UNIVERSITY OF NAIROBI

DESIGNING AN INNOVATION SYSTEMS APPROACH TOWARDS ENHANCED FARMER ADOPTION OF CLIMATE SERVICES WITHIN DRYLAND AGROECOSYSTEMS IN KITUI, KENYA.

BY

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A thesis submitted in partial fulfillment for the award of the degree of Doctor of Philosophy in Climate Change and Adaptation of the University of Nairobi

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PLAGIARISM STATEMENT

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DECLARATION

I hereby declare that this thesis titled “An innovation systems approach towards enhanced farmer adoption of climate services” is my original work and has not been submitted for a degree in any other University.

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DEDICATION

This thesis is dedicated to my entire family. Thank you for your prayers and encouragement throughout the long journey.

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AR5	Fifth Assessment Report
ASALs	Arid and Semi-Arid Lands
CBOs	Community Based Organizations
CDM	County Director of Meteorological Services
CHIRPS	Climate Hazards Group Infrared Precipitation with Station data
CHIRTS	Climate Hazards Group Infrared Temperature with Station data
FAO	Food and Agricultural Organization
GDP	Global Domestic Product
GFCS	Global Framework for Climate Services
GOK	Government of Kenya
IPCC	Inter-governmental Panel on Climate Change
IL	Inner Lowland zones
ISRIC	International Soil Reference and Information Centre
KNBS	Kenya National Bureau of Statistics
LH	Lower High zones
LM	Lower Midland zones
MDG	Millennium Development Goals
NGO	Non-Governmental Organization
SDGs	Sustainable Development Goals
SMS	Short Message Services
SSA	Sub-Saharan Africa
Tmax	Maximum Temperature
Tmin	Minimum Temperature
UM	Upper Midland zones
UH	Upper Highland zones

ABSTRACT

Climate change and vulnerability are major challenges in ensuring household food security. In response to this, many adaptation options are being implemented in the form of small, time-bound pilot-based projects in developing countries. Among these is the promotion of the use of climate services in an attempt to cushion rural households from extreme climate risks. This study endeavored to enhance the resilience of smallholder farmers in Kitui county through improved adoption of climate services. The study employed a mixed type of methods and approaches. The sampling was done through a mixed stratified and systematic random sampling. Systematic literature review method was used to interrogate the past climate services pilot projects in order to establish good practices, which could inform future efforts towards enhancing adoption of climate services. The study attempted to transfer those good practices to the study area, Kitui County. The study also assessed the vulnerability of smallholder farmers in the study area using the indicator approach to vulnerability assessment. In addition, the study defined a climate services innovation system comprised of key actors at the county level, which was operationalized throughout a crop growing season in a transdisciplinary approach to realize enhanced adoption of climate services among the smallholder farmers. The innovations systems approach embraces a network of heterogeneous actors working together throughout the value chain, that is, from production to use in a way that the flow of information is not linear but composed of very complex. The results showed that the pilot projects have contributed enormously to climate risk management at the farm level through informing strategic farm decisions. The vulnerability assessment results pointed to a general vulnerable population in the county albeit with spatial disparities. Further, the study revealed the use possible of innovation systems approach in overcoming inherent climate services challenges, which resulted in enhanced adoption of climate services among smallholder farmers. In conclusion, the study revealed that climate services offer great opportunity to smallholder farmers in managing impending climate risk, which contributes to building their adaptive capacity to climate change. It also revealed that participatory approaches, which view knowledge adoption more systematically and interactively, such as innovation systems approach, present opportunities to enhance adoption of adaptation interventions. The study recommends a more systems approach in place of the current linear and top-down delivery approach of climate services, because it has the potential to enhance salience, credibility and legitimacy of the scientific information and ultimately lead to enhanced adoption.

CHAPTER ONE: INTRODUCTION

1.0 Background

This Chapter presents the general introduction and background of the research study, gives information on the study area, a brief highlight on the biophysical and economic characteristics of the study area, the problem statement, research questions, objectives, justification and significance of the study.

The position of agriculture as a leading gross domestic product (GDP) earner, employer and food provider for most sub-Saharan African countries is increasingly being threatened by climate variability and change (Muller *et al.,* 2011; Kotir, 2011; Calzadilla *et al.,* 2013). Because of their heavy dependency on climate-dependent industries and their limited capacity to adapt, low- and middle-income countries are more vulnerable to the effects of climate change. This notwithstanding, reliability of age-old climate risk coping strategies has decreased due to increasing climate variability (Plotz *et al.,* 2017), thereby increasing the vulnerability of the poor populations to impacts of climate extremes such as droughts and floods. In response to these threats many adaptation options are being implemented in the form of limited, small and time-bound pilot-based projects in developing countries (Singh *et al.,* 2016; Hansen *et al.,* 2011). In similarity to Appadurai (2015), this study defines pilot-based projects as a set of time-bound activities designed to explore and experiment novel ideas and innovative approaches of climate change adaptation. These initiatives are usually donor-funded and implemented in small scales, both geographically and temporally.

Majority of the world's most vulnerable populations reside in the territories of the arid and semi-arid lands (ASALs) (Kotir, 2011; Oba *et al.,* 2001; Buhaug *et al.,* 2015). About 80% of Kenya's land falls under the ASALs whose inhabitants suffer from many issues such as weak natural resource base, increasing frequency of climate extreme events and climate related diseases (Njiru, 2012; Omoyo *et al.,* 2015; Shisanya *et al.,* 2011; Bobadoye *et al.,* 2016). Climate change will not only exacerbate these factors within the ASALs but will also put forth additional threats to agriculture and food security, health as well as water availability and access, among others. With ruinous impacts of climate variability and change conjoining with inherent variability of the ASALs, implementation of adaptation strategies is crucial for the achievement of sustainable development in the 21st century. The negative impacts of climate change to the ASALs inhabitants have not gone unnoticed by the national government, international aid agencies and non-governmental organizations who have continued to fund adaptation initiatives as climate management options mostly in form of pilot projects to support the livelihood systems in the ASALs.

This recognition has resulted into multimillion-dollar investments through pilot initiatives in search for solutions to buffer vulnerable communities in many ASALs of Africa against the impacts of climate variability and change. Common characteristics of pilot initiatives are their limited scale in terms of time and space and lack of lasting impacts to intended beneficiaries due to unsustainability of their good practices (Van Buuren *et al.,* 2018). Among the many climate change adaptation options fronted through pilot initiatives is the promotion of climate services use. Climate services encompass the provision and use of both weather and climate information, coupled with advisories, to facilitate decision-making among smallholder farmers. The devastating impacts of the 1997/1998 El-Nino event led to a rise in climate services pilot projects, especially in East Africa (Hansen *et al.,* 2011). These pilot projects have received increased attention globally in the recent past due to the mounting evidence of the added value they impart on the agricultural sector (Ouedraogo *et al.,* 2018; Vaughan *et al.,* 2018; Nikulin *et al.,* 2018). Consequently, this has led to an increase in the number of donor-funded short-term pilot initiatives promoting this adaptation option.

These pilot initiatives arouse demand and expectations for continued services even after they end (Singh *et al.,* 2016). On the flip side, the demand for continued services is only sustained as long as the pilot projects are in existence and therefore their capacity to benefit a critical mass of the target population is limited. This is because the provision of services and their application by the beneficiary communities are not sustained. In addition, the end of pilots also marks an end to the dialogue that existed between the pilot research actors and beneficiaries. Hansen *et al.,* (2011) and Meza *et al.,* (2008) noted the great potential of effective climate information combined with advisory services in informing farm level decision making and guiding the management of climate related agricultural risks among smallholder farmers. However, the impact of these pilot driven initiatives on the beneficiary communities is limited due to the sustainability issues cited above. In addition, good practices experienced by pilot beneficiaries do not go beyond the pilot scale to ensure wider adoption. These challenges are key factors that hinders Africa's agricultural production, adaptive capacity and resilience to climate change impacts. Acceleration of adoption of tested and proven good practices that emanate from past pilot initiatives has the potential to increase the adaptive capacity of smallholder farmers.

In line with the process of devolution and decentralization, the constitution of Kenya (2010) offers opportunity for services to be moved closer to the citizens. In view of this, the Kenya Meteorological Department has established county meteorological offices in each county headed by a County Director of Meteorology Services (CDM). One responsibility of the CDM is to develop and provide climate services which can support the county's climate sensitive sectors such as agriculture and food security among others. In as much as this offers a great opportunity to reach the grassroots with climate services, there is an unseen challenge. The CDM, operating within national budget constraints, will have to grapple with the challenges of meeting demand for climate services provision that is left behind by previous pilot projects in the county.

Food insecurity has been a pressing issue due to low adoption of climate management options. This insecurity manifests in form of starvation, food rationing, malnourishment and deaths (Parry *et al.,* 2007). In addition to these impacts, Carter and Barret (2006) observed that peoples' response to such shocks could trap them into poverty cycles, for instance through selling farm properties to buy food. Moreover, high food insecurity has exacerbated urban poverty through accelerating rural to urban resettlement (Black *et al.,* 2011; Barnett and Adger, 2007; Barrios *et al.,* 2006). Projected climate change adds considerable urgency to the situation. Wheeler and Braun (2013) and Kotir (2011) demonstrate that even the 2^{o}C target will bring even more severe and devastating impacts for the poor of the developing countries. It is no doubt that climate change puts forth a myriad of risks to food supply and security a threat that can be reduced by increasing the adaptive capacity of vulnerable communities such as smallholder farmers.

Thus, inherent in the fight against climate change is the need to search for new ways to ensure that good practices of past pilot initiatives inform future research endeavors that seek to enhance adoption of any adaptation option among a wider population and contribute to development outcomes sustainably. In this regard, and with climate services as the focus adaptation option, this research aimed to thoroughly interrogate past pilot initiatives in order to understand their contributions to climate risk management and to extract the good practices they offer. The research further endeavored to enhance adoption of climate services among a wide population of smallholder farmers by implementing these good practices through an innovation systems approach, which views climate services in a more systematic and interactive way. Lastly, the research consolidated factors that can contribute to sustained massive adoption of climate services among smallholder farmer communities.

