reduce food crop yield potential, particularly in many tropical and mid latitude countries (Rosenzweig *et al*., 2014).

Rising atmospheric CO2 concentrations will decrease food and forage quality (Myers *et al*., 2014). Price and yield volatility will most likely continue to rise as extreme weather continues, further harming livelihoods and putting food security at risk (Wheeler *et al*., 2013).

Global demand for agricultural products, be they food, fiber or fuel, continues to increase because of population growth, changes in diet related to increases in per capita income and the need for alternative energy sources while there is less and less additional land available for agricultural expansion. Agriculture thus needs to produce more on the same amount of land while adapting to a changing climate and must become more resilient to risk derived from extreme weather events such as droughts and floods.

Foley *et al*.,(2011) pointed out that climate smart agriculture was put forward to combat the negative contributions of conventional agriculture such as biodiversity loss, climate change, and degradation of terrestrial and fresh water systems. There was a global challenge to develop sustainable agricultural systems to produce enough food for the growing population and adapt to the changes in climate while maintaining lower carbon footprints and staying in critical ecological thresholds (Lal, 2010; FAO, 2011). The study is silent on the impact of climate smart technologies yet it was the central focus of this study.

According to the Uganda CSA draft program 2015-2025, CSA is designed to reduce vulnerability of Uganda's agriculture sector by increasing productivity, enhancing adaptation and resilience of the farming systems and reducing emissions intensity in the context of achieving sustainable development and poverty eradication (MAAIF, 2015). CSA is an integrated (holistic) approach that considers input supply, production, agricultural services, marketing and business support services as necessary building blocks. Under the approach, both public and private sectors are seen as critical actors in the value chain. Knowledge and capacity building are critical strategic priorities to leverage innovations and increase efficiencies. The approach also provides enabling framework for integrating gender and the needs of the youth.

In Uganda, Climate Smart Agriculture programs stem from the concerted efforts by the government to mainstream climate change considerations into the national development planning and budgeting, sectoral policies, strategies and plans. The CSA approach was designed to identify and operationalize sustainable agricultural development within the explicit parameters of climate change. A multi-stakeholder/multi-disciplinary National CSA task force was formed, cutting across ministries of Agriculture, Animal Industry and Fisheries (MAAIF) and Water and Environment, parastatals, civil society organization (CSOs), non-governmental organizations

(NGOs), community-based organized (CBOs), private sector, researchers, academia and individuals (MAAIF and Ministry of Water and Environment,2015).

2.3 Climate Resilience

Climate change poses serious threats to agriculture and such include increased temperatures, shifts in rainfall distribution and increased frequency of extreme weather events are expected to adversely affect agricultural production and productivity around the world. With the rising awareness of climate change impacts by both national and international bodies, building climate resilience has become a major goal for many institutions. The key focus of climate resilience efforts is to address the vulnerability with regards to the environmental consequences of climate change. Currently, climate resilience efforts encompass social, economic, technological, and political strategies that are being implemented at all scales of society (Lal, 2010). However, it appears that a wide array of adaptation options have been put in place to cope up with climate change as well as build farmer's resilience.

Resilience refers to the ability of a production landscape to absorb or recover, in terms of both ecosystem processes and socio-economic activity from various pressures and disturbances without lasting damage (Lal, 2010). More generally, resilience refers to the capacity of a system to deal with change and continue to develop; withstanding shocks and disturbances and using such events to catalyze renewal and innovation. Climate resilience therefore means the ability for a landscape to absorb or recover from various pressures and disturbances resulting from climatic changes. In essence, actions that bolster climate resilience are ones that will enhance the adaptive capacity of social, industrial, and environmental infrastructures that can mitigate the effects of climate change (Adger, 2005).

2.3.1 Climate-resilient development

Climate-resilient development means ensuring that people, communities, businesses, and other organizations are able to cope with current climate variability as well as adapt to future climate change, preserving development gains, and minimizing damages (Lal, 2010).

The concept is about adding consideration of climate impacts and opportunities to development decision-making in order to improve development outcomes, rather than implementing development activities in a completely new way. Climate risks cannot be eliminated, but negative impacts on people and economies can be reduced or managed. Climate-resilient development helps minimize the costs and consequences of climate impacts so they do not hinder progress toward development goals. In bridging the gap, the researcher notes that there is a wide variety of actions that can be pursued to improve climate resilience at multiple scales. The 2015-2030 agenda for Sustainable Development (composed of 17 SFGs) is a plan of action that seeks to strengthen universal peace, eradicate poverty and enhance sustainable development. This puts emphasis on environmental sustainability (climate action), clean energy production (conservation), targets to reduce poverty and hunger thereby promoting economic growth of a country. Therefore, it calls for every one's responsibility, Government, NGOs and communities in to embrace and adopt the development agenda so as to safeguards the environment, social and economic assets and hence become more resilient.

Kibria (2015) noted that Climate Financing is a key element for climate resilient development. It directly influences most of the adaption and mitigation development programs in line with the SDGs, essential in climate resilient development. The same author observes that SDG elements like disaster management, climate resilient infrastructure, climate smart food production (agriculture, aquaculture), water and health security, clean/renewable energy and afforestation/reforestation programmes and many related SDG variables all require sustainable financing, thus Climate Financing. Climate financing would make it possible for research and technology development, construction of soil conservation structures, energy saving technologies, training and capacity development which are all relevant to the SDGs.

2.3.2 Climate resilience and Sustainable Development Goals (SDGs)

Climate resilience is key to achieving sustainable development goals. Delivering on the promise of global development commitments including the possibility to end extreme poverty by 2030 requires building resilience to the growing impacts of climate change and associated disasters. Specifically, SDGs 9, 11 &13 are closely related to building communities resilience to climate change (Lal, 2010). SDG 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. This SDG aims at developing quality, reliable, sustainable and resilient infrastructure, including regional and Trans- border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all. It also strives to facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and Small Island developing States, enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending. Further, this SDG focuses on support to domestic technology development, research and innovation in developing countries, by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities.

SDG No. 11: Make cities and human settlements inclusive, safe, resilient and sustainable. This SDG targets among others to; substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations. It supports the reduction of adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management. It also provides for universal access to safe, inclusive and accessible, green and public spaces. It seeks to substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels by 2020 (UNISDR, 2015).

Uganda was one of the first countries to develop its 2015/16–2019/20 national development plan in line with the SDGs. The Government estimates that 76 per cent of the SDGs targets are reflected in the plan and adapted to the national context. The UN Country Team has supported the government to integrate the SDGs also into sub-national development plans, in line with the national plan.

The Financing Agreement for the new Climate Fund, signed between the government of Uganda and UNDP on August 23rd 2017, is an indicator that plans are under way to address climate change impacts and build communities' resilience while enhancing implementation of global sustainable development goals. The new climate fund project will be geared towards wetland restoration, building community resilience and development of early warning systems (UNDP report, 2017). This will result into realization of Vision 2040 as well as Global Sustainable Development Goals in Uganda.

2.4 Climate Smart Technologies for Small Holder Farmers

Climate-smart agriculture has the potential to increase sustainable productivity, increase the resilience of farming systems to climate impacts and mitigate climate change through greenhouse gas emission reductions and carbon sequestration. A number of technologies have been developed, tested, adapted and adopted by small holder farmers in Uganda. Neufeldt *et al*.,(2011) categorized climate smart technologies into crop management practices (intercropping, crop rotation, new crop varieties, crop diversity and improved storage and processing techniques); livestock management (improved feeding strategies (e.g. cut and carry) rotational grazing, fodder crops, grassland restoration, manure treatment and improved livestock health. Soil and water conservation strategies included conservation agriculture, contour planting, terracing, planting pits, water storage and alternative wetting and drying as for rice. Agro forestry is also emphasized and practices here include boundary trees and hedgerows, on farm nitrogen fixing trees, improved fallows with fertilizer shrubs, woodlots and fruit orchards. Under integrated food energy systems are biogas production, production of energy plants and promotion of improved stoves (Neufeldt *et al*., 2011).

The Food Agriculture and Natural Resources Policy Analysis Network (FANRPAN) declares In-Field Rain Water Harvesting (IRWH) as one good example of a sustainable climate smart technology affordable for small holder farmers. It involves the capture and retention of rainfall runoff within fields. Rainfall runs off compacted strips or bunds and is collected in small basins running along crop rows. The basin areas are covered with locally available mulch to further retain soil moisture. Water harvested and stored in this fashion is then available for crop, fodder, fruit or vegetable production. In-field rain water harvesting is considered a climate smart approach because it increases the plant availability and productivity of rainwater.

The practice is very suitable for farmers in semi-arid areas as this will conserve limited rain water for longer periods allowing farmers to grow crops despite low and erratic rainfall.
In addition, this practice helps conserve nearly 10% more carbon than traditional tillage methods. If also significantly reduces soil erosion and nutrient depletion since there is controlled runoff (Amy *et al*., 2013).

In relation to IRWH are Zai Pits.These pits consist of dug holes roughly 15cm x 15cm, which are then filled with manure to improve soil fertility. The practice can help rejuvenate degraded soils by breaking up the soil crust to improve water infiltration and adding manure to improve soil fertility. Zai pits increase soil water holding capacity by up to 5 times while collecting up to 25% of the runoff in the immediate area surrounding the hole (Lal, 2010).

According to Thornton and Herrero, (2010), agro-forestry is one of the technologies adopted to mitigate climate change. It is an integrated approach to the production of trees and non-tree crops or animals on the same piece of land. Agro-forestry is important both for climate change mitigation (carbon sequestration, improved feed and consequently reduced enteric methane) and for adaptation in that it improves the resilience of agricultural production to climate variability by using trees to intensify and diversify production and buffer farming systems against hazards. Shade trees reduce heat stress on animals and help increase productivity. Trees also improve the supply and quality of forage, which can help reduce overgrazing and curb land degradation. The study is silent on the aspect of resilience yet it is very important for this particular study.

One of the main strategies for mitigating climate change is through rotational grazing, which can be adjusted to the frequency and timing of the livestock's grazing needs and better matches these needs with the availability of pasture resources. Rotational grazing allows for the maintenance of forages at a relatively earlier growth stage. This enhances the quality and digestibility of the forage, improves the productivity of the system and reduces CH_4 emissions per unit of LWG (Eagle*et al*., 2012). It is important to note that rotational grazing is more suited to manage pasture systems, where investment costs for fencing and watering points, additional labour and more intensive management are more likely to be recouped.

Recent developments in energy policy have also enhanced its economic profitability in countries such as Germany and Denmark (AEBIOM, 2009). Manure application practices can also reduce N2O emissions. Improved livestock diets, as well as feed additives, can substantially reduce CH4 emissions from enteric fermentation and manure storage (FAO, 2009b). Energy-saving practices have also been demonstrated to be effective in reducing the dependence of intensive systems on fossil fuels. However, it is observed that by this, the resilience of the local communities to climate change is strengthened.

Furthermore, Lal, (2009) reported integrated soil-crop-water management as one of the adopted technologies to respond to climate change and enhance resilience. He said soil and water are intrinsically linked to crop and livestock production and for that reason, an integrated approach to soil and water management is vital for increasing efficiency in the use of resources, adapting to and mitigating climate change and sustaining productivity. For example, increasing the organic content of the soil through conservation tillage improves the soil's water holding capacity, reduces erosion and makes yields more resilient. Existing soil and water adaptation technologies include: minimum or zero tillage; erosion control; the use of crop residues to conserve soil moisture and improved soil cover through cover crops. By increasing water infiltration, reducing evaporation and increasing storage of rainwater in soils, many crop management practices (e.g. mulching, green manures, conservation tillage and conservation agriculture) help land users in areas projected to receive lower levels of precipitation adapt to climate change.