1.1 Problem Statement

The promotion of use of climate services among farming populations not only in the ASALs but also across Sub Saharan Africa has received a lot of attention recently. However, many meteorological organizations have not been able to provide climate services on a sustained basis, a problem that Tall *et al.,* (2014) discusses in the context of scaling up climate services for farmers. In view of this there has been a rise in the number of pilot scale and project-based initiatives in attempt to supplement the supply deficiency of climate services to user communities especially in the ASALs. However, the level of adoption of pilot driven solutions by farmers after the pilots come to an end has remained low making it difficult to resolve problems of food insecurity and rural poverty (Millar and Connell, 2010; Jonasova and Cooke, 2012; Pachico, 2004). As a result, food insecurity remains a stark reality for most smallholder communities.

There is a large body of literature discussing delivery of climate services specifically short-term weather information by state and civil society actors. This notwithstanding, it is not evident to what degree these past pilot project experiences inform improved provision of climate services by national meteorological services. In addition, there has been failure to move good practices to scale beyond pilot initiatives in order to ensure wider adoption of climate services. Good practices that made past pilot projects to be successful or unsuccessful can guide effective and sustainable provision of current and future climate services.

This study therefore sought to interrogate past climate services pilot initiatives in order to establish and document good practices, which can be transferred to inform effective and sustainable future provision of climate services. Further, the research aimed to demonstrate, through a participatory approach, an efficient way of implementing the identified good practices to enhance massive adoption of climate services at a county level.

1.2 Research Questions

The following are the research questions that guided the study:

1. How have past climate services pilot projects contributed to climate risk management and what good practices do they offer?
2. How vulnerable are Kitui county communities to persistent climate risks and how have they coped over the years?
3. Which climate services approach works best for climate resilience development in selected communities of Kitui county?
4. Under what enabling environment will the proposed approach for enhancing climate services adoption function optimally as a guarantee for effective scale up?

1.3 Research Objective

The overall purpose of this study was to contribute to the enhancement of climate risk management of smallholder farmers in Kitui county through improved adoption of climate services. To achieve this, the following specific objectives were addressed.

1. Review the contribution of past climate services pilot projects in climate risk management in order to establish good practices;
2. Determine the vulnerability of Kitui county communities to climate risks and document their coping strategies;
3. Co-design and test appropriate approach for enhanced climate services adoption necessary for increased resilience through participatory action research; and
4. Determine the enabling environment for effective scale up and sustainability of climate services through the proposed approach.

1.4 Justification and Significance of the Research

Strengthening adaptation is particularly critical in developing countries where peoples' lives and livelihoods are most vulnerable to climate shocks and stresses such as erratic rainfall, droughts and floods. The Intergovernmental Panel on Climate Change (IPCC) through its 5th Assessment Report (hereafter AR5) echoes this statement by reinforcing the urgency of supporting adaptation whether among the rural poor communities that depend on rainfed agriculture and other climate sensitive resources or among the urban poor exposed to climate hazards (IPCC, 2014). Enhancing adoption of climate services will enable more farmers to improve their ability to face a changing climate while increasing production and income.

The Constitution of Kenya (2010) requires decentralization of all national services and therefore this research will contribute to this course by informing climate services decentralization efforts to reach the village level. The aim deadline for the completion of the Millennium Development Goals (MDGs) was 2015. The post 2015 Sustainable Development Goals (SDGs) have been adopted. This post 2015 sustainable development agenda has been envisioned to address many issues including ending poverty and hunger, improving health and combating climate change among others. Enhanced adoption of climate services will contribute to addressing many of the SDGs, especially food security. In addition, the vision of the Global Framework for Climate Services (GFCS) is "to enable the society to better manage the risks and opportunities arising from climate variability and change, especially for those who are most vulnerable to such risks" (Lucio and Grasso, 2016). Ensuring greater availability of, access to and use of climate services which formed the main focus of the study has the potential to build the capacity of the vulnerable population and therefore contribute to realization of GFCS vision.

Kitui County in Kenya is the focal area for this study since it is semi-arid with a large number of small-scale subsistence farmers who are highly vulnerable to climate risks. The smallholder farmers in this region have not used climate services adequately to manage climate risks through seasons. This is despite the existence of public extension services. This can be attributed to the fact that the ratio of public service extension officer to farmer is very small. In addition, the public extension officers have been working without close collaboaration with the county director of meteorological services. Given the semi-arid nature of this region, improving farmers' preparedness through wide scale adoption of climate services can create a big impact in the agricultural production system. This is in cognizant that agriculture is the leading economic sector in the county. The results of the study have the potential to inform adaptation efforts in other ASALs regions of Kenya and beyond.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This section discusses the literature review relevant to the study. A detailed discussion on climate variability and change as well as its impacts on smallholder farming is presented. This discussion is informed by relavant existing literatures whose citations have been provided accordingly. In addition to this, literature on use of climate services as a coping mechanism to climate risk is also presented. The climate services have been widely researched. In this regard, their discussion is informed from diverse relevant literatures to assess the knowledge gap(s) that exist. Lastly, the innovation systems concept is discussed visa viz the linear technology diffusion in the context of mobilizing science and technology in order to realize more social and economic benefits. The information from previous artcles on innovation systems will inform the research on how best to co-design and test a climate services innovation systems.

2.1 Climate variability and Change

The warming of the climate system due to climate change has been described as unequivocal with many unprecedented changes over decades (IPCC, 2014). There has been mounting evidence of human influence on the changes in the climate system through anthropogenic greenhouse gas emissions driven largely by economic and population growth. The IPCC AR5 attributes over half of the observed global average surface temperature rise in recent years to increase in anthropogenic greenhouse gases concentration and anthropogenic forcing. Climate change may be characterized by average changes that occur for a long period of time, such as decades or longer (IPCC, 2014). Integral to this, is climate variability which includes deviations and inconsistencies in the mean state of climate on timescales longer than weather events including year to year short-time fluctuations.

Climate change is expected to bring warmer temperatures, changes in rainfall patterns and increased return period and intensity of extreme weather events (Wheeler and Von 2013). Global mean temperature by the end of this century are projected to be 1.8^{o} C to 4.0^{o} C warmer than the previous century (*ibid*). Rainfall amount and distribution within a season is the most important climate element in the rainfed smallholder agricultural systems. In addition, floods, droughts and extreme weather phenomena strongly affect agricultural productivity. This implies that changes in climate or weather patterns affects farming activities and poverty reduction efforts. Climate change and variability in African smallholder farming systems can be considered as an additional threat to other existing pressures such as population growth, poverty and killer diseases such as malaria (Mapfumo *et al.,* 2008). Climate change and variability cause significant threats to water resources, food security, health, infrastructure as well as ecosystem services and biodiversity. Many studies point to the fact that impacts of climate change will be differentiated among the world's population (Thornton *et al.,* 2008), which can be due to the reality that ability to respond to impacts vary across nations. However, there is a high confidence from research findings that vulnerability to climate change will be more for developing countries. Among the developing countries Sub Saharan Africa (SSA) is considered the most vulnerable to impacts of climate change because of low adaptive capacity of its populations, warmer baseline climates, low precipitation and greater reliance on climate sensitive sectors such as agriculture and pastoralism for their livelihoods (*ibid*). Communities in this region are already struggling to cope with current climate variability and will therefore face a daunting task in adapting to future climate change. In addition, Dinar *et al.,* (2012) attribute the high climate change vulnerability in SSA to already existing severe climate, poor present information access and slow technological advancement. Empirical results show that periodic droughts and floods associated with climate variability lead to major macro-economic costs (Ochieng *et al.,* 2016), which has a potential to bring economic growth to a decline.

Kenya like the rest of the world is experiencing climate change and variability as well as the associated adverse impacts (GOK, 2010). The state of climate change and variability in Kenya is documented in several articles including the Farm Management Handbook of Kenya (Jaetzold *et al.,* 2006), the National Climate Change Response Strategy (GOK, 2010), The National Climate Change Action Plan (2013) among others. An analysis of trends in temperature, rainfall patterns, and extreme events in all these documents, points to a clear evidence of climate change in Kenya. Another recent research indicates a reduction in extreme cold temperature occurrences (Ouma *et al.,* 2018). According to Ouma *et al* (2018), ASALs of Kenya have recorded an increase in maximum and minimum temperatures between the years 1961 and 2013, with the highest increase being recorded at night.

In addition, these authors also point to a decreasing seasonal rainfall trend with the long rainfall season (March April May) recording the highest decrease. Spatially, the southern parts of the ASALs had a larger decreasing trend in rainfall than the northern parts. These findings are somehow similar to those of Kenya Climate Change Response Strategy (GOK, 2010), which states that temperatures have risen throughout the country, rainfall has become irregular and unpredictable and that extreme and harsh weather is now a norm in Kenya. In specific this document points out that, since early 1960s, both minimum (night time) and maximum (day time) have been on an increasing trend. In addition, rainfall variability has increased within the years, and year to year. Moreover, it also states that the main rainfall season of March to May (the long rains) has generally declined, which is to mean that drought has become more frequent and prolonged during this season. However, in contrary to Ouma *et al.,* (2018), GOK (2010) reports a general positive trend for the short rainfall season (October to December) with rainfall extending into the usually hot months of January and February.

The National Climate Change Action Plan (GOK, 2013) establishes that temperatures will continue to increase and the frequency of hot days and nights will rise. In addition, precipitation is likely to increase with the largest increment occurring in the highlands and coastal regions. In contrast the ASALs of Kenya, which make the greater part of the country are expected to become significantly drier. Focusing on Africa, a key conclusion of the IPCC AR5 Summary for Policy Makers was that in some nations, yields from rain-fed agriculture could be reduced by up to 50 percent by 2020. Agricultural production, including access to food, in many African countries is expected to be severely compromised. This would further adversely affect food security and exacerbate malnutrition (IPCC, 2014).

Going by this conclusion and without questioning the underlying science, climate change adaptation looms as an important policy area for African nations. The major impacts from slow changes for instance, rising temperatures and sea level rise, will be realized in the coming decades (IPCC, 2014). However, farmers already have to deal with present changes in weather patterns and rising intensity and frequency of extreme weather events, which make farming even more risky. Therefore, enhancing the ability of African communities to cope better with the risks and opportunities of current climate variability is a necessary step for adapting to future climate change. This points to the need for building capacities of households, communities and relevant institutions in order to respond to these changing conditions. Mitigation efforts to reduce the sources of or to enhance the sink of greenhouse gases will take time and requires international cooperation.

On the contrary, adaptation can reduce climate related risks and often with a shorter lead time. Mitigation tackles the causes of GHG while adaptation tackles the effect of climate change. Therefore, adaptation actions to reduce risk matter more and are urgent to developing countries. A lot of peer reviewed literature already exists on climate variability and change as well as on mitigation and adaptation and the numbers are increasing each year as a result of research work. With enormous number of research findings and the need to understand how past research can inform present research, there is a necessity to shift from the conventional means of conducting literature review to a more systematic and transparent way of interrogating past research (Berrang-Ford *et al.,* 2015; Ford *et al.,* 2014). This more transparent way has been termed as systematic literature review and is discussed in the next section.

2.2 Systematic literature review

A systematic literature review is a summary and an assessment of the state of knowledge on a research question or a given topic, which is structured to summarize existing understanding (Ford and Pearce, 2010). This review approach is different from the traditional literature review approach in many ways. One outstanding difference is that the systematic review methodology avoids the inherent bias relating to selection and interpretation of content that characterizes traditional literature review methodologies (Biesbroek *et al.,* 2013). Recent studies in climate change research notably Ford and Pearce, (2010); Thompson *et al.,* (2010); Ford *et al.,* (2014) and Biesbroek *et al.,* (2013) have demonstrated the value of this methodology in summarizing state of knowledge from existing literature.

Ford and Pearce (2010) and Berrang-Ford *et al., (*2015) give a discourse of other ways in which the systematic literature review approach differs from the traditional literature reviews. First, systematic literature reviews employ pre-defined eligibility criteria for inclusion and exclusion of documents, which enhances both transparency and replicability of the review process. This pre-defined eligibility criteria for documents ensures that the final reviewed documents are based on a criterion that can be defended instead of an ad hoc and biased document selection (Berrang-Ford *et al.,* 2015). Secondly, systematic reviews present a disclosure of the databases searched through the review process and the search keywords used for every searched database. Lastly, systematic reviews permit the use of qualitative and quantitative approaches to extract and discuss information from the selected documents. In short, unlike the systematic reviews, the traditional literature review approaches do not provide any details on the review procedures used, which makes it difficult to replicate such studies and validate interpretation (Ford *et al.,* 2014). Traditional literature reviews are therefore subjected to researcher bias, which can influence the direction of a research question through a biased selection of documents.

Systematic literature reviews have been applied across diverse disciplines but more so in health and health related sciences (Berrang-Ford *et al.,* 2015). Despite diverse applications, a systematic review process follows systematized methodology consisting of five general steps: (a) formulate research question/s and scope, (b) develop criteria for document inclusion and exclusion as well as search terms to guide document selection across databases, (c) critically appraise and filter selected documents based on the inclusion and exclusion criteria, (d) analyze review results using quantitative and/or qualitative approaches, (e) present results (Higgins and Green 2011; Barth and Thomas 2012; Berrang-Ford *et al.,* 2015; Ford *et al.,* 2014; Biesbroek *et al.,* 2013). The findings that result from this systematized way of conducting research can inform present and future research especially in framing research problems and advancing knowledge. In addition, it presents a more bias free and transparent way of studying a complex issue such as climate variability and change. Next section presents a discussion of the impacts of climate variability and change on smallholder agriculture.

2.3 Impacts of climate variability and change on smallholder agriculture

Smallholder farmers are the majority in the agricultural sector and form the backbone of the agricultural production in Africa (Morton, 2007; Mapfumo *et al*., 2013; Jost *et al*., 2016). According to Kalungu *et al* (2013) the smallholder farmers are estimated to be 36 million across the continent and have an access to an average of two hectares or less of land for their agricultural production. The contribution of the smallholder farmers to the domestic food production is hence important due to their dominance in the sector.

One of the main threats facing smallholder agriculture in sub-Saharan Africa is climate change because of its associated extreme weather conditions (Ochieng *et al.,* 2016; Morton, 2007). In addition, Ochieng *et al* (2016) and Jayne *et al* (2010) conclude that agriculture remains an important livelihood source for most rural sub-Saharan communities through employment provision and contribution to the gross domestic product. Despite the high dependency of economies on agriculture, the region is already experiencing high temperature and highly variable rainfall coupled with low adoption of modern technology (Ouma *et al.,* 2018). All these authors point out to the fact that the smallholder sector in sub-Saharan Africa is already vulnerable to environmental degradation and rainfall variability. This is in addition to other development stresses, notably poverty and food insecurity (FAO, 2008).

Similarly, in Kenya, agricultural sector plays a significant role in the country's economy. In 2010 and 2011 for example, agriculture as an income-generating sector contributed 21.4% and 24% respectively (KPMG, 2012) to the national GDP. Despite this contribution, the sector is mainly made up of smallholder farmers who provide 75% of the labor force and 75% of the market output produce (Alila and Atieno, 2006). The agricultural sector is affected the most by climate variability and change especially in the arid and semi-arid areas of Kenya where smallholder farmers rely solely on rain-fed agriculture. About 80% of Kenya is arid and semi-arid (ASAL) and the main livelihood activities in these areas are pastoral and agro-pastoral in form of smallholder agriculture. The crops grown are just enough for subsistence use and not for commercial purposes. To venture commercially, these farmers would need more capital and to operate through a larger organization such as a cooperative sacco. Drought is the most pervasive hazard encountered by households on a widespread level in Kenya's ASALs (Chantara *et al.,* 2013). According to Mutimba *et al* (2010) climate variability and change in Kenya has resulted in a decrease in drought return period from 20 years (1964-1984) to 12 years (1984-1996) to 2 years (2004-2006) and recently to annually (2007/2008/2009/2010/2011/2012).

Farming in ASALs, where season-to-season rainfall variability determines productivity, is a risky endeavor especially for the smallholder farmers with limited land and financial resources (Rao *et al.,* 2011). Climate change causes negative impacts on agriculture destabilizing smallholder farmers' livelihoods (Below *et al.,* 2010). A number of regional and national studies have highlighted the possible negative impacts of climate variability and future change on agricultural productivity and the urgent need to develop improved coping and adaptation strategies. This is especially true for the ASALs of Kenya, which are particularly vulnerable to the impacts of climate variability and change due to high dependency on rainfed agriculture and limited capacity to adapt (Lobell *et al.,* 2008; Schlenker and Lobell, 2010; Rao *et al.,* 2011).

Kitui County, which is located in the ASALs of Kenya, suffers from a myriad of climate-induced impacts. These include: increased crop failure, dry river beds, widespread malnutrition, famine and dependency on relief food, increased poverty level, increased criminal activities such as theft due to loss of livelihoods, rural-urban migration, increased school dropouts, and increased food prices (Evelyn *et al.,* 2017). Although smallholder farmers have been adapting their agriculture to changing climate they are still vulnerable to the impacts of climate change. Compared to commercial agriculture, smallholder farmers are less adapted to climate change and usually do not have access to financial instruments such as credit and insurance to hedge against climate risk, which makes them more vulnerable.

Agriculture is a viable economic sector that can contribute to self-dependency and poverty eradication. However, with the projected continuing warming of the globe, glaring challenges are in store for smallholder farmers especially in the ASALs, where large-scale catastrophes spark humanitarian crisis inducing emergency response by government in form of food aid. The cost and frequency of emergency drought response has grown in Kenya promoting exploration of more comprehensive and effective risk management strategies (Chantara *et al.,* 2013). However, vulnerability to climate change is differentiated even among closely located communities (Brooks *et al.,* 2005). Understanding the vulnerability of a region is, therefore, a critical first step before targeting adaptation assistance. The vulnerability assessment concept and its importance in informing adaptation assistance for populations are discussed in the net section.

2.4 Climate change vulnerability assessment

Vulnerability can be defined differently from different perspectives. The IPCC AR5 describes climate change vulnerability as the degree to which biological, geophysical and socio-economic processes, are susceptible and unable to cope with adverse climate change impacts (IPCC, 2015). The most commonly used concept of vulnerability is the IPCC structure. This structure acknowledges that the susceptibility to harm is determined not only by a stressor, but also by the sensitivity of the system and its ability to deal with losses or resist effects (Shirley *et al.,* 2012; Mechler and Boumer, 2015, Parry *et al.,* 2007). It also splits climate vulnerability into three components: exposure, sensitivity and adaptive capacity of the system being exposed.

Coulibaly *et al.,* (2015) describes exposure "as the degree to which climate danger is exposed to a system." Long-term climatic changes or changes in climate variability, including both the severity and frequency of extreme events, can characterise this component (O'Brien *et al.,* 2004). Sensitivity on the other hand, is the state of the system that may minimize or exacerbate the effect (*ibid*) and can be affected by a system's characteristic. In other words, it is the responsiveness to climatic stimuli (either positively or negatively). The third parameter is adaptive capability, which indicates a system's ability to adapt to a changing environment. This can be correlated with asset ownership, meaning that the higher the adaptive capacity, the more an individual has.