Promoting the capture of carbon in the soil is also being use to mitigates climate change. Soil management practices that limit soil compaction reduce tillage and retain crop residues lower the potential for N2O loss, increase soil carbon and at the same time improve yields. In addition, managing pests, diseases or weeds using technologies such as the 'pull-and-push technology' can contribute to improving the availability of food and animal feed in crop livestock systems (Lenné and Thomas, 2005). The study was carried out in a developed nation compared to the current study that was carried out in a developing nation Uganda

Thornton(2009) stated that diversification of sensitive production systems can enhance adaptation to the short- and medium-term impacts from climate change which eventually enhance resiliency. Transitions within mixed farming systems are already occurring.

In marginal areas of southern Africa, reductions in length of growing period and increased rainfall variability are leading to conversions from mixed crop livestock systems to rangeland-based systems, as farmers find growing crops too risky in marginal environments. Changing the mix of farm products (e.g. proportion of crops to pastures) is an example of a farm-level adaptation option. Farmers may reassess the crops and varieties they grow, and shift from growing crops to raising livestock, which can serve as marketable insurance in times of drought. They may also introduce heat-tolerant breeds that are more resistant to drought. In a case study covering villages in three South African provinces, Thomas (2007) found that during dry spells farmers tended to reduce their investment in crops or even stop planting altogether and focused instead on livestock production.

Animal breeding to select more productive animals is another strategy to enhance productivity and thereby lower CH4 emission intensities. Research has recently been done on the mitigation benefits of using residual feed intake as a selection tool for low CH4 emitting animals, but so far findings have been inconclusive (Waghorn and Hegarty, 2011). There is also evidence that cross-breeding programmes can deliver simultaneous adaptation, food security and mitigation benefits. For example, composite cattle breeds developed in recent decades in tropical grasslands of northern Australia have demonstrated greater heat tolerance, disease resistance, fitness and reproductive traits compared with pure shorthorn breeds that had previously dominated these harsh regions. In general, cross-breeding strategies that make use of locally adapted breeds, which are not only tolerant to heat and poor nutrition, but also to parasites and diseases, has become more common with climate change.

A finding from Pascal and Socolow (2005) revealed that carbon sequestration in soils has the potential to mitigate climate change and bolster climate change adaptation and the climate-smart strategy involves creating a positive carbon budget in soils and ecosystems by using residues as mulch in combination with no-till farming and integrated nutrient management (i.e. the

appropriate application of both synthetic and organic fertilizer). In addition, soil carbon sequestration delivers numerous ancillary benefits by improving soil quality and other ecosystem services. Other technologies are restoration of degraded soils, through increases in soil organic carbon pools, improves production which helps foster food security and improves nutrition.
Increasing the pool of soil organic carbon is also important for improving efficiency in the use of nitrogen and potassium. Water quality also improves through a greater control of non-point source pollution, (Lal, 2009).

Pasture management measures involve the sowing of improved varieties of pasture, typically the replacement of native grasses with higher yielding and more digestible forages, including perennial fodders, pastures and legumes. For example, in tropical grazing systems of Latin America, substantial improvements in soil carbon storage and farm productivity, as well as reductions in enteric emission intensities, are possible by replacing natural cerrado vegetation with deep-rooted pastures such as Brachiaria (Thornton and Herrero, 2010). However, there are far fewer opportunities for sowing improved pastures in arid and semi-arid grazing systems.

The intensification of pasture production though fertilization, cutting regimes and irrigation practices may also enhance productivity, soil carbon, pasture quality and animal performance. These approaches however, may not always reduce GHG emissions. Improved pasture quality through nitrogen fertilization may involve tradeoffs between lower CH4 emissions and higher N2O emissions (Smit*et al*., 2006).

Herrero *et al.,* (2011) pointed to sustainable soil management as one of the ways to mitigate climate change. He estimates that crop residues can represent up to 50 percent of the diet of ruminants in mixed farming systems. While these feed resources provide an inexpensive feed source, they are usually of low digestibility and deficient in crude protein, minerals and vitamins. This low digestibility substantially limits productivity and increases CH4 emissions. Increasing the digestibility of feed rations by improving the quality of crop residues, or supplementing diets with concentrates reduce CH4 emissions. Other existing feed management practices in mixed farming systems include the use of improved grass species and forage legumes. Animal productivity can be improved by using a multidimensional approach for improving the quality and thereby the utilization of food-feed crops. This can also lead to a reduction in animal numbers, lower feed requirements and reduced GHG emissions which eventually enhance resiliency to climate changes (Herrero,*et al*.,2011).

2.5 Impact of Climate Smart Technologies on Small Holder Farmers' Output

Weather variability as an effect of climate change has greatly contributed to low yields. Low yields are also resulting from poor farming practices and this challenges food security (NEPAD), 2003). Generations of researchers and practitioners have sought appropriate ways for smallholder farmers to increase their production and productivity, given their resource constraints (Kiratu, 2014). Climate Smart Agriculture (CSA) has been an identified alternative that can increase agricultural productivity, while at the same time mitigating the multiple effects of climate change. A range of climate smart agricultural technologies and practices is available for Small holder farmers to minimize the adverse effects of climate change and variability. However, the set technologies to be taken up; depends largely on the economic benefits associated with the technology (Arun 2016). Every small holder farmer strives to have improved yield for food and income security and the respective practices adopted must be those that will have a contribution to increased yields per unit area.

Different climate smart practices have been reported to have varying contributions to increased crop yields among farmers in Sub Saharan Africa. These are achieved in different agronomic aspects that include soil fertility improvement, provision of enough cover for soil protection, provision of micro climate for pest and disease management and other as shall be discusses below.

2.5.1 Intercropping

This practice has been reported to have a number of benefits. One rare example often not quoted by many agronomists is provision of micro climate. One crop may provide favorable micro-climate for another growing in association. Shading effect in some of the intercrops may reduce plant temperatures and so favor productivity and partitioning of the manufactured food, resulting in high yield. The shade from the tall crops can reduce day temperatures and this in turn reduces leaf temperature (Neufeldt *et al*., 2011). Reduced leaf temperature in areas with high day temperatures; results in increased net assimilation rate.

Traditional intercropping is also well appreciated for increasing yield stability. Kagoda *et al*., 2016 noted that farmers practice intercropping as an insurance against insect pests, diseases, and weather and price fluctuations, to ensure stable ‘yields. The authors affirm that intercropping systems give more stable yields than sole cropping systems. Under intercropping, when one component crop suffers from drought, pests or diseases and does not perform properly, the loss of this crop is compensated partially by the other component crop since there is now less competition for resources.

Intercropping has been said to contribute to improved crop yield because of its relevant role in weed management. It is one of the major practices in achieving integrated weed and pest management. Rao, 2013 reported a decreased intensity of weed infestation in a pigeonpeas/sorghum intercrop as compared to their sole crops. Balosubramanian (2015) stated that the more complete cover provided by intercropping reduces weed growth by competition for light and other resources. According to Balosubramanian (2015), pulses reduce weed population and dry matter when grown as intercrops with sorghum as compared to sole crops of sorghum. The same author reported further that weed smothering efficiency of pulses in intercropping ranged from 28.3 - 36.2%. This is because in intercropping the total canopy at any one time is higher than in sole cropping and the ground is covered quickly due to the simultaneous growth of two crops or more. The larger canopy thus obtained competes better for inputs, creating an environment unfavorable for weed growth (Rao, 2013). The same author stated that the more complete crop cover and high plant density available in intercrops cause severe competition with weeds and reduce weed growth. Lastly soil fertility improvement through provision of nitrogen in legume/non-legume association is a key feature of intercropping that leads to yield increase (Rao, 2013).

2.5.2 Crop diversification

This ensures differential nutrient uptake and use between two crops. For instance, inclusion of nitrogen fixing crops such as groundnuts, beans, and cowpeas will enhance soil fertility and nutrient supply to subsequent crops and eventually improves yields. Crop diversification over time can be considered as a safety net on farmers' income if one crop is severely affected by the climate extremes (Campbell *et al*., 2011).

2.5.3 Fertilizer use

Okoboi(2012) reported that the low crop yields in Uganda are due to low or no use of improved technologies like fertilizer use and improved seeds. This reduces profits and leads to low incomes among small holder farmers. Okoboi further affirms that application of fertilizers to improved maize seed results into higher yields than planting similar improved seed without fertilizer. Fertilizers particularly potassium based fertilizers like Korn Kali are good at responding to the effects of dry spells. They help the plant resist water stress, improve water and nutrient uptake by the plant and enhance proper grain filling thus enhancing yields (Magambo *et al*., 2016).

The Urea Deep Placement (UDP) technique, developed by the International Rice Research Institute (IRRI) and International Fertilizer Development Center (IFDC), is a good example of a climate-smart solution for rice systems. In the UDP technique, urea is made into "briquettes" of 1 to 3 grams that are placed at 7 to 10 cm soil depth after the paddy is transplanted. This technique decreases nitrogen losses by 40 percent and increases urea efficiency to 50 percent. It also increases yield by 25 percent with an average 25 percent decrease in urea use. UDP has been actively promoted by the Bangladesh Department of Agricultural Extension with IFDC assistance. According to IFDC, imports of urea have been reduced, with savings in import costs estimated at USD 22 million and in government subsidies of USD 14 million (2008), for an increase of production of 268 000 metric tons (FAO, 2014). Globally, UDP has reduced GHG emissions caused by the production and management of fertilizers. It also increases the agricultural system's resilience. As fertilizers prices are linked to energy prices, and consequently very volatile, reducing fertilizer use also increases farm and country's resilience to economic shocks.

In-Field Rain Water Harvesting (IRWH), Small Reservoirs and Zai Pits. In-Field Rain Water Harvesting (IRWH) promotes the capture and retention of rainfall runoff within fields. With this

technology, rainfall runs off compacted strips or bunds and is collected in rectangular basins running along crop rows and infiltrating deep into the soil beneath the surface evaporation zone. The basin areas are covered with locally available mulch to further retain soil moisture.
Water harvested and stored in this fashion is then available for crop, fodder, fruit or vegetable production (Lal, 2010).

2.6 Challenges Small Holder Farmers Encounter when Adopting CSAs

According to a report by Wisner *et al*.,2004, the vulnerability of agriculture is not determined by the nature and magnitude of environmental stress like climate change per season, but by the combination of the societal capacity to cope with and/or recover from environmental change. While the coping capacity and degree of exposure is related to environmental changes, they are both also related to changes in societal aspects such as land use and cultural practices.

Lack of education, information and training is frequently a key limiting factor to smallholder development. The report of IFAD (2007) confirmed that the poor state of the country's education has also had its toll on the poor people, majority of who are farmers in rural areas. In addition, they are faced with limited social services and infrastructure.