According to the concept of vulnerability by the IPCC, the most vulnerable populations or regions are most susceptible to climate changes, are climate-sensitive and have the lowest capacity to respond and recover. However, the vulnerability of populations to climate stressors and adaptation capacities are spatially distinct, even within similar regions (de Sherbinin *et al.,* 2015), so that a combination of these factors produces different patterns of vulnerability. In addition, Brooks *et al.,* (2005) also states that vulnerability is context-specific and that what makes one community/region vulnerable can be different. Understanding the vulnerability of a community/region is, therefore, a critical first step before targeting adaptation assistance.

One of the ways to reduce vulnerability to climate change and food insecurity challenges is through enhanced use of agro-meteorological data to help manage climate related risks (Kotir, 2011). Access to climate information and services has the potential to enable farmers make informed farm management and adaptation decisions in the face of climate variability and change. This forms the main discussion in the next section.

2.5 Climate Services as climate risk management tool for smallholder farmers

According to Tall *et al* (2014), climate services include the provision of relevant weather and climate information coupled with a range of advisory services to support decision-making. They reduce uncertainty for farmers so that they can better adapt to climate variability and climate risks. Such services also increase farmers' preparedness and lead to better social, economic and environmental outcomes within the agricultural production systems (Meza *et al.,* 2008). The value attached to them has made them to be considered critical to risk management and adaptation to climate change especially for the world's most vulnerable farmers (Hansen *et al.,* 200; Dinku *et al.,* 2011).

Climate services are receiving increasing attention globally as an important option for climate adaptation. Efficient climate knowledge and advisory services have tremendous potential to inform farm-level decision-making in the face of climate change volatility, to enhance climate-related agricultural risk management and to increase farmers' sensitivity to climate change (Tall *et al.,* 2014). The growing proof of their added value in promoting better decision-making in sectors such as agriculture and food security, disaster prevention, sanitation and water management is another factor that has played an important role in advocating climate services (Rummukainen, 2016; Ouedraogo *et al.,* 2018). The use of climate services to inform disaster preparedness by the Kenya Red Cross is one good example of how climate services can influence sound decision making. Participatory scenario planning by CARE (Cooperative for Assistance and Relief Everywhere) is another example of how climate services have impacted positively on smallholder farming systems by influencing farm level decisions.

Many studies have documented the potential use of climate services in decision-making. Several authors argue that advance provision of these services has significant potential to contribute to agricultural management and food security (Hansen *et al.,* 2011; Mase *et al.,* 2014; Dayamba *et al.,* 2018). Other authors indicate that providing climate services early enough to adjust pre-planting management decisions has the potential to improve agricultural risk management (Ouedraogo *et al.,* 2018; Partey *et al.,* 2018; EwBank, 2016; Nesheim *et al.,* 2017). Ziervogel (2004) through surveys and pilot studies in Southern Africa showed that farmers see opportunities to benefit from seasonal forecasts.

Knowing the ability of climate networks to minimize climate threats, a great deal of study has been committed to highlighting conditions that need to be met and problems that need to be tackled in order to optimize their potential (Patt and Gwata 2002; Meinke *et al.,* 2006; Hansen *et al.,* 2011; Stigter *et al.,* 2014). Inspired by the results from such research, National Hydrological and Meteorological Services independently or in collaboration with other organizations such as the Non-Governmental Organizations (NGO) across Africa and Asia have improved accessibility, relevance and communication mechanisms of climate services to the end users (Hansen *et al.,* 2011; Tall *et al.,* 2014).

However, a few national agrometeorological services provide climate services on a sustained basis (Tall *et al.,* 2014), which has led to an upsurge of pilot project initiatives in an attempt to supplement unmet demand. Recent research has focused on search for approaches to help agricultural sector make better use of new knowledge and for designing alternative interventions that go beyond research pilot investments. One of the approaches that appears to offer exciting opportunities is the 'innovation systems' approach, which forms the main discussion of the next section.

2.6 Innovation system approach

Innovation can be defined in different ways. Madukwe and Obiora (2012) define it as the process of developing, adapting and subsequent adoption of technologies that are new to a specific context. Conventionally this process was understood to take place through a linear process from research, technology development, dissemination and adoption (Hall *et al.,* 2001). In the linear technology diffusion process, knowledge, information and technology were generated from a central source with information flowing from researchers to farmers through extension agents. However, this linear technology diffusion has met a lot of criticism since it fails to explain the knowledge adoption process. First it is likely to hinder participatory approaches of local actors (Kibwika et al., 2009). Secondly, it regards farmers as spectators in the development process thereby making it restrictive in nature and hinders adoption of technology by farmers (Hall et al., 2003; World Bank, 2006). This has contributed to the introduction of the idea of the innovation systems method that views the adoption of information more systematically and interactively.

The innovation systems approach fosters a change in the viewing of knowledge production and how this is supported. It shifts attention away from research and the supply of science and technology (that is, a shift from research and extension services) to include the whole innovation process, in which research and extension are elements (Lundvall *et al.,* 2009; Pound and Conroy, 2017). Innovation networks have been described by the World Bank (2006) as a network of organizations, businesses and individuals focused on putting new goods, new processes and new modes of organizations into economic usage, along with institutions and policies that influence the actions and efficiency of the systems. From this definition, this approach fosters a shift from the conventional linear models of research and development to arrangements that resemble a network or system of researchers, farmers and other organizations involved in the creation, diffusion, adaptation and use of knowledge.

Many proponents of this shift argue that this type of a system is conducive for knowledge sharing and interactive learning that promotes adoption of new knowledge and technology among farmers. According to Hall *et al.,* (2005) an innovation system consists of a web of dynamic interactions among several actors such as researchers, extension agents, farmers, traders, and processors. Innovation systems have emerged around conservation agriculture practices across the developing world (Erenstein *et al.,* 2008; Dixon *et al.,* 2008; Kanda *et.al,* 2019) and rural development (Hellin 2012). With the recognition of farmers as part of the process it is further believed that it may serve as an incentive to promote adoption of any technology that is developed through this process (World Bank, 2006).

However, innovation system exists only as social construct and not as objective realities (Daane, 2009) implying that it can be defined according to the need at hand, for example, specific domain, value chain, climate change or farming system. For instance, Mudukwe and Obiora (2012) define climate change innovation system as comprising organizations and individuals that together demand and supply knowledge and technology needed for climate change adaptation and mitigation, and the mechanisms through which different actors interact. Informed by Daane (2009) and Mudukwe and Obiora (2012), one can define a climate service innovation system as comprising organizations and individuals that supply and demand climate services together with the rules or mechanisms by which different actors in the network interact.

However, while networks of actors are important for an effective innovation systems, qualities of actual linkages among actors are more essential (Woodhill, 2005). This points to the need for effective communication and working relationships among actors if an innovation system has to achieve any social impact. As indicated by Mudukwe and Obiora (2012) it is worthwhile to identify actors and to map linkages between these actors as a first step in developing an effective innovation system. In this regard, pertinent question would be: 'who are the actors in the climate services innovation system?'; 'are there any linkages between these actors?'; if yes, how does one identify and map these linkages?'.

An overarching finding from the studies referenced in this chapter is that the traditional method of distribution of linear information is an oversimplification of dynamic processes illustrated by non-linear processes, feedback loops, and other complex interactions involving even more heterogeneous actors. As such, a more systemic approach is necessary in place of the linear knowledge delivery approach to help mobilize science and technology to deliver benefits that can enhance the salience, credibility and legitimacy of scientific information. Taking such an approach supports the understanding of the social networks, including identification of key information nodes as well as existing and potential pathways to disseminate information effectively to all farmers (Cash *et al.,* 2006)

CHAPTER THREE: STUDY AREA, DATA AND METHODS

3.0 Introduction

This chapter presents a description of the study area, conceptual framework, methodological approach, data and specific methods used for each objective of the study.

3.1 Study area

3.1.1 Location and description

The study was conducted in Kitui county, which lies in the lower eastern parts of Kenya 160km east of Nairobi city. It is located between latitudes $0^{o}10'$ and 3^{o} south, and longitudes 37^{o} and $39^{o}0$ east (GoK, 2013). The county borders Taita Taveta county to the south, Tana River county to the east, and Machakos and Makueni counties to the west. It has eight (8) Sub-counties namely: Kitui Central, Kitui West, Kitui East, Kitui South, Kitui Rural, Mwingi North, Mwingi Central and Mwingi West (Figure 3.1). The county is further sub-divided into forty (40) wards. It extends over 30,570 square kilometers of which 6,369 square kilometers are occupied by Tsavo East National park. The topography is low lying over most of the county (400 and 1800 m above sea level). The general landscape is flat but gently slopes towards the east and northeast parts of the county reaching as low as 400m above sea level.

The higher areas experience more rain more frequently, and therefore lend themselves to agriculture. The county inhabitants are heavily dependent on agro-pastoralism (combination of livestock keeping and smallholder farming) and there are two principal livelihood systems namely mixed farming and marginal mixed farming. Mixed farming takes place in LM4 (Lower midland zone 4), LM5 (Lower midland zone 5) and UM4 (Upper midland zone 4) agro-ecological zones. In this regard, the study purposively selected three wards within the county based on their placement in the mixed farming climate zones as follows Kyangwithia west (LM5 93% and LM4 7%), Matinyani (UM4 100%), and Kwa-Vonza (LM5 73%, and LM4 6%). Marginal mixed farming takes place in the IL5 (Inner midland zone 5) and IL6 (Inner midland zone 6) agro-ecological zones of the county which are mainly pastoralist areas with little or no crop farming. The balance between agriculture and pastoralism changes across the county, becoming more agricultural in the northern, western and central areas where annual rainfall is relatively high and more livestock oriented in the drier sub-locations of the far south and eastern areas.

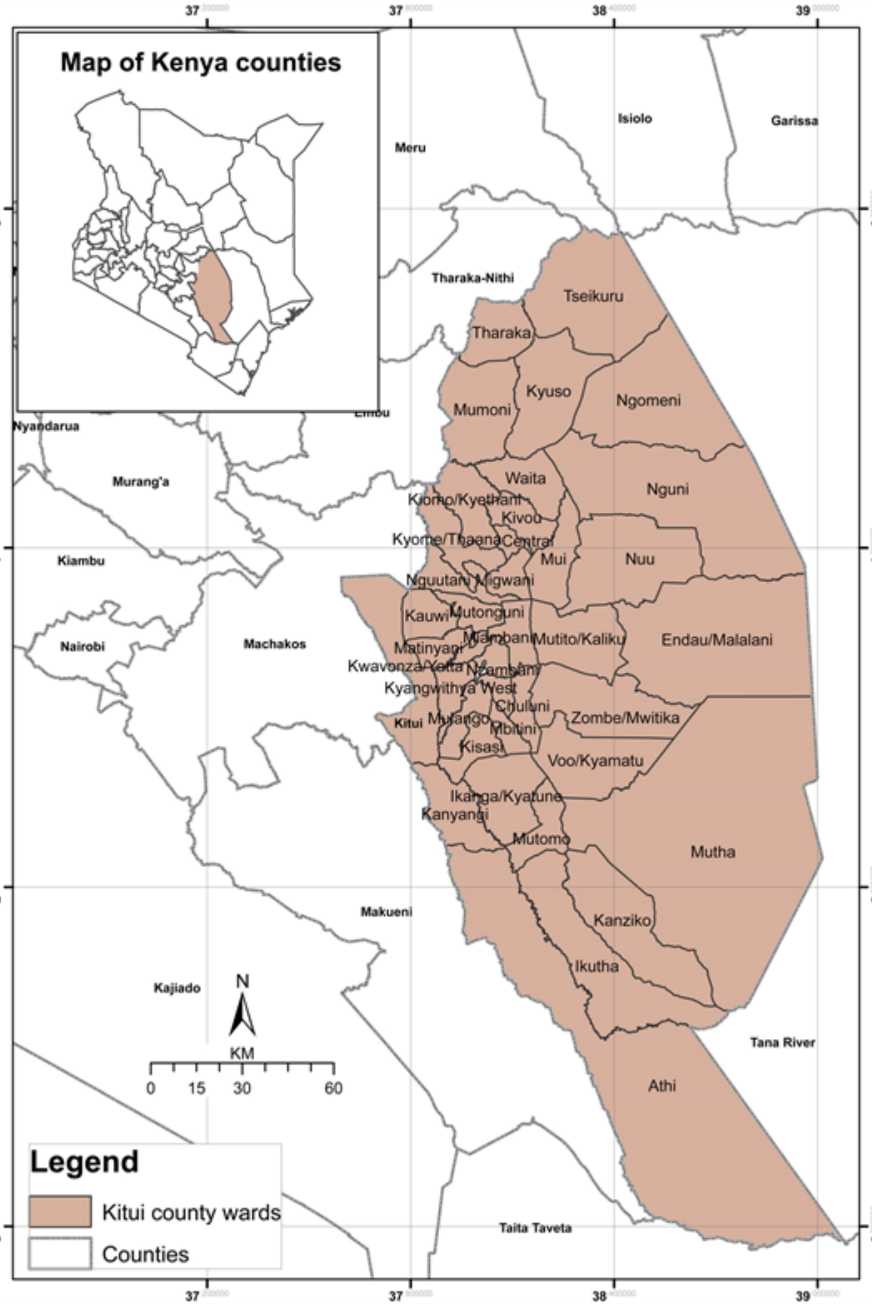


Figure 3.1: The political and administrative boundaries of the study area

(Source: https://m.scirp.org/papers/99585. Accessed 29th July 2020)

3.1.2 Biophysical setting

3.1.2.1 Climate

Annual rainfall ranges between 500mm to 1050mm and is received twice in a year (GOK, 2013): March to May and October to December as shown in Figures 3.2 and 3.3 respectively. The October to December rainfall season is more reliable (66%) and the principal production season (GOK, 2013). The March to May rainfall season is usually very erratic in this region with 40% reliability. The highland areas receive relatively high rainfall amounts compared with lowland areas. High temperatures are experienced throughout the year with a range between 14°C and 34°C. Annual mean maximum and minimum temperatures range from 28-32°C and 22-28°C respectively.

3.1.2.2 Vegetation

According to Luvanda (2016), savannas and drought deciduous woodlands largely characterize the vegetation of Kitui county. Topographic features determine the distribution of vegetation varieties and species. There are many tree species with the most dominant being the *Lannea triphylla* and *Commiphora Africana*. The acacia species is most valuable but scarce due to its preferred uses as firewood and timber (*ibid*). The area is also abundant with natural grasses and shrubs of *lantana camara* as well as other species (Munywoki *et al.,* 2004).

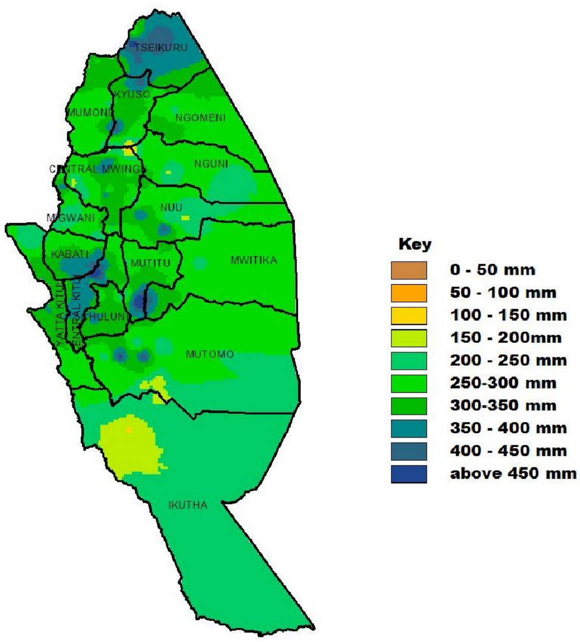


Figure 3.2: Average rainfall distribution in Kitui county over March April May

(Source: Kitui county climate services information strategic plan 2015).

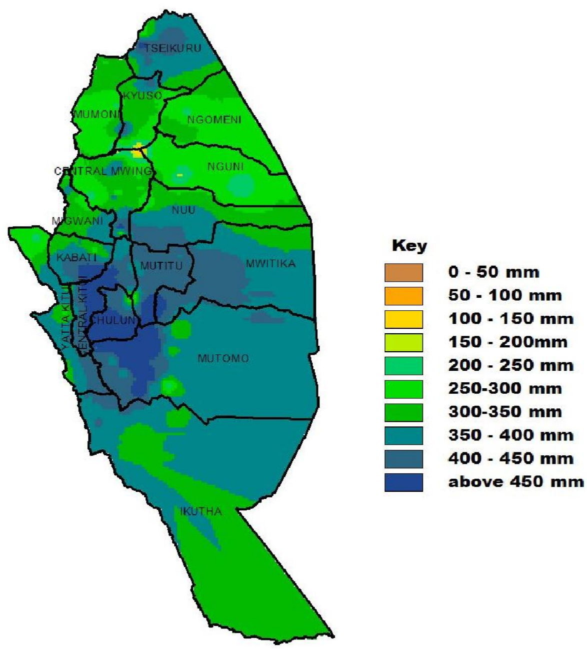


Figure 3.3: Average rainfall distribution in Kitui county over October November December (Source: Kitui county climate services information strategic plan 2015).

3.1.2.3 Water resources

There are only two perennial rivers in the county (Tana and Athi). Other water sources include seasonal rivers, dams, boreholes and water pans. During the rainy season, precipitation fed ephemeral rivers start flowing in the region and these are important water sources for the inhabitants. Surface and groundwater resources are scarce owing to erratic rainfall combined with poor drainage of the soils in the county. According to Milelu *et al.,* (2017) water availability is scarce in the area and only approximately 6% of the population have access to potable water. The rest of the population has to walk sometimes even as far as 20km in search for clean water.

3.1.3 Socio-economic setting

3.1.3.1 Social setting

The main ethnic group in the county is Akamba community but there is an increased influx of other ethnic groups from other regions of Kenya who have settled in the area. The county's population was projected to be 1,136,187 (2019 Kenyan census) with the male population and female population projected to be 549,003 and 587,151 respectively. Availability and accessibility of water as well as soil fertility largely influence the pattern and distribution of the population (*ibid*). This could explain the reason why population density is high on the foot hills where agriculture is possible. There is also high population in large towns due to employment opportunities and availability of reliable social amenities.

3.1.3.2 Economic setting

Rain-fed crop farming and livestock production are key economic activities in the county (KNBS, 2015). Irrigated agriculture only takes place on small plots on the riverbanks. At the household level income sources include agriculture, rural self-employment, wage employment and urban self-employment. Other sources of income are charcoal burning, brick making and weaving (Milelu *et al.,* 2017; Luvanda, 2016).

3.1.3.3 Socio-economic vulnerabilities

There is change in the physical environment due to deforestation, over grazing and land-use change. Major hazards associated with climate change in the county include droughts and flash floods.

3.2 Conceptual Framework

The conceptual framework (Figure 3.4) reflects climate variability and climate change interaction with smallholder communities within the adaptation arena. The arrows give an indication of the interlinkages between these categories. Community characteristics can make some communities more vulnerable than others. For instance, communities that rely on climate sensitive resources have a higher sensitivity to impacts from climate variability and change. Also, communities with little or no access to finances and assets, which would aid in adopting risk coping options are more sensitive to climate change impacts and hence more vulnerable than those with more access to the same. Such are the characteristics of smallholder farmer communities.