McCornick(2013) stated that there is lack of data and information and appropriate analytical tools at local and national levels. He explained that in many African countries, there are no long-term climatic and landscape level data and where some data exist they are dispersed and difficult to access. He said global models of climate change are at scale and resolution difficult for local, national or regional managers to work with and the capacity and analytical tools to downscale the results of global models to regional, national and watershed scales are not readily available in most countries.

As a result, decision makers lack knowledge of current and future projected effects of climate change in their country and the implications for agricultural practices, food security and natural resource management. The lack of information, limited human and institutional capacity as well as lack of research-based evidence impedes the ability of decision makers to target CSA implementation to areas most at risk and to implement adequate financing plans.

Although farmers have always adapted and coped with climate variability manifested, for example, in delayed onset of rains, seasonal water deficit and increasing seasonal maximum temperature, they often lack knowledge about potential feasible options for adapting their production systems to increasing frequency and severity of extreme weather events (droughts and floods) and other climate changes. Another constraint concerns land tenure and access to land and water resources. Millions of poor farmers, including women hold tenuous and unsecured water and land rights in many parts of SA. Existing customary and institutional factors as well new drivers, for example, large-scale foreign investment in agricultural land that leads to the displacement of current poor land users have exacerbated this state of affairs (Williams, 2012; Williams, 2014). At another level, lack of accurate and timely information and technical advisory services, unavailability and lack of access to inputs, including suitable crop varieties constrain their ability to assess the risks and benefits of CSA and make informed investment decisions. Competing resource use (e.g. labour, cash, biomass) at the farm scale have been a major constraining factor. Furthermore, smallholders in particular face obstacles in gaining access to domestic, regional and international markets.

Socioeconomic factors also limit the widespread implementation of climate-smart agriculture, even where policy is appropriate and funding is sufficient. Poverty, cultural factors, income, education, access to markets and credit, investment costs, institutional capacity and lack of land and tree tenure, among others are all known to affect the effective adoption of sustainable agricultural practices and farmer land-use decisions (McCarthy, 2011). In many cases, the lack of clear land or tree tenure makes it difficult for farmers to adopt sustainable agricultural practices (Benard, *et al*., 2015).

Williams (2014) pointed inadequate empowerment of women and youth to be one of the challenges in the implementation of CSA among small scale farmers. According to his statement, women contribute significantly to food production in Africa, yet remain marginalized and lack access to factors of production. He pointed out that gender stereotypes on such issues as land and water rights, education, access to technologies, labour, capital, support services and credit, are some of the stumbling blocks to women's effective participation in the agricultural sector. The author concluded that overlooking women means Africa is losing out on a great income and livelihood creating opportunity as the World Bank estimated that if women worldwide had equal access to productive resources (seeds, extension services, etc.), 100-150 million fewer people would go hungry every day.

There is also lack of adequate and innovative financing mechanisms and effective risk-sharing schemes. In many countries there are no financing plans to promote the uptake of CSA, yet the transition to climate-smart agricultural development pathways requires new investments.
As farmers in Africa face major risks arising from the effects of climatic hazards, they also face the challenge of managing risks associated with the high costs (at least initial costs) of adopting new technologies (e.g. conservation agriculture and agro forestry) whose benefits often only come after several years/seasons) of production. Most of the farmers have little or no access to credit, micro-financing and/or insurance (Mapfumo *et al*., 2015).

CHAPTER 3: METHODS AND MATERIALS

3.1 Introduction

This chapter presents and describes the approaches and techniques used to collect and handle data in this study. These include the research design, study population, sample size and selection, sampling techniques and procedure, data collection method, data collection instrument, data quality control (validity and reliability), procedures of data collection, data analysis and measurement of variables.

3.2 Research Design

A descriptive cross sectional survey design was adopted for the study. This entailed collecting data from a cross section of respondents at a single point in time as stated by Kothari (2004). The study also applied both quantitative and qualitative approaches. Creswell (2009) noted that quantitative methods are more objective and help to investigate the relationships between the identified variables. This study applied qualitative approaches which involved in depths probe and application of subjectively interpreted data. The quantitative and qualitative approaches were adopted in sampling, collection of data, data quality control and in data analysis. Triangulation was adopted for purposes of getting quality data but also as a way of assuring the validity of research through the use of a variety of methods to collect data on the same topic, which involves different types of samples as well as methods of data collection (Creswell,2009).

3.3 Study Area

The study was carried out in Nakaseke District found in Central Uganda. The district is bordered by Nakasongola District to the north and northeast, Luweero District to the southeast, Wakiso District to the south, Mityana District to the southwest; while Kyankwanzi and Masindi Districts lie to the west and northwest respectively. The location of the district headquarters lies approximately 66 kilometers (41 miles), by road, north of Kampala, the capital city of Uganda.*See Fig: 3.1* below.

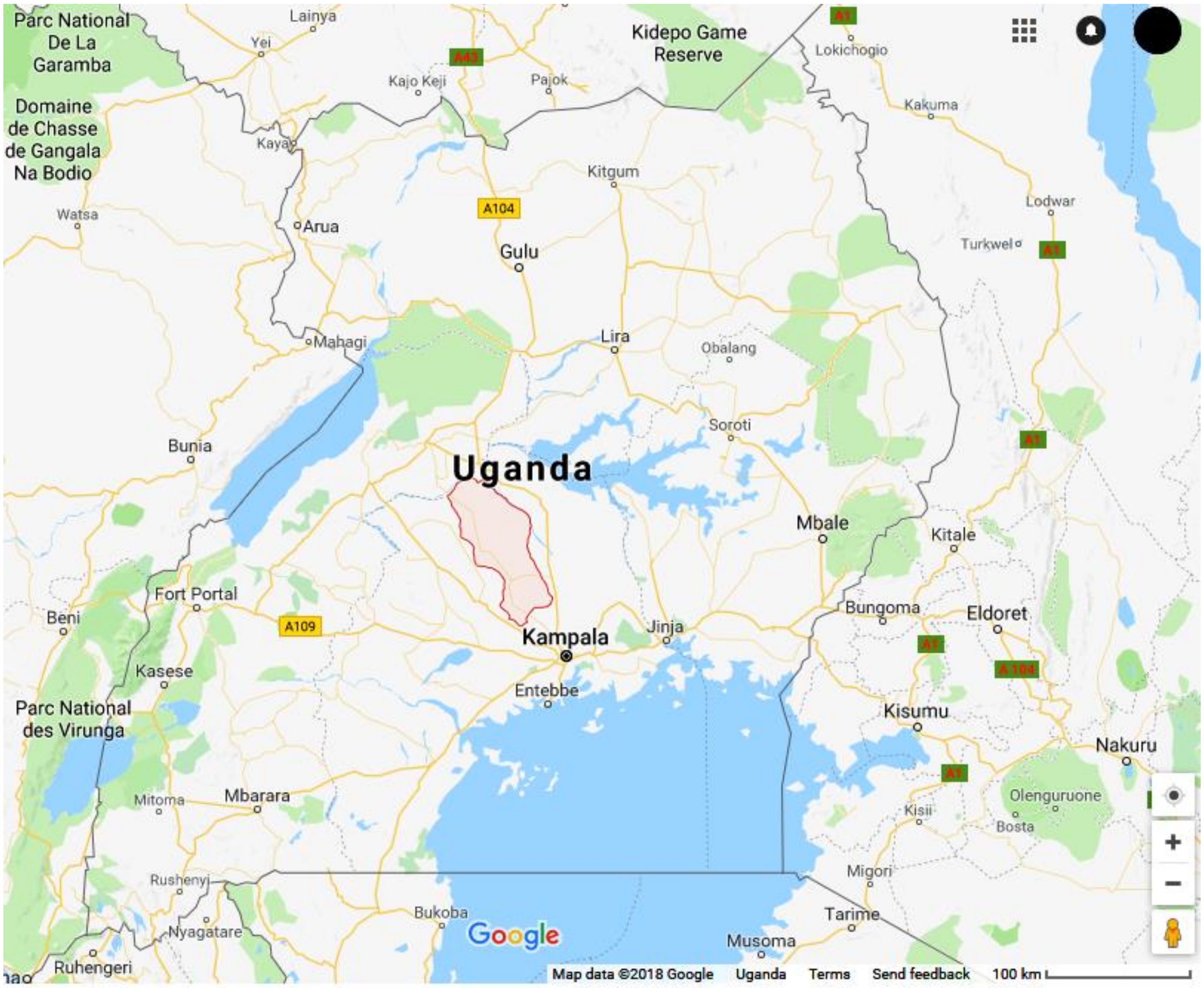

Figure 3.1: Map of Uganda indicating Nakaseke District (Red Boundary Line/ Pink Shading)

Nakaseke district lies between coordinates; 00 44N, 32 25E. It is composed of 7 sub counties and 36 parishes, and has a total population of 197,369 people (UBOS, 2016). The study was carried out in three out of seven sub counties of Nakaseke, Semuto and Kikamulo shown in the map below.

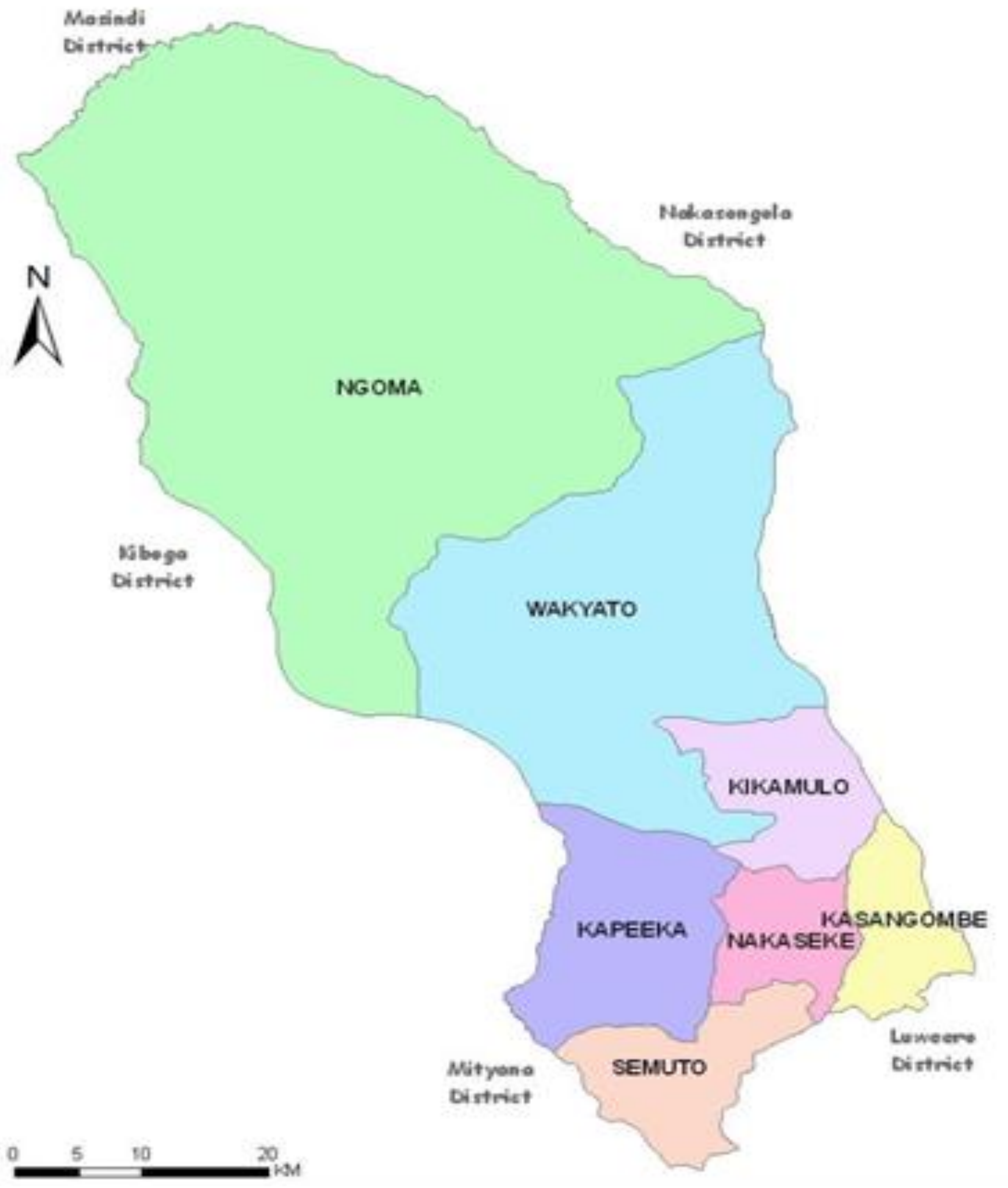

Figure 2.2: Map of Nakaseke District showing its Sub counties

The District was purposively selected because it is in the cattle corridor prone to prolonged drought that affects farmers. The district has also received interventions from different NGOs, and government programs like NAADS, Luwero-Rwenzori Triangle, and PMA, SG2000, UNDP, AFRII among others, some of which were focusing on climate change adaptation through promoting climate smart agriculture**.**