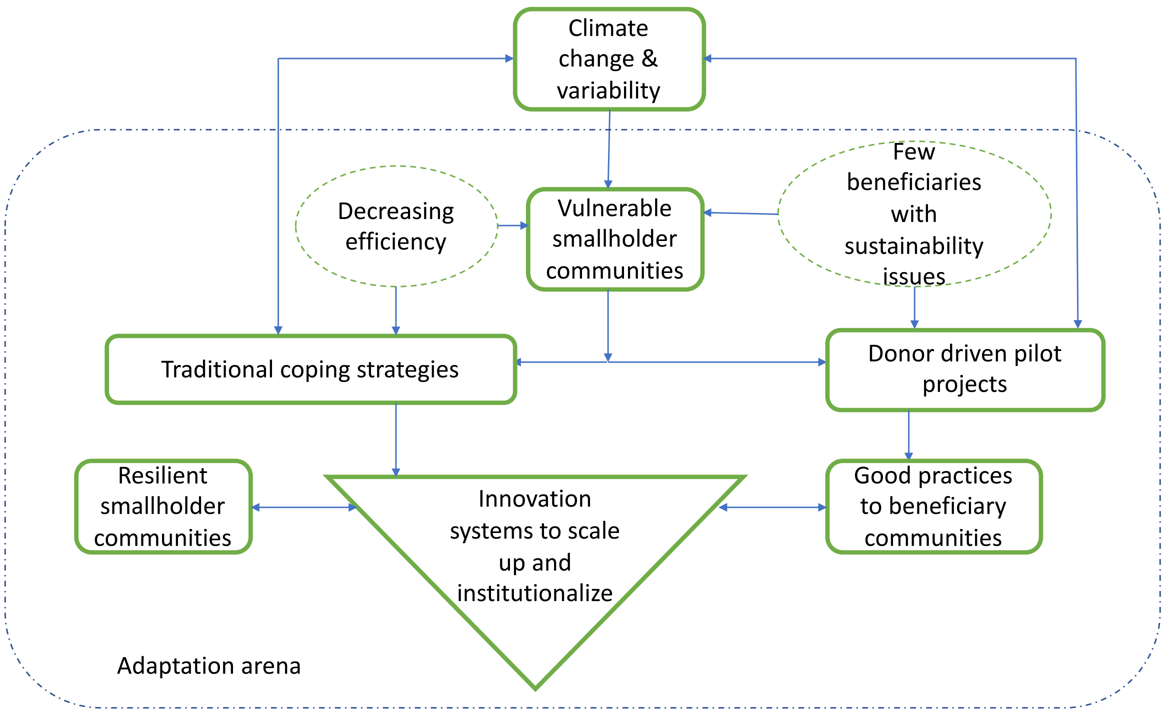


Figure 3.4: Schematic illustration of the Conceptual framework.

In the wake of increasing vulnerability to climate variability and change, these communities have existing traditional coping strategies, which are becoming increasingly inefficient. More modern adaptation options are necessary to supplement the existing coping stragies in order to reduce vulnerability levels. However, a lot of them are being championed through short-term donor funded pilot projects, such as those promoting use of climate services, with few community beneficiaries and issues of sustainability of good practices. As the framework illustrates, good practices that have made past pilot projects successful can be up scaled and institutionalized through an innovation systems approach to reduce community vulnerability and enhance resilience.

3.3 Research Design

The study employed a mixed type methods research design. A purely qualitative approach consisting of focus group discussions was used to get the community views and suggestions. These were further validated through key informant interviews. A quantitative approach using majorly secondary data was used in assessing the vulnerability of communities. The qualitative approach was used to collect primary data on existing coping strategies from the community as well as identifying potential stakeholders who would form the proposed climate services innovation system. On the other hand, the quantitative approach was used mmainly in objective two of the study to manipulate secondary data on vulnerability component indicators in order to produce an overall vulnerability map for the study area.

3.4 Data

Both secondary and primary data were used in this study. The sources of these data and how they were collected are presented below.

3.4.1 Secondary data

The secondary data included vulnerability indicators for vulnerability assessment and peer reviewed literature for systematic review.

3.4.1.1 Vulnerability indicators

A thorough quest for appropriate high-resolution predictor datasets to represent each of the three components of vulnerability was the starting point. In the sense of smallholder farming, which is the main livelihood method of the majority of the population in Kitui county, these proxy indicators were chosen. Instead of mapping different vulnerability elements for the populations, the study centred on mapping the general vulnerability of the community. Table 3.1 displays the list of metrics used and their origins for each vulnerability variable. In contrast to other vulnerability mapping analyses, metrics were chosen based on their representativeness of the vulnerability aspect in question, as well as the availability and accuracy of data.

As shown in Table 3.1, the first step included identification of appropriate indicators for each vulnerability component. The second step included a search for indicator variables to represent each identified indicator in step one (IPCC, 2014). As a result, exposure component indicators were identified as precipitation and temperature change. Indicator variables whose data was collected to represent precipitation change indicator included long-term trend, long-term average, and long-term coefficient of variation. All these data sets were derived from CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data) enhanced precipitation for the period 1983 to 2016 (http://legacy.chg.ucsb.edu/data/chirps/). CHIRPS is a quasi-global rainfall dataset that covers 30 years, from 1981 to near-current, covering 50°S-50°N (and all longitudes). In order to establish a gridded rainfall time series for pattern analysis and seasonal drought tracking, it combines 0.05° resolution satellite imagery with in-situ station data.

On the other hand, data collected to represent temperature change indicator included long-term average and long-term trend of temperature. These were obtained from CHIRTS (Climate Hazards Group Infrared Temperature with Stations) enhanced temperature for the period 1983 to 2016. CHIRTS is a global maximum temperature (Tmax) product that directly combines satellite and station-based estimates of Tmax at 0.05° resolution to produce routinely updated data to support the monitoring of temperature extremes.

Indicators used for the sensitivity component included: poverty with poverty index as the indicator variable from KNBS (Kenya National Bureau of Statistics), 2016; malaria susceptibility with malaria susceptibility index as the indicator variable sourced from Malaria Atlas Project, 2010; soil health with soil organic carbon stock as the indicator variable sourced from FAO-ISRIC (Food Agricultural Organization – International Soil Reference and Information Centre) soil grids, 2017; population with population count as indicator variable sourced from KNBS, 2010; and housing with house wall type index as indicator variable sourced from KNBS, 2013. The last vulnerability component was adaptive capacity. Indicators used for this component included: water access with access to safe drinking water as the indicator variable sourced from KNBS, 2015; Markets with access to markets in terms of travel time as the indicator variable sourced from KNBS, 2015; and literacy level with female literacy as the indicator variable sourced from KNBS, 2013.

Table 3.1: A list of indicators representing each vulnerability component in Kitui county

Vulnerability Component	Indicator	Indicator variable	Data Source
Exposure	Precipitation change	Long term average	CHIRPS enhanced precipitation, 1983 - 2016
		Long term trend	CHIRPS enhanced precipitation, 1983 - 2016
		Long-term coefficient of variation	CHIRPS enhanced precipitation, 1983 - 2016
	Temperature change	Long term average	CHIRTS enhanced temperature, 1983 - 2016
		Long term trend	CHIRTS enhanced temperature, 1983 - 2016
Sensitivity	Poverty	Poverty index (%)	KNBS, 2016
	Malaria susceptibility	Malaria susceptibility index	Malaria Atlas Project, 2010
	Soil health	Soil organic carbon stock	FAO-ISRIC Soil Grids, 2017
	Population	Population count	KNBS, 2010
	Housing	House wall type index	KNBS, 2013
Adaptive capacity	Water access	Access to safe drinking water	KNBS, 2015
	Markets	Access to market services (travel time)	KNBS, 2015
	Literacy level	Female literacy	KNBS, 2013

3.4.1.2 Peer-reviewed publications for systematic literature review

The other set of secondary data used in the study included peer reviewed articles obtained through key word search terms in Google Scholar (https://scholar.google.com/). The study used expert consultations with librarians to refine the choice of key words used for the searches. Key word searched included ["climate services" OR "climate information service*" OR "agro-advisor*"] AND ["smallholder farm*" OR "farmer*"] AND ["pilot project*" OR "pilot*"]. The study recognizes the existence of additional resources on use of climate services among the smallholder communities in Africa in form of non-peer reviewed forms; for example, working papers, project reports, newsletters and brochures prepared by different organizations. However, in order to obtain authoritative information, this review included only articles in peer reviewed journals. The review focused on applied research studies in Africa. This focus was chosen to facilitate generation of themes across similar social economic and social background contexts. Focusing on different continents would have made it difficult to justify generation of common themes from literature.

3.4.2 Primary data

Primary data was collected to identify the climate risk coping strategies employed by communities as well as assessment of farmers' climate services requirements. To achieve these aims, the study employed the data collection tools presented in the following sub-sections.

3.4.2.1 Sampling procedure

A mixed stratified and systematic random sampling procedures were used. Stratified maximizes the inclusion of different production methods and livelihood types. In this regard, it was used to ensure that the sampling represented livelihood variation in Kitui, and also minimized biases relating to the impact of climate on particular livelihoods. Three wards (Kyangwithia west, Matinyani and Kwa-Vonza) were identified from a sampling frame stratified by the location of the wards in the climatic zones. Kitui county has different climate zones (UM3 - upper midland 3; UM4 – upper midland 4; LM3 – Lowmidland 3; LM4 – Lowmidland 4; LM5 – lowmidland 5; LM6 – lowmidland 6, IL5 – inner lowland 5; and IL6 – inner lowland 6). The wards were purposively selected due to their placement in the mixed farming climate zones as follows Kyangwithia west (LM5 93% and LM4 7%), Matinyani (UM4 100%), and Kwa-Vonza: (LM5 73%, and LM4 6%). The climatic zones IL5 and IL6 although they exist in Kitui county are mainly pastoralist areas with little or no agriculture activities. In this regard, the two climate zones were not considered in the study.

To ensure a random selection of villages within wards, names of villages were placed in alphabetical order. Systematic random sampling was used to pick every 4^{th} village so that the systematic selection was not influenced by corresponding systematic biases (Neumann, 2005). As a result, three villages (Tungutu, Kitumbi and Kyosini) were selected as shown in Table 3.2. In each of the villages selected, one farmer group was purposively identified on the basis of owning a group farm and having at least 15 active members. This resulted in three farmer groups as units of the study.

Table 3.2: Livelihood Zones, Wards and Villages

Agro-Climatological Zone	**UM4**	**LM4**	**LM5**
Wards	**Kyangwithya west**	**Matinyani**	**Kwa-Vonza**
Villages	Mbusyani, Mulutu, Ndumoni Tungutu**	Kathuma, Kauma, Kavuvuu, Kitumbi** Kyambusya, Kyondoni, Maseki, Musosya, Nzakame,	Kawongo /Kathome Makusya, Mikuyuni, Kyosini** Muvitha /Kathemboni Ndunguni, Nyaanyaa,

Selected Villages**

3.4.2.2 Focus group discussions

Focus group discussions (FGDs) were held in three research locations to assess current societies' climate risk coping strategies. The units of discussions were three farmer groups (one in each study site). In each study location, a first series of FDGs were conducted with farmers groups and findings were checked via main informant interviews. In addition, a search for past literature done in the area on climate risk coping strategies were reviewed to compare and validate the results. A second set of FGDs were employed to investigate access and utilization of climate services at farm level. The main focus was to determine the levels of access, understanding, precision of the forecasts in influencing farm decisions and ability to interpret probabilistic forecasts into management decisions. Finally, a third set of FGDs were conducted to inform post season survey. During discussions, interactions were monitored closely to maintain participation of all members. In total, nine FGDs were conducted between June 2018 and March 2019. The standard number of participants in FGDs is 8 to 12 people (Polit and Beck, 2008). However, due to variations in availability of the smallholder farmers, the FGDs in the study were arranged with more participants. The distribution of the FDGs sites is shown in Table 3.3.

Table 3.3: Focus Group Discussions

Sub County	**Ward**	**Village**	**Farmer group**	**Number of FGDs**	**Participants per FGD**		**GPS Coordinates**
					Men	**Women**	
Kitui Rural	Kwavonza	Kyosini	Seven Up	3	12	19	1°30.223'S 37°44.394' E
Kitui Central	Kyangwithya West	Tungutu	Mucerere	3	9	10	1°18'49.8168" S 37°58'47.4168" E
Kitui West	Matinyani	Kitumbi	Kanzoya	3	8	13	1°17'47.8464" S 37°58'47.2116"E

As it can be seen from Table 3.3, the statistics showed that there were more women than in men in all the FGDs. This can be attributed to the fact that women population is bigger than that of men according to the 2019 Kenyan census. Another possible reason for this is about the gender roles of men and women in rural settings, where normally the men go out to look for casual jobs and leave the women and children behind.

3.4.2.3 Key Informant interviews

The main key informant was the County Director of Meteorological Services. Other informants included the village elders, chiefs, and representatives of Non-Governmental-Organizations working in the county (World Vision, Red Cross, Action Aid and CARITAS). A total of 13 key informant interviews were conducted: three with the county meteorologist, three with the chiefs, three with village elders and four with the NGOs. Results from these interviews were used to triangulate the findings from FGDs.

3.5 Methods of analyses

3.5.1 Systematic literature review

This method was used to achieve specific objective one. A systematic literature review methodology was adopted to investigate the contributions of past climate services pilots to smallholder farming systems and emerging good practices. The method was carried out through several phases as described below.

3.5.1.1 Search for peer review literature

The review began with the following research questions:
1. What are the contributions of past climate services pilot project experiences in climate risk management? 2. What good practices can be learned from past pilot projects to inform enhanced and sustained adoption of climate services in future? The review was carried out in phases. In phase one of the review process articles were excluded if published prior to January 2000 and after March 2020. The year 2000 was chosen because it marked a surge of pilot scale research with African farmers following the much publicized 1997/1998 El Nino (Hansen *et al.,* 2011). All articles within this range were included in the search. The search also included only articles published in English and excluded any other. As was stated earlier only peer reviewed publications were included. Articles that passed phase one proceeded to phase two.
In phase two a more thorough review of the articles' titles and abstracts was done based on the last two inclusion and exclusion criteria detailed in Table 4. In this phase the review focused on applied research studies in Africa. This focus was chosen to facilitate generation of themes across similar social economic and social background contexts. Focusing on different continents would have made it difficult to justify generation of common themes from literature.
In addition, this phase ensured inclusion of studies that demonstrated actual engagement with smallholder farmers and excluded those with a purely theoretical focus. In phase three full text review of articles was carried out to confirm relevancy. Table 3.4 illustrates the inclusion and

exclusion criteria that were used in the search while Figure 3.5 shows the document selection process.

Table 3.4: Criteria used for including and excluding articles in the systematic review

Criteria	**Excluded**	**Included**	**Justification**
Peer-review	Non peer-reviewed publications (editorials, reviews, book chapters, meetings etc.)	Peer-reviewed publications	In order to obtain authoritative information
Date of publication	Articles published prior to January 2000	Articles published after March 2019	2000 marked the emergence of climate services pilot projects following the 1997/98 El Nino
Language of publication	Non-English articles	English articles	To facilitate understanding
Full text availability	Not available in full text except by purchasing	Available in full text	To facilitate access amidst limited finances
Publication's main theme	Articles that did not have practical engagement of smallholder farmers thorough use of climate services	Articles that had focused mainly on practical engagement of smallholder farmers through use of climate services	Since the focus of the study was to explore smallholder experience in using climate services
Country/ region of study	Articles that focused on developed countries	Articles that had Africa or any African country as the major region of study	To facilitate extraction of themes across similar social and economic contexts

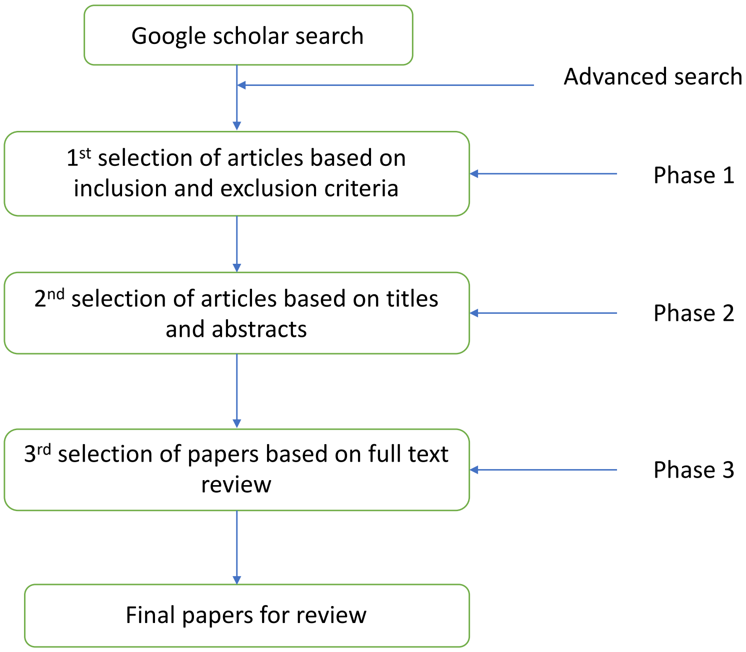


Figure 3.5: Document selection process

3.5.1.2 Identification of themes

The study attempted to generate common themes emerging from the final review articles as a basis for discussing the contributions of climate services use to smallholder farmers and lessons for scaling up good practices.

3.5.2 Indicator approach to vulnerability assessment

This method was used to achieve objective two. The indicator approach to vulnerability evaluation was preferred by this review, which was driven by the IPCC conceptual context of vulnerability. This methodology results in a composite vulnerability index created from aggregated feature indicators for each vulnerability component, which can be converted to a vulnerability map (Parry *et al.,* 2007). Instead of mapping different vulnerability elements for the populations, the study centred on mapping the general vulnerability of the community.

Following the protocol described in section 3.4.1.1 for collecting high-resolution indicator datasets that represent each of the three susceptibility groups, a few indicators were winsorized to a maximum value, with all values above this maximum being set to this maximum. This was done by trimming the extreme values in the statistical data to reduce the effect of outliers. The extreme values were assigned a lower weight. As an example, minutes taken to reach a certain market were trimmed to a limit of three hours, such that anything longer than three hours marked the least and highest adaptive capability and vulnerability respectively.

In a few other instances, reversals were made for indicators that had their high values corresponding to low vulnerability and vice versa (for example, precipitation, water access, soil organic carbon and female literacy) in such a way that high and low values reflect high and low vulnerability across all indicators comparable to de Sherbinin (2013). Rainfall was measured in millimetres, temperature was measured in degrees Celsius, travel time to markets was measured in minutes, and the poverty level was measured in percent. Before aggregating them, it was appropriate to resolve this incommensurability. In this respect, an effort was made to normalize each data layer into a unit-less scale of 0 to 100.

The mean of indicators was then obtained to generate component maps for exposure, sensitivity and adaptive ability, a process called additive index construction by de Sherbinin (2014). Finally, to create an overall vulnerability map, these three components were averaged together. The R statistical package was used to transform data before production of maps in ArcGIS software. In addition to vulnerability assessment, this objective also involved identification of climate risk coping strategies through FGDs, desk review and key informant interviews as was discussed in section 3.4.2.2. The study followed the participatory action research approach and treated the research participants as equal collaborators rather than research subjects. This ensured that the research was conducted with the farmers not on farmers.

3.5.3 Co-designing and testing a climate services innovation system

This was carried out through a combination of several approaches and iterative stages as described in sections 3.5.3.1 to 3.5.3.5 in order to obtain results of objective three.

3.5.3.1 Assessment of farmers climate information requirements

First an assessment based on focus group discussions with farmer group members in the three study sites were carried out to investigate access and utilization of climate services at farm level. The main focus was to determine the levels of access, understanding, precision of the forecasts in influencing farm decisions and ability to interpret probabilistic nature of forecasts into management decisions. Content analysis was used to transform the discussion results into a concise summary. The initial step was to read and re-read the interviews to get the general understanding of what the participants were communicating. After this, the texts were divided into meaningful units, which were used to form the summary.