3.4 Sample Techniques and Sampling Procedure

Simple random sampling and purposive sampling were employed. The main respondents were but not limited to small holder farmers that once hosted demonstrations under the different government and partner organizations. The other group of respondents was extension agents, community based facilitators and sub county local leaders who are expected to hold a vast volume of knowledge in the subject accumulated over time.

3.5 Sample Size and Determination

The concept of precision and confidence guided the sample size. The sample size determination formula by Sarandakos (1997) was used to calculate the appropriate sample.

The actual sample size was estimated using the formula;

Equation 1: Sample size estimation

$n = Z^2$ x P $(1-P)/C^2$

Where n = sample size required, P is the estimated percentage of picking a choice (population estimate with the desired attributes to the researcher), C is the confidence interval and Z is the estimated confidence level.

Assuming; Z=Confidence limits of the survey results (in this case, Z=1.96 for a 95% degree of Confidence or the value corresponding to the confidence level chosen for the study).

P=Population estimate or proportion of the population with the attributes of interest to the researcher and in this case 80% will be used. A proportion of 80% was chosen because it indicated a greater level of the attributes in the population.

Then sample size was calculated as follows;

$$n = \frac{1.96^2 (0.8)(0.2)}{0.05^2} = 246\ ;$$

Therefore, the sample size was estimated to be 246 respondents. In a nutshell, 246 respondents were used and deemed appropriate as by the formula above.

3.6 Data Collection

The study used both primary and secondary methods including: surveys, interviews, focus group discussions, and seasonal calendars.

3.6.1 Questionnaires

The questionnaire was used as it is practical, large amounts of information can be collected, questionnaires data can easily be quantified, it is also a cheap way of collecting data, a large group of respondents is covered within a short time. Questionnaires also allow in-depth research to gain first-hand information and more experience over a short period of time (Kothari, 2004). In this research, a self-administered questionnaire was used to draw information. The questionnaire consisted of both open and closed ended questions structured in nature. A copy of the questionnaire is appended as Appendix (i).

3.6.2 Focus Group Discussions

These activities were conducted with members of the communities where data was collected, using participatory techniques, and approximately 40 minutes. The Focus Groups were composed of 5 to 10 participants. All of the sessions explored participants' opinions about the study. Each group discussion was led by the researcher and a research assistant, and participants' comments and discussions were recorded by a note-taker. Consent was obtained from each individual participant along with permission for any materials produced in the sessions to be kept by the research team for analysis.

3.6.3 Interviews

According to Kothari (2004), interviews describe the life events and experiences of the respondents with respect to analysis of the significance of the portrayed phenomena. They are basically the correct technique to use when exploring sensitive topics, to create conducive environment for respondent to take part. This method constituted the fundamental part of the data collection for this study. Both structured interview and semi structured interviews followed the why and how questions. Interviews were used because they have the advantage of ensuring probing for more information, clarification and capturing facial expression of the interviewees (Somekh and Lewin, 2005) which was essential for this study.

In addition, the method also presented to the researcher an opportunity to revisit some of the issues that had been considered less important in other instruments and yet they were considered vital for the study.

3.7 Data Collection Procedure

The researcher obtained an introductory letter from Uganda Martyrs University which she used for purposes of introduction to the participants when collecting data from the field. Data was collected using questionnaires that were administered to household representatives. The questionnaires were administered by the researcher assisted by research assistants.

3.8 Data Analysis and Presentation

3.8.1 Quantitative data analysis

Quantitative data was analyzed using the Statistical Package for Social Sciences (SPSS). Means, frequency counts and percentage were computed to interpret the data. The analyzed data was presented in form of tables, charts and narratives to compile the report. To analyze the effect of the climate smart technologies on crop output(objective2), a Paired sample test was performed to determine the statistical significance between the two periods i.e. Period 1(before CSATs) and Period 2(After CSATs).

3.8.2 Qualitative data analysis

To grasp the meaning of all qualitative data produced by the interviews and focus group discussions, document analysis, explanation building through content analysis as an interpretive technique was adopted. The case content analysis is informed by deducing the inference of content textual data holding on to naturalistic patterns. The study took on a summative content analysis whose basis was to understand why certain issues were held.

3.9 Ethical Considerations

Honesty: The researcher adhered to honesty as an ethical norm. The researcher was open to the respondents on the aims of the research and therefore asked the respondents to be honest in their responses. For example, respondents were asked not to fabricate, falsify, or give responses that would misrepresent the actual situation on ground and lead to errors. Also in order to avoid plagiarism, works of different authors were acknowledged whenever they were cited.

Informed consent: The ethics framework is essential as it entails the voluntary informed consent of the participants. Participants were given adequate information about what the study involved and an assurance that their consent to participate would be free and voluntary rather than coerced. The researcher also took through the respondents the objectives of the study and what possible benefit the findings could result into.

Anonymity: Respondent's names were withheld to ensure anonymity and confidentiality in terms of any future prospects. In order to avoid bias, the researcher interviewed the respondents one after the other and ensured that she informed them about the nature and extent of her study and on the other hand gave them reasons as to why is interviewing them.

CHAPTER 4:PRESENTATION, ANALYSIS AND DISCUSSION OF RESULTS

4.1 Introduction

This chapter entails presentation, analysis and interpretation of the findings on evaluating the effect of climate smart technologies on small holder farmers'resilience to climate change in Nakaseke District, Uganda. The findings logically follow the four specific objectives stated in Chapter 1 which are: to establish the various (indigenous and introduced) Climate Smart Technologies being practiced by small holder farmers in Nakaseke District, to analyze the effect of Climate Smart Technology packages on small holder farmers' output, to examine small holder farmers' perception on the introduced smart technologies towards climate resilience, and to establish the challenges in adoption and sustainable use of key climate smart technologies in the area of study. The findingsare preceded by a discussion of the responsesbased on the background characteristics of the respondents and related literature.

4.2 Response Rate

In this study, the total number of expected respondents was 246. However, a total of 196 respondents actually responded to the survey questionnaires yielding a response rate of 79%. This is satisfactory since it is higher than theinternationally recommended response rate of 50 percent according to Kothari, (2004:11-45).

4.3 General Information about the Sample

4.3.1 Socio-demographic characteristics

Responses were got from three sub counties, Nakaseke (38.8%), Kikamulo (35.7%) and Semuto (25. 5%).The socio-economic characteristics considered for respondents in the study were age, sex, education, and marital status of the farmer as presented below.

a) Sex of respondent

The study involved both male and female respondents. Results indicate that there were more female respondents (64%) than males (36%) as shown in the figure 4.1 below;

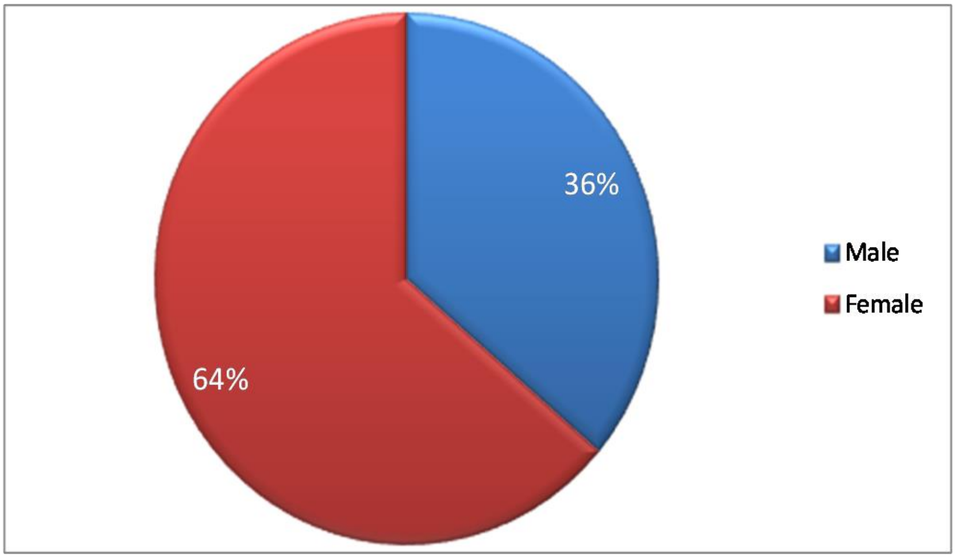

Figure 3.1: Sex of the Respondents

b) Age of respondents

The respondents in the study were cutting across the different age groups including youth and adults. Results show that the majority of the respondents (54%) fall in the productive age between 31-50 years. Table*4.1*below presents the different age categories that participated in the study.

Table 4.1: Age of the respondents

Age (years)	Number of Respondents	Percent
15 to 30	53	27.0
31 to 45	82	41.8
46 to 50	24	12.2
>50	37	18.9
Total	196	100.0

From the results in the table 4.1 above, it is mainly the active age (15-45 years) who are mostly engaged in farming activities in the area of study. This is probably because farming activities are laborious and require energetic people.

c) Marital status of respondents

Most of the farmers (86.2%) were married compared to 7% who were singles, 3.6% divorced/separated and 2.6% widowed as shown in table 4.2 below. This is a common practice especially in developing countries where most of the farm work is done manually and therefore there is heavy dependence on family labour for most farm work. This finding agrees with the findings of Everton and Magnus (2004) who reported that marriage is key in increasing labour force for most activities in agriculture.

Table 4.2: Marital status of the respondents

Marital status	Number of Respondents	Percent
Single	15	7.7
Married	169	86.2
Divorced/ separated	7	3.6
Widowed	5	2.6
Total	196	100.0

d) Education levels of respondents

On education levels, results show that in all the three sub-counties visited, most of the farmers (66.3%) had attended primary level, compared to 19.9% and 1.5% who reached secondary and tertiary levels respectively. Only 12.2% of the farmers had not had formal education (table 4.3).

Table 4.3: Education level of the respondents

Education level	Number of Respondents	Percent
No formal education	24	12.2
Primary level	130	66.3
Secondary level	39	19.9
Tertiary level (Vocational/ University)	3	1.5
Total	196	100.0

From the above results, the minority of the respondents had made it to tertiary education as opposed to majority who completed primary level. This probably means that those educated above tertiary level are not involved in farming activities and are probably involved in other occupations. In view of this, it is probable that education levels may be a factor affecting adoption of some technologies in Nakaseke district. According to Daku (2002), education positively affects technology uptake. It creates a favorable mental attitude for the acceptance of new practices and reduces the complexity perceived in a technology thereby increasing a technology's adoption.

4.3.2 Type of farming enterprise

Farming is the major occupation of the people of in the three study sites of Nakaseke, Semuto and Kikamulo through which they raise money to sustain their families. Results indicated that farmers engaged in different farming enterprises including crop production, livestock production and fish farming. A summary of their current enterprises is given in *Table 4.4*below.

Table 4.4: Major Enterprises in the area (n=196)

Enterprise	Number of Respondents	Percent
Crop farming	16	8.2
Livestock farming	35	17.9
Crop and livestock farming	127	64.8
Crop, fish and livestock farming	15	7.7
Livestock and poultry farming	3	1.5
Total	196	100.0

From the table 4.4 above, most farmers (64.8%) were involved in both crop and livestock farming. However, there were more farmers practicing livestock farming only (17.9%) as compared to those who practices crop farming alone (8.2%). Results also showed a significant difference between males and females as far as the type of farming activities they carried out. This was significant at 10% with a chi square value of 13.355*. More females were involved in crop and livestock compared to their counterparts (table 4.5 below).

Table 4.5: Farming activity by sex

Sex	Crop farming	Livestock farming	Crop and livestock farming	Crop, fish and livestock farming	Livestock and poultry farming	Chi square
Male	18.8	17.1	40.2	60.0	66.7	13.355*
Female	81.2	82.9	59.8	40.0	33.3	
Total	100.0	100.0	100.0	100.0	100.0	

Significance at 10% level

4.3.3 Farming experience

Results show that 30.6 percent of the respondents had been farmers for about 10 years, while 25.5% had been in farming for 11-20 years and only 15.3% had spent over 30 years in farming. This shows that farming is a major occupation and income generating activity for farmers in Nakaseke district. From their own experience, all respondents acknowledged that the climate had been changing over the years and this manifested through shorter rainy and longer dry spells (59.7%), unusual heavy rainfall (35.9%) and increase hailstorms and wind storms (4.4%). Respondents also reported that occurrence of new pests like the fall army worm which they attributed to climate change.

4.3.4 Crops grown in the area

Throughout the study area, farmers majorly grew legumes (beans, ground nuts and soy bean), cereals (maize) and tubers (sweet potatoes). Table4.6 below summarizes the percentage responses for the different crops.

Table 4.6: Percentage number of farmers growing specific crops by sub-county

Crop type	Nakaseke	Kikamulo	Semuto	Total
Beans	100.0	100.0	99.1	**99.6**
Groundnuts	55	55	63.2	**31.4**
Soybean	65	65	43.6	**21.6**
Maize	97.5	97.5	95.0	**96.2**
Sweet potatoes	100.0	100.0	66.7	**83.3**
Bananas	40.3	40.3	67.5	**54.0**
Cassava	0.8	0.8	19.2	**10.0**

From the table above, it is noted that 97% of the farmers practiced mixed cropping, with each farmer growing at least beans, sweet potatoes, maize, and cassava. This mixed cropping potentially has the advantage of diversification, beneficial to farmers in case of pest or disease outbreak to one crop or seasonal failure in another. From the interviews with the District Production and Marketing Officer, Nakaseke, it was clear that most farmers lost their maize crop for 2017 first season (Feb-June) due to the fall army worm but were able to compensate from other crops like beans and sweet potatoes.

Farmers practiced mixed cropping majorly for compensation in case of pest or disease outbreaks, theft, weather variability but also for food security. This is in agreement with the diversification principle of sustainable production according to Thornton (2009) according to whom a mixture of crop species in a farm has a yield advantage and contributes to pest and disease management.Kagoda *et al*., (2016) alsoaffirm that mixed cropping systems give more stable yields than sole cropping systems. More so, crop diversification over time is considered as a safety net on farmers' income if one crop is severely affected by the climate extremes (Campbell *et al*., 2011). Therefore, by practicing mixed cropping, farmers in Nakaseke district are at an advantage of sustainable food production.

Results in table 4.6 above also indicate that legumes (beans, soybeans and groundnuts) were grown in the 3 sub counties of study with beans being a major legume crop across the areas. These crops were grown for food security but also they would be rotated and intercropped with other crops like cassava and maize to improve soil fertility. This is in line with Herrero *et al.*, (2011), who pointed out crop rotation and intercropping with legumes as a measure to sustainable soil management to mitigate climate change.

4.3.5 Major livestock in the area

The most common livestock reared in the study areas were chicken, cattle and goats. Table 4.7 below shows responses against the different livestock reared in the three sub counties.

Table 4.7: Percentage number of farmers rearing specific livestock by sub-county

Type of Livestock	Nakaseke (n=87)	Kikamulo (n=63)	Semuto (n=46)	Total (n=196)
Chicken	88.0	87.4	88.0	87.7
Cattle	56.5	88.2	56.5	73.1
Goats	65.7	47.1	65.7	55.9
Pigs	59.3	21.0	59.3	39.2
Sheep	77.8	2.5	77.8	38.3
Rabbits	46.3	9.2	46.3	26.9
Ducks	4.6	8.4	4.6	6.6
Turkeys	1.1	5.0	1.1	2.6

From the table above, chicken was the most reared (87.7%) followed by cattle (73.1%), goats (55.9%) and pigs (39.2%). This is not a surprising finding because the study area is located in cattle corridor agro-ecological zone.

4.4 Objective 1: CSA Technologies Practice in Nakaseke District

4.4.1 Source of information about climate smart technologies

Respondents reported different ways in which they were made aware of climate change and the different climate smart technologies they could employ to respond to its effects and sustainably produce under the changes. These sources included mass media (Radios, TVs and newspapers) - 52.4%, Extension agents from government and NGOs (36.6%) while 11.1% of them got information from fellow farmers. The different partners involved in dissemination of climate smart technologies in the last 5 years were identified and responses summarized in table 4.8 below. Responses indicated that there were more NGOs involved in promotion of the CSATs than government programs.

Table 4.8: Organizations involved inpromoting climate smart technologies in Nakaseke District

Organization/Partner	Number of Respondents	Percent
NARO	156	25.8
Sasakawa Global 2000	272	45.0
Local Government	111	18.4
UNDP	30	5.0
Operation Wealth Creation	13	2.2
VEDCO	3	.5
Swiss Contact	18	3.0
World Vision	1	0.2

4.4.2 Climate Smart Technologies practiced in the area

A range of climate smart technologies and practices was given as indicated in the *Table 4.9* below. These included those introduced by the different organizations while others were indigenous in the area. These technologies are referred to as climate-smart because they address the challenge of meeting the growing demand for food, fiber and fuel, despite the changing climate and fewer opportunities for agricultural expansion on additional lands. Respondents noted that even with the constant dry spells in the area, they are still able to plant and harvest.

The most commonly practiced technologies included use of improved crop varieties including drought and disease tolerant varieties, fertilizer use, construction of physical soil conservation structures like bunds and ridges, use of permanent planting basins for moisture conservation, seed priming (soaking seeds before planting), mulching, use of organic manures, mixed cropping, agro forestry and irrigation. Of these technologies and practices mentioned, mulching, mixed cropping and seed priming were reported to be indigenous to the area although most farmers did not really understand the core science behind the practices. Other indigenous practices mentioned as climate smart included timely planting, crop rotation (14.9%), farming near rivers and low lands (2.2%), and use of cover cropping (19.1%) and planting tree shades in the fields (14.1%). Use of trash lines and hedges were also mentioned but with negligible percentages.Figure 4.2 below shows results for the different climate smart technologies practiced in the district.

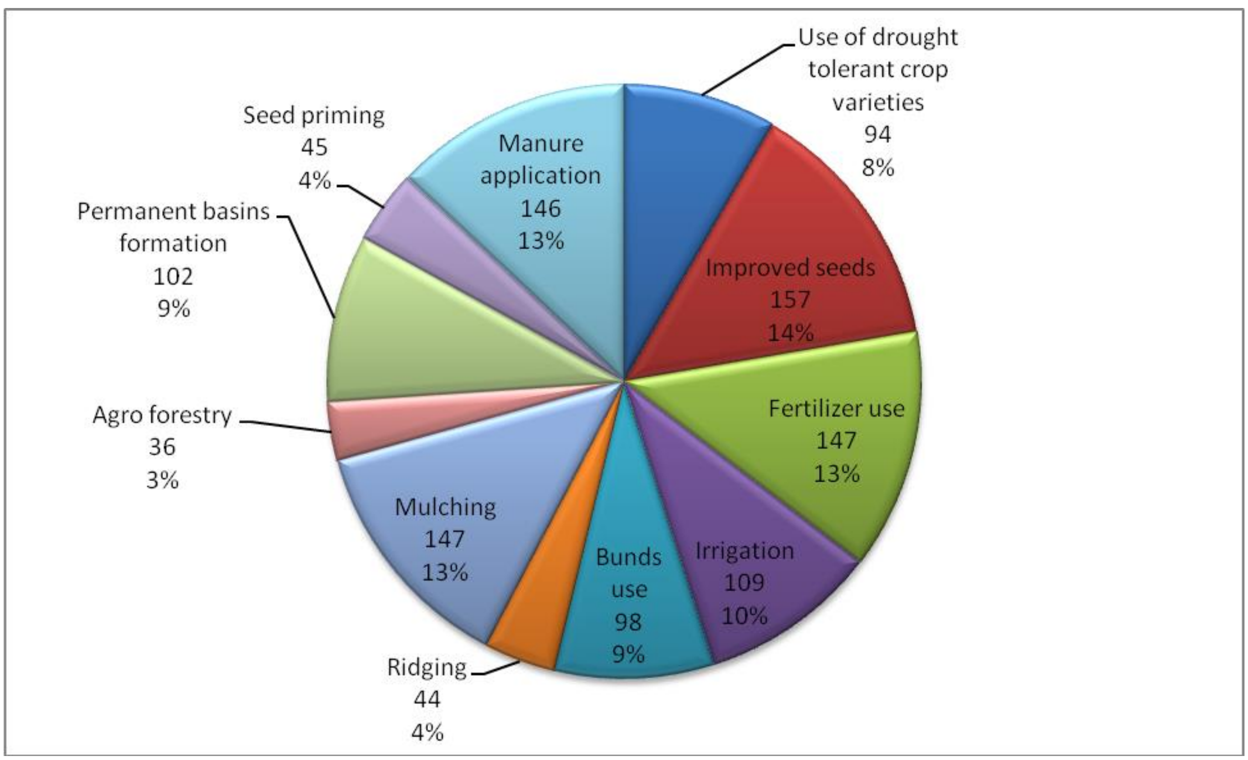

Figure 4.2: Climate smart technologies commonly practiced in the area

Results and observations obtained from the study show that a number of approaches were being applied to sustainably produce while responding to the changes in climate. The technologies mentioned by the respondents (fig.4.2 above) are in line with literature from other researchers.

Kiratu (2014) observed that mitigating the multiple effects of climate change at farmer levels can be achieved through promoting tested and proven practices such as intercropping, conservation agriculture, crop rotation, mulching, integrated crop-livestock management systems, and agro forestry.

4.4.3 Reasons for specific climate smart technologies and practices

Majority of the farmers were using improved seeds/ crop varieties. These were reported to be drought and disease tolerant, and high yielding. Among the drought tolerant crop varieties grown were Longe 10H and Fortune 5 for maize, while disease resistant varieties were mostly for cassava, a case of NASE 14 resistant to Cassava Mosaic Virus disease. The use of such varieties as climate smart is in line with the findings of Okoboi *et al*., (2012) according to whom improved seed varieties were key for improved yields among smallholder farmers.

FAO (2011) also affirms that use of improved seed and planting materialsof well adapted crops are an indispensable input for climate smart agriculture and ultimate yield increase. Therefore, in view of this, there is need to promote more use of improved crop varieties among the farmers in Nakaseke district to cope up with the changing climate and become more resilient.

Farmers were encouraged to maintain bands, because of their effectiveness in (a) controlling soil erosion, (b) maintaining soil fertility, and (c) bands acting as boundaries with neighboring plots. This technology was mainly emphasized by Sasakawa Global 2000. Neufeldt *et al*., (2011) and McCarthy (2011), revealed that physical soil and water conservation structures like bands and terraces are essential for reducing runoff and therefore minimize soil erosion. Such structures are categorized as climate smart under sustainable land management practices.

In line with the findings by Kagoda *et al*., (2016) who noted that farmers practiced intercropping as an insurance against insect pests, diseases, and weather and price fluctuations, to ensure stable ‘yields, farmers in Nakaseke also had the same reasoning for intercropping. According to them, intercropping was being practiced mainly yield stability (one crop would compensate the other in case of un favourable weather), low labour requirement for example in weeding, reducing the effect of pests and diseases for other crops, and improving soil fertility especially with legumes.

Basin Farming approach was introduced by NARO as a water management technology for smallholder farmers in Semuto, Kikamulo and Nakaseke sub counties. Farmers who reported to be using this technology (9.1%) reported the lowest seasonal runoff losses, regardless of soil type and field slope. This agrees with the findings by Tenywa (2012) who noted that basin farming can save more than 50% of water use than surface irrigation systems, provided that farmers receive adequate training to operate and maintain the system in addition to back up for servicing the drip systems.

Most respondents who reported use of organic manures acknowledged the advantages of manures over artificial fertilizers and majorly these included low cost of manures compared to inorganic fertilizers, moisture retention in the soil, and improved yields. Notably, maize production was improved in the three sub counties for the first season of 2017(Jan to June) following the use of mulching and compost. This is in agreement with Mupangwa *et al*., (2007) who noted that organic manure has comparable advantages over inorganic fertilizer. The authors reported that organic manure buffers the soil against extreme temperatures, reduces evaporation and surface runoff, protects the soil from trampling, and improves soil structure, fertility and biota in subsequent years as the manure decays.

The majority (93%) of the respondents who practiced terracing indicated that they were encouraged to maintain terraces because of their effectiveness in controlling soil erosion, followed by maintenance of soil fertility (51%*)*, and the importance of terrace bands as boundaries between plots owned by different farmers (40%). Other reasons given included ability to grow a wide variety of crops (7%), getting good crop yields (6%), and elephant grass on the band could be used for feeding livestock (2%); reduction of land due to bands collapsing, use of elephant grass for house construction, conserving of soil moisture and wind breaking were given by less than 1% of the respondents. However, a percentage of 36% indicated terraces were not farmer friendly; that maintaining of terraces was very tedious, that rodents and moles hid in the bands and later destroyed crops (30%). Other factors thought to discourage the use of terraces in descending frequency were: high maintenance costs and loss of land to the band (17%), destruction of bands by livestock (13%), lack of labour (12%), neighbors encroaching on bands (8%) and torrential rains (5%). Land fragmentation, and land being rocky, were each named by a negligible percentage of the respondents. These results comply with the findings of Lal (2009) who recognized terracing as an effective method in soil and water conservation despite the difficulties involved.

4.5 Objective 2: Effect of CSA Technologies on Small Holder Farmers' Output

It is perceived that CSA can increase yields by fostering biological processes and management practices that enhance soil fertility, pest and weed control where agrochemicals are not available or not affordable. In this particular study, over 80% of the respondents acknowledged that by applying the climate smart technologies demonstrated to them, their yields increased from what they were normally producing. This section spells out the effect of CSATs on small holder farmer's crop output. It is presented inform of mean difference and comparison between crop output and the levels of dispersion between crop output in the two periods (Before CSATs and After CSATs). This determines whether there is a statistical significance between crop output before CSATs and After CSATs or not. Tables following tables presents results from the paired sample test that gives the mean differences in crop outputs before and after the CSATs (table4.10) and the corresponding levels of significance (table 4.11).

Table 4.9: Mean difference in crop outputs between before and after CSATs among crops grown

Paired Samples Statistics

Mean Difference in Crop Output Before CSATs and After CSATs		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Maize after CSATs	1108.7763	152	1268.74273	102.90862
	Maize before CSATs	737.5987	152	498.40801	40.42623
Pair 2	Beans after CSATs	501.6286	105	216.97014	21.17412
	Bean before CSATs	327.2000	105	170.86946	16.67515
Pair 3	Bananas after CSATs	500.0000	1[a]	.	.
	Banana before CSATs	0.0000	1[a]	.	.
Pair 4	Cassava after CSATs	15740.0000	4	2260.28022	1130.14011
	Cassava before CSATs	7032.2500	4	1009.15621	504.57810
Pair 5	Coffee after CSATs	3023.6667	3	198.48006	114.59251
	Coffee before CSATs	1251.6667	3	62.40459	36.02931
Pair 6	Ground nuts after CSATs	248.7059	34	113.54308	19.47248
	Ground nuts before CSATs	246.3529	34	111.26051	19.08102
Pair 7	Soya beans after CSATs	160.2000	5	80.75085	36.11288
	Soya bean before CSATs	98.6000	5	57.04209	25.51000
Pair 8	Rice after CSATs	766.5000	4	283.51426	141.75713
	Rice before CSATs	661.2500	4	207.03683	103.51842
Pair 9	Sweet potatoes after CSATs	1900.2273	22	850.21431	181.26630
	Sweet potatoes before CSATs	1115.4091	22	478.77449	102.07506

* a. *The correlation and t cannot be computed because the sum of case weights is less than or equal to 1.*

The paired samples statistics (group statistics) of the different crop outputs in two periods (before and after CSATs) in table4.10 above indicate that there is statistical mean difference between crop output before and after CSATs. The differences in means (Mean After CSATs – Mean Before CSATs) from different crop outputs were, Maize 371.1776, Beans 174.4286, Banana 500, Cassava 8707.75, Coffee 1772, Gnuts 2.353, Soya bean 61.6, Rice 105.25 and Sweet potato 784.8182. The results indicate that, there is statistical mean difference between crop output in both before and after CSATs in crops grown in the study area. The mean differences for maize, beans, cassava, sweet potatoes, coffee, soya bean and rice are greater than 3, thus statistically significant as opposed to the mean difference in output of ground nuts less than 3 that denotes no statistical difference in output before and after the CSATs.

This indicates that CSATs intervention has done much in improving the crop output of most the major crops except ground nuts.

Level of significance of the SCATs

To analyse the effect of the CSATs on crop out, the periods (before and after CSATs) were analysed at a confidence interval of 95% with 5% standard error. Table 4.11 below presents the results from the paired sample statistics for the two periods before and after CSATs.

Table 4.10: Level of significance between crop output before and after CSATS among crops grown

Paired Samples Statistics

		Paired Differences					T	df	Sig. (2 Tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Maize after CSATs - Maize before CSATs	371.17763	1080.52497	87.64215	198.01437	544.34089	4.235	151	0.000
Pair 2	Beans after CSATs - Bean before CSATs	174.42857	258.00875	25.17908	124.49752	224.35962	6.928	104	0.000
Pair 4	Cassava after CSATs - Cassava before CSATs	8707.75000	1536.54035	768.27018	6262.77142	11152.72858	11.334	3	0.001
Pair 5	Coffee after CSATs - Coffee before CSATs	1772.00000	136.17636	78.62146	1433.71918	2110.28082	22.538	2	0.002
Pair 6	Groundnuts after CSATs - Groundnuts before CSATs	2.35294	7.12606	1.22211	-.13346	4.83934	1.925	33	0.063
Pair 7	Soybeans after CSATs - Soybeans before CSATs	61.60000	25.35350	11.33843	30.11947	93.08053	5.433	4	0.006
Pair 8	Rice after CSATs - Rice before CSATs	105.25000	91.09473	45.54737	-39.70204	250.20204	2.311	3	0.104
Pair 9	S. Potatoes after CSATs - S. Potatoes before CSATs	784.81818	451.34715	96.22754	584.70207	984.93430	8.156	21	0.000

From the above table, a $P<0.05$ for maize indicates that there was a significant yield increase for the crop as a result of CSATs.

The test also showed a $P<0.05$ for beans, cassava, sweet potatoes and soybeans. This too indicates that there was a significant yield increase for the crops as a result of CSATs in the area.

On the other hand, $P>0.05$ for ground nuts and rice indicates that there was no significant yield increase in the two crops as a result of the CSATs.

Therefore, the results in the table 4.11, confirms that there is sufficient evidence of a significant improvement in the crop output especially maize, beans, cassava, sweet potatoes, coffee, soya bean as a result of CSATs but not evidenced in rice and ground nuts in the two periods.

Results show significant increase in output (yield) for the period before and after the technologies. This can be attributed to such factors like improved varieties grown. The farmers in the area were growing superior crop varieties for example Longe 10H and Fortune5 for maize, and Maksoy3N soybean. According to NARO, these are high yielding varieties and drought tolerant thus higher yields were expected. This is in line with FAO (2011) that recognises use of high quality improved seed and planting materials of well adapted crops as an indispensable input for climate smart agriculture and ultimate yield increase. FAO (2011) also reports that most sub Saharan Africa maize farmers lose 10-25% of their maize yields to droughts. Therefore, it is probable that the yields in maize difference in crop yields for maize were due to the fact that the varieties were drought and disease tolerant.

In a related technology adoption study in Nakaseke by Magambo *et al*.,(2016), yields from demonstration plots where the smart technologies were applied were compared with those from farmers' own fields (farmer's practice where no technology was included). Results indicated that where improved technologies (i.e. drought tolerant seed planted with fertilizer and field banded) were applied, yields were higher (5.7Tonnes/Ha) than in farmer practice plots that yield averagely 3Tonnes/Ha for Maize. This therefore implies that climate smart technologies are positively contributing to crop productivity in the district.

The difference in yields between the periods before and after CSATs could also be attributed to other technologies like use of fertilizers and manures. This corresponds to the findings by Okoboi *et al*(2012), who reported that the low crop yields in Uganda are due to low or no use of improved technologies like fertilizers. The authors further affirmed that application of fertilizers to improved seed results into higher yields than planting similar improved seed without fertilizer. In other literature, it is concluded that fertilizers particularly potassium based fertilizers are good at responding to the effects of dry spells as they help the plant to resist water stress, improve water and nutrient uptake and enhance proper grain filling thus enhancing yields (Magambo *et* *al*., 2016). The same reason could hold for the increase in crop yields of other crops like beans, soybeans, coffee and cassava.

On the other hand, there was no significant yield increase for ground nuts between the period before and after CSATs. This is probably because the farmers were still using varieties that were prone to effects of dry spells and susceptible to diseases. Farmers reported Red beauty variety as the most commonly grown variety of groundnuts in the district. According to the legumes department of NARO, red beauty is susceptible to ground nut rosette, a disease known to result into significant yield losses even up to 100 percent. The overall finding on this objective suggests that with the current climatic changes, it is more rewarding for small holder farmers to invest in climate smart technologies like drought tolerant crop varieties and fertilizers.

4.6 Objective 3: Users' Perceptions of CSA Technology

According to Kasirye, (2013) the rate of adoption of technology depended on technological attribute factors derived from the attributes of innovations namely; relative advantage, compatibility, complexity, and trial-ability. The attributes were said to influence individuals' judgment of a technology which affects the rate of its adoption. When a technology took less capital, saved time, labour, space, money, attracted organizational support and was effective then it would be sustained by the users. For a technology to be adopted, it had to be profitable and possessed one or more of the following attributes: lower per unit expenditures on production inputs, increase output per unit input, produce more profitable crops and livestock, reduce capital expended on machinery, reduce crop and animal losses, and result into fuller use of available land, labour and capital (Kasirye, 2013).

Similarly, the respondents to this study, both in the survey questionnaire and focus group discussions highlighted factors they would consider to rate a technology's usefulness and these do not differ from the above of Kasirye, (2013). For instance, terrace users face a number of difficulties, namely the high labour costs for construction and maintenance; loss of land to physical conservation structures sometime was up to 5-10% of the farm holding. In Nakaseke Sub County, farmers claim a large amount of cropping land has been lost to terraces. This land loss would be at the expense of the immediate need to produce sufficient food for the family.

From the findings of this study, most respondents (36%) indicated that maintaining terraces was very tedious, while 30% indicated that the rodents and moles hid in the bands and later destroyed crops among others. Besides that, all respondents agreed that terraces were good for soil and water management, thus a good climate smart technology. These findings are in line with those of McCarthy (2011) who found out that physical soil and water conservation structures like bunds and terraces are essential for reducing runoff and therefore minimize soil erosion. The structures also provide benefits to neighbors and downstream water users by preventing flooding, enhancing biodiversity and reducing sedimentation of water ways. The author however remarked that the structures are a form of fixed investment on the farm and do not guarantee immediate yield increase.

From the survey, respondents also gave their perceived reasons as to why they were using or not using certain practices. These were summarized in the table 4.12 below.

Table 4.11: Least used climate smart technologies and why

Technology/Practice	Frequency	%	Reason for not using
Use of drought tolerant crop varieties	47	6.7	Seed is costly yet cannot be replanted
Mulching	27	3.9	Mulching material not readily available. No bushes to provide mulch
Agro forestry	81	11.6	Most land is rented. Not sure of which trees to plant
Building water harvesting schemes (bunds, Basins and ponds)	61	8.7	Labour and capital intensive
Irrigation	63	9.0	Capital intensive, no nearby water sources
Fertilizer application	136	19.4	Not accessible, costly, and need repeated use,
Herbicides and pesticides use	108	15.4	Not nearby shops, expensive, not effective(fake)
Crop rotation	39	5.6	Shortage of land does not allow rotation.
Terracing	52	7.4	Topography - Areas not so hilly, labour intensive, time consuming, rented land

In relation to the above, voices from some members of the focus group discussions also indicated perceived reasons for or against certain technologies as in box 1 below.

BOX 1: Farmers' voices on some climate smart technologies

1) "*With irrigation, yes. One is able to produce throughout the year even with scanty rains*." KibukaMitusera- Kikamulo.
2) "*I cannot go in for irrigation at my level. It is only good for crops that will pay you back in one season. It's costly and results are not immediate except for vegetable.*," says Mr. Kitayimbwa of Kikamulo.
3) "*Use of improved crop varieties with fertilisers leads to increased yield. The problem is they are expensive*." Ssekimpi of Semuto.
4) "*Band construction is very tedious especially for us women*" Unspecified farmer
5) "*These technologies would not be hard to do but I think we are not exposed. When projects come, they are limited to very few groups of farmers, leaving most of us behind*" Mr. Kamya Lawrence of Nakaseke.

From the above reasons against individual practices, it is clear that farmers will only apply a technology that is cost and labour effective thus affordable, accessible and contributing to increasing yield. This is in agreement with the findings of Okoboi (2012). These noted that access to and use of crop production technologies is influenced by the economic (price of inputs**,** produce prices, price of other inputs that complement or substitute each other**,** costs or returns to factors of production, distance to markets).

Additionally, technologies like irrigation and fertiliser use are more suitable for commercial farmers dealing majorly with high value crops. Results from Nakaseke indicated maize and beans as the major crops(above 96%) and given the high cost of irrigation and fertilisers the low prices of the commodities say maize; farmers may not be encouraged to use such a technology although it was proven as climate smart. This may tally with Okoboi's argument that the cost of returns determines the type of technology a farmer can apply on a given enterprise (Okoboi, 2012).

Furthermore, Okoboi (2012) revealed that non-economic factors like age, marital status, education, household size, access to land, membership in farmer organizations, and experience in farming) may be intervening variables in adoption of a given technology.

In other perception studies; Daku, 2002 observed that education positively affected perception and adoption of technologies. This is because education is expected to create a favorable mental attitude for the acceptance of new practices especially of management and intensive practices (Caswell *et al*., 2001). Education also is assumed to reduce the complexity perceived in a technology thereby increasing a technology's adoption.

Kiratu (2014) noted that the Kilimo Program - a program initiated by the Kenyan government in 2007 to help small holder farmers fight food insecurity with the provision of maize seeds and fertilizers inputs of 10kg and 100 kg respectively was given a positive welcome and interestingly adopted by the farmers because it helped them to produce more yield and earned more in their increased farm produce. In line with this, respondents to this study acknowledged that improved drought and disease tolerant seed varieties survived the adverse effects of dry spells while maintaining good yields.

Conclusively, respondents in the study area remarked that the climate-smart agricultural practices were relevant although they incur establishment and maintenance costs and it can take considerable time before farmers benefit from them. Some of the success stories generated from the focus group discussions for example that of Mr. Ssekimpi Kikomeko Muhammad from Semuto Sub County (*Box 2* below) also provided more information on over all perception of smart technologies in the community. These are also in agreement with the findings from World Agro Forestry Center, 2011.

BOX 2: Success story on Climate Smart Technologies; Ssekimpi from Semuto

Mr. Ssekimpi, 38, is a senior four graduate from Semuto Sub County. He is a progressive farmer who once served as a community based facilitator leading other farmers under the Sasakawa Global 2000 from 2012 to 2016. He is a proud farmer with his 1 acre of beans, 2 acres of maize and 2 acres of coffee although some other coffee is intercropped in other crops. Mr. Ssekimpi confesses that he had never realized that farming was a beneficial economic activity not until he joined Sasakawa Global 2000 extension project. He notes that his role as a community based facilitator required him to be a role model to the farmers so as to help them change their mind set towards improved farm technologies. "Drought, pests and diseases and reduced soil fertility were my major challenges in farming, but since I started applying the climate smart technologies demonstrated to us, I realize farming is possible with minimal disturbance. I currently practice use of drought tolerant varieties like Longe 10H, drip irrigation using bottles, fertilizer use both organic manure from chicken droppings and commercial fertilizers like DAP and urea. I apply commercial fertilizers usually on maize while organic manure is for coffee and other crops. I have constructed a water tank for water harvesting whenever it rains. I am also practicing planting basins in beans and backyard vegetable gardens," explained Ssekimpi.

He mentioned some of his successes from applying the climate smart technologies as good yields (3000kg/acre from maize and 1200kg/acre from beans-attributed to good varieties and improved technologies applied). He has been able to raise school fees for his children (eldest in S.5, one in S.3, and 2 in Primary). He was also able to acquire a motorcycle from one good coffee season and he is currently constructing a modern poultry house.

According to him, advising fellow farmers is an enjoyable exercise and he is proud to have mentored 18 farmer groups in Semuto into Climate Smart Agriculture adoption.

4.7 Objective 4: Challenges Small Holder Farmers Encounter with CSA

Despite the potential of CSA technologies to improve resilience and to enhance agricultural production, systematic response to climate change through adoption of these practices and technologies is still limited for most small holder farmers in Africa (Benard *et al*., 2015). This is possibly because of the different challenges small holder farmers encounter with the technologies? Farmers in Nakaseke district mentioned a number of challenging factors to adoption and sustainable use of climate smart technologies and some of them are summarized in the following table below;

A big number of respondents (124) reported that limited or no access to credit in addition to low incomes (115 responses) are their major challenge to sustainable use of the technologies. Such technologies mentioned to require credit included fertilizer use, use of improved drought tolerant crop varieties and irrigation. This response corresponds to the findings by Neufeldt, (2011) who remarked that Access to markets and capital are key constraints for resource-poor farmers, and limit their ability to innovate and raise their income. Barnard *et al*.,(2015) also adds that limited access to capital/finance will result into unavailability of the right tools, equipment and other material inputs like seed to implement smart innovations. Milder, *et al*.,(2011) also noted that smallholder farmers aiming to adopt CSA practices often are constrained by inadequate cash to invest in the land, equipment, labor, seeds, breeds and other farm inputs.

Limited extension services were another major challenge mentioned by the respondents. According to the respondents, the climate smart idea was brought in majorly by non-government organization projects that have little coverage in terms of numbers reached. Majority of the farmers were meant to learn from the demonstration sites hosted by fellow farmers and incase the host farmer missed out on anything, the rest of the community would miss it out too. Government programs like NAADS and OWC were not much into climate smart technologies despite the poor yields farmers were getting due to long dry spells. Table 4.13 below shows the challenges farmers in the study area face during implementation.

Table 4.12: Challenges in implementation of climate smart technologies

Challenge	Frequency	Percent
Little or no education and training	66	6.4
Limited extension services	103	9.9
Limited access to information	95	9.1
Incompatibility with societal norms and values	67	6.4
Inadequate income	115	11.1
Limited or no access to credit	124	11.9
Sustainability	86	8.3
Long time to see results	73	7.0
Land tenure issues	94	9.0
Land topography issues	67	6.4
Labour scarcity and labour intensiveness of practices/ technologies	90	8.7
Little or no access to water for irrigation	59	5.7
Total	1039	100.0

Many researchers pointed out the relevance of adequate information, knowledge and Skills on Climate Smart Agriculture adoption, as a way to adaptation to climate change and variability. Ngigi, 2009 stresses that extension services are key in enhancing information, knowledge and skills which are a powerful tool in technology adoption. According to McCarthy (2011), provision of extension services builds adaptive capacity, scientific understanding of the problems, openness to face challenges, enhances community involvement and commitment. The same author noted that inadequately trained and skilled personnel can- limit a community's or a nation's ability to implement innovative options. In the same perspective, it was found out that adopting CSA technologies requires substantial changes not only in practices, but also in mindset and that mindset change can be achieved through provision of extension services to communities (McCarthy, 2011).

Another challenge mentioned by respondents was Labour scarcity and labour intensiveness of practices/ technologies. Technologies like banding, planting basins, and terraces were seen to be labour intensive to farmers who use them. These require deep-digging to penetrate soil crusts, a task that is very arduous and may increase the initial labor requirements for land preparation, also as noted by Milder, *et al*., 2011. In agreement to this finding, most women respondents from the focus groups said they would not go in for banding because the energy required to construct a band around the field can be reserved for other agronomic activities like weeding.

Land tenure and topography were other challenges reported by the respondents. Respondents were farming on hired/rented lands and this discouraged them from investing in capital and labour intensive climate smart structures like agro forestry, bunds, pits and contour lines. From the focus groups, respondents would make statements like," why invest in expensive technologies on someone's land that you only have for a season or two? This was mostly reported in Kikamulo and Semuto sub counties. Benard, *et al*., 2015 classifies this challenge under non adaptable agro ecosystems. This is also in line with FAO, 2014 that reveals that potential for expanding agro forestry is limited by land ownership and land tenure systems as activities related to tree planting and retention are mainly of interest to land owners.

In relation to land tenure was small plots of land and generally shortage of land was reported to hinder indigenous practices like crop rotation and fallowing. Most farmers owned small plots of land with some going to as low as less than an acre. This definitely would not favor practices like crop rotation and fallowing. Mulching was also not possible for some farmers due to in availability of mulching materials. Most of them were using grass material which they reported was no longer available due to scarcity of idle land. This means therefore that availability biomass, particularly crop residues and mulches is a critical component of CSA and a major barrier to its adoption also as noted by Milder, *et al*., 2011.

Lastly, duration of time taken for some climate smart technologies to show results was also reported by a good number of respondents as a limitation to adoption of such technologies. Particularly, agro forestry was pointed out on this. This finding also relates to the findings by Benard *et al*.,2015 who observed that many climate-smart agricultural practices incur establishment and maintenance costs and it can take considerable time before farmers benefit from them.

CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

This study applied a cross-sectional comparative approach in analyzing the climate smart technologies being practiced by farmers in Nakaseke District, the effect of such technologies on small holder farmers' output and the perception of the same farmers on the technologies. Data was collected from 196 respondents split amongst the three Sub counties; 70, 76 and 50 for Kikamulo, Nakaseke and Semuto sub counties respectively.

Females formed the bulk of the sample (64%) compared to males (36%). Most respondents were between 15 to 55 years of age. Farming was the major economic activity in the area and with both crop and livestock enterprises.

Major climate smart technologies practiced in the area included use of improved crop varieties (drought and disease tolerant varieties), fertilizers, and planting basins. Organic manure, mulching, seed priming, timely planting and crop rotation were among the indigenous practices mentioned. Other technologies included construction of physical soil conservation structures like bunds and ridges, mixed cropping, agro forestry and irrigation. These technologies were majorly implemented by Sasakawa Global 2000 (45%), NARO (25.8%), and local Government (18.4%).

Results generated by the paired sample (2-tail) test showed statistical mean difference in the output of maize, beans, cassava, sweet potatoes, coffee, and soya bean ($P<0.05$) but not for rice and ground nuts ($P>0.05$) as a result of these CSATs. This means therefore that the CSATs contributed significantly to crop out (yield) for maize, beans, cassava, sweet potatoes, coffee, and soya beans but not for rice and groundnuts.

The general perception of the respondents was that climate smart technologies mainly fertilizer use and drought resistant varieties were important for increasing their crop yields. However, farmers also faced some challenges in adoption of the climate smart technologies including lack of credit access, inadequate extension services, labour intensiveness of some technologies, land tenure system, and longtime taken for some technologies to show impact, a case of agro forestry.

5.2 Conclusion

From the results obtained from the study, it can be concluded that farmers in Nakaseke district are trying to apply climate smart technologies to address the challenges of climate change and variability, mainly the persistent dry spells. Both introduced and indigenous technologies and practices are being practiced majorly to improve on crop yields, improve soil fertility and manage pests and diseases related to poor farming methods. From the yield advantage reported by the farmers, it is clear that the smart technologies are helping farmers become resilient-increase their yields despite the varying climatic conditions, become food secure and improve their incomes.

5.3 Recommendations for Improved Adoption of Climate Smart Technologies

A number of limiting factors were raised by respondents on smooth implementation of climate smart technologies which when left un-responded to, will discourage more smallholder farmers from adopting the valuable technologies. The following measures can help reduce the challenges and at the same time promote the use of climate smart technologies for increased farmers' resilience.

i. Creating more awareness about climate change and what CSA can do
ii. Build farmers' capacity in application of right technologies
iii. Facilitating access to finance and credit
iv. Create appropriate information channels for farmers
v. Facilitating information and knowledge use in climate change and CSA
vi. Provision of subsidies to some technologies like irrigation equipment

5.4 Further Research

A detailed study needs to be carried out onthe costs and benefits to the farmers applying Climate Smart Technologies. Knowledge of the cost/benefit ratio involved in the application of these farming practices will be helpful to farmers.

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Appendices

Appendix 1: Questionnaire for Data Collection

INTRODUCTION

This questionnaire is aimed at collecting data on the impact of climate smart agriculture technologies on small holder farmers' resilience to climate change. It is designed by CHRISTINE KYOMUGISHA and is part of the study on impact of climate smart agriculture technologies on small holder farmers' resilience to climate change, a requirement for completion of the degree of Master of Science in Agro Ecology from Uganda Martyrs University. The results of the questionnaire will be summarized and presented in the report. Results will help the different stakeholders in agriculture and also guide in decision making especially on the technologies suitable for small holders.

SECTION A:
DEMOGRAPHICS

1. Sex of respondent
   a. Male
   b. Female
2. Age of the respondent
   a. 15 – 30 years
   b. 31 – 45 years
   c. 46 – 50 years
   d. 51 years +
3. For how long have you been staying in this place?
   a. 15 – 35 years
   b. 36 – 55 years
   c. 56 years +
4. What is your level of education/
   a. No formal education
   b. Primary

c. Secondary (O and A level)
d. Tertiary (Diploma or vocational/University)

5. What is your marital status?
   a. Single never married
   b. Married
   c. Divorced / separated
   d. Widow / widower
6. How many people do you have in your family?
   a. 1 – 4 people
   b. 5 – 9 people
   c. 10 people +
7. What type of farming do you practice?
   a. Crop farming
   b. Live stock farming
   c. Fish farming
   d. Crop and live stock farming
   e. Fish and live stock faming
   f. Crop, fish and live stock farming
8. For how long have you been practicing your occupation mentioned above?
   a. < 5 years
   b. 5< 10 years
   c. >10 <20 years
   d. >20 < 30 years
   e. >30 years
9. Which type of agriculture do you practice/
   a. Rain fed only
   b. Irrigation only
   c. Rain fed and irrigation
   d. Others (specify) ……………………………..

SECTION B

CLIMATE SMART TECHNOLOGIES BEING PRACTICED BY SMALL HOLDER FARMERS

10. Do you agree that climate change is one of the major drawbacks to agriculture production in Nakaseke district?
    a. Yes.
    b. No
11. Have you experienced any changes in rainfall/snowfall within last 15 years?
    a) Yes……………b) NO……
12. If yes, what type of change?
    a) Rainfall/Snowfall increasing
    b) Rainfall/Snowfall is decreasing
    c) I don't know
13. Do you have any experiences on the followings?
    a. Unusual rainfall …………….
    b. Increasing cloud burst (heavy rainfall at once)…………….
    c. Longer rainy season……………………………..
    d. Shorter rainfall……………………………
    e. Longer drought……………………….
    f. Increased in hailstorm/windstorm………………….
14. If yes have you made any changes/adjustment in your farming practices in response to the variation (shift in climate variables) over the last 10 years?
    a. Yes
    b. No
15. Where did you get the knowledge and skills on the ways to respond to climate change?
    a. Media (Radio, TV, news paper etc)
    b. An extension worker
    c. Friends

d. Others specify ……………………………………..

16. Are there any NGOs in your area promoting the use of climate smart technologies? Please fill in the table below;

NGO	Year of intervention	Technologies/practices of emphasis	Usefulness of technology 5=very useful, 4= useful.3= fairly useful, 2= not useful

17. What adjustment have you made to your farming ways after shifts in climate variables?

a. Planted trees for shade
b. Cover cropping
c. Crop rotation
d. Fertilizer application
e. Pesticides and herbicides application
f. Use different varieties of crop types
g. Farming near rivers and low land
h. Mixed cropping
i. Others (specify) …………………………………….

18. If you practice fertilizer application how often do you always do it?

a. Once a year
b. Two times a year
c. Once after every 2 years
d. Once after every 3 years
e. Others (specify) ………………………………………………..

19. Which of the technologies below are mainly practiced in your area? Please rank in order.

   i. Use of drought tolerant crop varieties
   ii. Improved seed
   iii. Fertilizer use
   iv. Irrigation
   v. Banding
   vi. Ridging
   vii. Mulching
   viii. Agro forestry
   ix. Permanent basins
   x. Half moons
   xi. Seed priming
   xii. Others (specify)

20. What indigenous measures (technologies) would you consider to enable farmers mitigate climate change?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

………………………………………………………………………………

21. Have you observed any changes in your harvests as a result of using some of the above practices? Give approximate figures………………..

SECTION: C

SMALL HOLDER FARMERS PERCEPTION ON THE INTRODUCED SMART TECHNOLOGIES TOWARDS CLIMATE CHANGE RESILIENCE

22. Please tick from the under listed practices, the one you are **NOT** using and state why you are not using them.

Climate Smart technology	✓ **(Tick)**	**Reason (s)**
Use different varieties and crop types		

Use of drought tolerant varieties		
Mulching		
Agro forestry		
Building water harvesting schemes		
Use of irrigation		
Change from crop to live stock		
Reduce number of live stock		
Fertilizer application		
Herbicides and pesticides use		
Crop rotation		
Cover cropping		
Mixed cropping		
Terracing (hilly/mountainous areas)		

SECTION: D

CHALLENGES IN ADOPTION AND SUSTAINABLE USE OF SELECTED CLIMATE SMART TECHNOLOGIES

23. What are/were the main constraints/ challenges/ difficulties in changing your farming ways? Check the answers listed below and then fill in the once not yet listed.

Difficulty	**Rank (order of severity)** **"High, very high, low, Very low"**	**Suggestions/Solutions**
Education level		
Limited extension service		
Limited access to information		
Incompatibility with societal norms and values		
Inadequate income		
No access to credit		
Sustainability		
Length of time to see the results		

Land tenure		
Topography of the land		
Labour intensive or non availability of labour		
No access to water for irrigation		
Others…………..		

Thanks for your time

FOCUSED GROUP GUIDE

Duration 30 Minutes: Groups of 5 to 12 Participants

1. What are some of the climate smart technologies being practiced in area to combat climate change?
2. Are these technologies improving your output (yields)?
3. What are the challenges being faced in adoption these technologies in response to climate change?
4. What are some of your perception as far as the use of these methods is concern?
5. In your own view, have the technologies introduced for climate smart adaptation helped you to become resilient?