3.5.3.2 Identification of stakeholders to form the climate services innovation system

As outlined in section 2.6, innovation systems help create and share knowledge, and foster learning. Networks of stakeholders/actors are important in an innovation system and are considered as the central element. Following Reed *et al.,* (2009) the study made effort to understand the context in which the analysis was to be conducted by setting clear boundaries and having a clear purpose as a first step in stakeholder identification. Stakeholders were considered in the context of climate services use by smallholder farmers (from producer to end user), within the boundary of Kitui county for the purpose of enhancing adoption.

A combined purposive snowball technique (for example in Bryman, 2012) and a desktop survey of main actors in climate services was used to identify all the relevant stakeholders. Purposive snowball sampling was exemplified through key informant technique in similarity with Garcia (2006), Lyon and Hardesty (2005), Gustad *et al.,* (2004) and Bernard (2002). In line with this, the Kitui County Director of Meteorological Services was solicited to act as the key informant because of the key role he plays in climate services within the county. Through a snowball sampling approach, the key informant led the process by identifying new stakeholder categories and their contacts in each of the study site. These new stakeholders also yielded other stakeholders and so on until no new stakeholders were identified. Even though snowball sampling may be biased by the social networks of the first individual, it is particularly useful for capitalizing on expert wisdom and experience.

3.5.3.3 Identification and mapping linkages between actors in the climate services innovation system

After stakeholder identification an attempt was made to map the linkages between individuals and organizations in the climate services innovation system. To do this, ego-based maps (maps that show individual actors and who they link with) were developed with individual actors (Matsaert *et al.,* (2005). The actors were asked to identify the key actors they link with and draw them up distinguishing whether the linkages according to their perception were strong or weak. After this was done with all the actors, an actor linkage map was used to combine and synthesize all the ego-based linkage maps allowing the overall network of links in the innovation system to be visualized.

3.5.3.4 Stakeholder integration through transdisciplinary approach

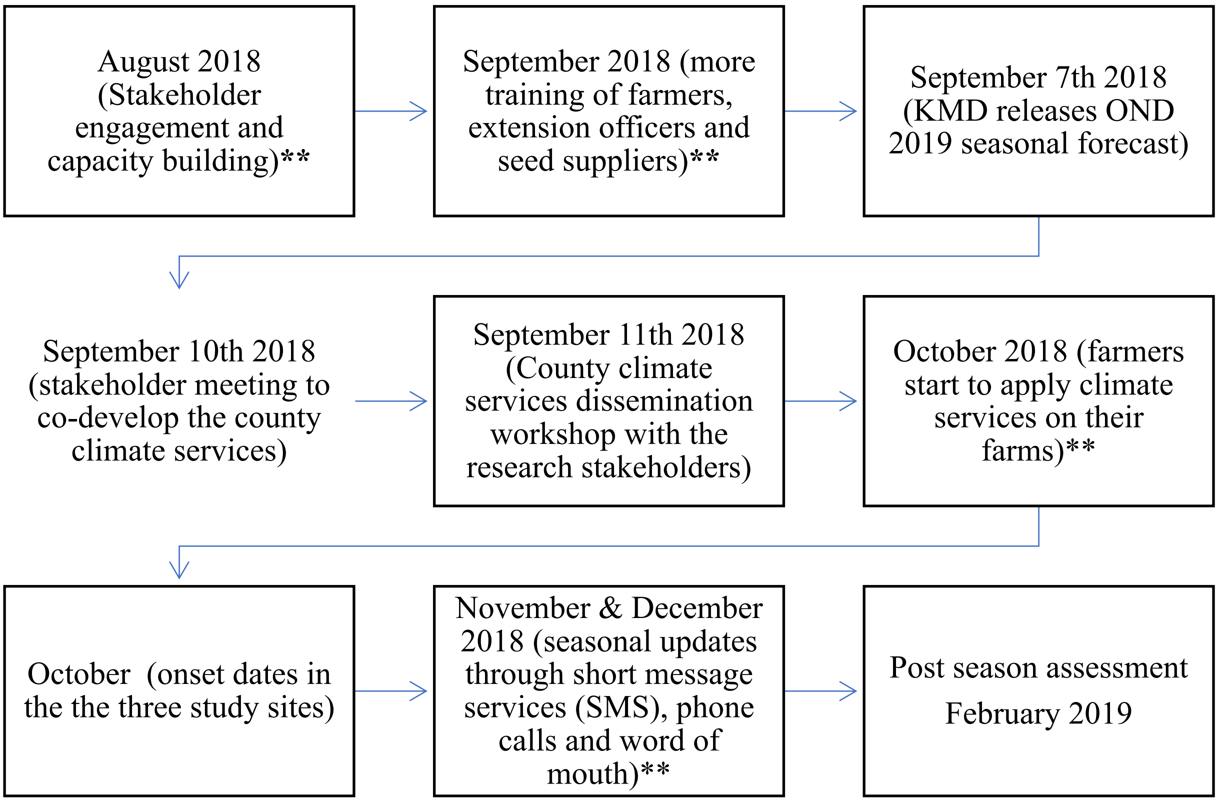
Once the innovation stakeholders were identified, the next step included integrating them into a transdisciplinary research. Transdisciplinary has been described "as a modern mode of learning and problem solving involving collaboration between various parts of society and academia in order to solve complex societal challenges" (Scholz, 2011). Since transdisciplinary research means more than just collecting information from stakeholders, the study integrated the stakeholders in ways beyond informative and consultative levels of participation. Transdisciplinary research has two parallel processes which are the research process and the change process. The research process in transdisciplinary research involves investigating the current situation and articulating possible future situation. It supports learning and knowledge integration and identifies stakeholders to understand their views. The change process in transdisciplinary research involves transformation of a society through mutual learning, knowledge integration and by involving all the stakeholders. Through these two processes, the study integrated all the stakeholders by deciding together and acting together as equal partners. The aim was to facilitate change rather than just collect information from the stakeholders. The integration of stakeholders took place in an iterative process from problem identification, engagement, capacity building and co-designing the climate services innovation system to post season survey.

3.5.3.5 Operationalizing the innovation system to realize enhanced adoption of climate services

Following identification of climate services baseline conditions in the study sites and guided by key lessons to improve adoption of these services, the innovation system was operationalized through iterative steps (the transdisciplinary change process) as follows:

3.5.3.5.1 Stakeholder engagement and capacity building

Stakeholders were engaged in October November December (OND) 2018 season through iterative phases. The engagement was through three pre-season meetings to strengthen stakeholders understanding of climate services jargon, co-establish stakeholders' roles for delivering climate services to participating farmer groups, and support effective application of probabilistic seasonal forecasts with special attention being given to farmers who would eventually apply the same on their group farms. First phase of engagement focused majorly on increasing stakeholders' knowledge of climate, use of seasonal forecast information at the farm level and probabilistic nature of seasonal forecasts. Second phase focused on capacity building for stakeholders to interpret probabilistic forecast information into farm management decisions, with a special attention given to the farmer group members who would be expected to apply the same on their group farms as well as train other farmers. The trainings took place at locations and on days suggested by the farmers (at the group farms and in coincidence with their weekly meetings respectively). The timelines for OND 2018 season activities were as shown in Figure 3.6.



** indicates activities that were carried out iteratively.

Figure 3.6: Timelines for OND 2018 activities.

3.5.3.5.2 Delivery and application of climate services (probabilistic forecast bundled with agricultural advisories)

On September 11th 2018 first suites of climate services were introduced into the three study sites as well as to the other stakeholders. The format of the downscaled seasonal forecast for the study was the default tercile probabilities, that is the probability of the below-normal, normal, and above-normal categories, of likely seasonal rainfall totals for each of the study site complemented with onset and cessation dates. Three group farms (one in each of the study sites) were used as demonstration farms and individual member farms as controls. Tercile probability forecast was used to guide farming activities on the group farms while decision making on the individual farms was based on deterministic forecast. Seasonal updates in form of dekadal forecasts were continuously shared with the innovation system stakeholders as the season progressed either through phone calls or short text messages (SMS). Farmers were encouraged to contact the study facilitators in case they needed any clarifications on the climate services provided. Climate services delivery was adjusted as needed following famer feedbacks throughout the study.

3.5.3.5.3 Post season survey

At the end of the crop growing season a post season evaluation was conducted to collect farmers views on the usefulness, credibility and effectiveness of climate services delivery. This was done through three FGDs with participating farmers, one in every farm group (Appendix I).

3.5.4 Desktop review of conditions that must exist to support the proposed innovation system

This was carried out to achieve the fourth objective. The activities majorly employed document review and some information also emerged from the systematic review in objective one. In addition, one participatory workshop with climate services stakeholders was also held to brainstorm and establish the conditions that must exist to support effective scale up of climate services. The large information from these sources was subjected to content analysis, which transformed it into a concise summary.

CHAPTER FOUR: RESULTS OF THE SYSTEMATIC LITERATURE REVIEW OF THE CONTRIBUTION OF PAST CLIMATE SERVICES PILOT PROJECTS IN CLIMATE RISK MANAGEMENT

4.0. Introduction

This chapter presents results from the first specific objective covering the systematic literature review. It begins with the contributions of the past climate services pilot projects to climate risk management in the context of African smallholder farming. This is followed by a presentation of the key insights that emerge from the reviewed studies, which can be transferred as good practices to enhance and sustain wide adoption of climate services in Africa.

4.1 Identification of publications for the systemic literature review

A graphical analysis of number of reviewed publications by year was also done and the results were as shown in Figur 4.1. The year 2018 had the most publications. In addition, factors that contributed to the success of the reviewed pilots were categorized into broad themes as presented in Figure 4.2. As it is evident from this figure, the reviewed pilots used a wide range of approaches to enhance the reach and use of CIS.

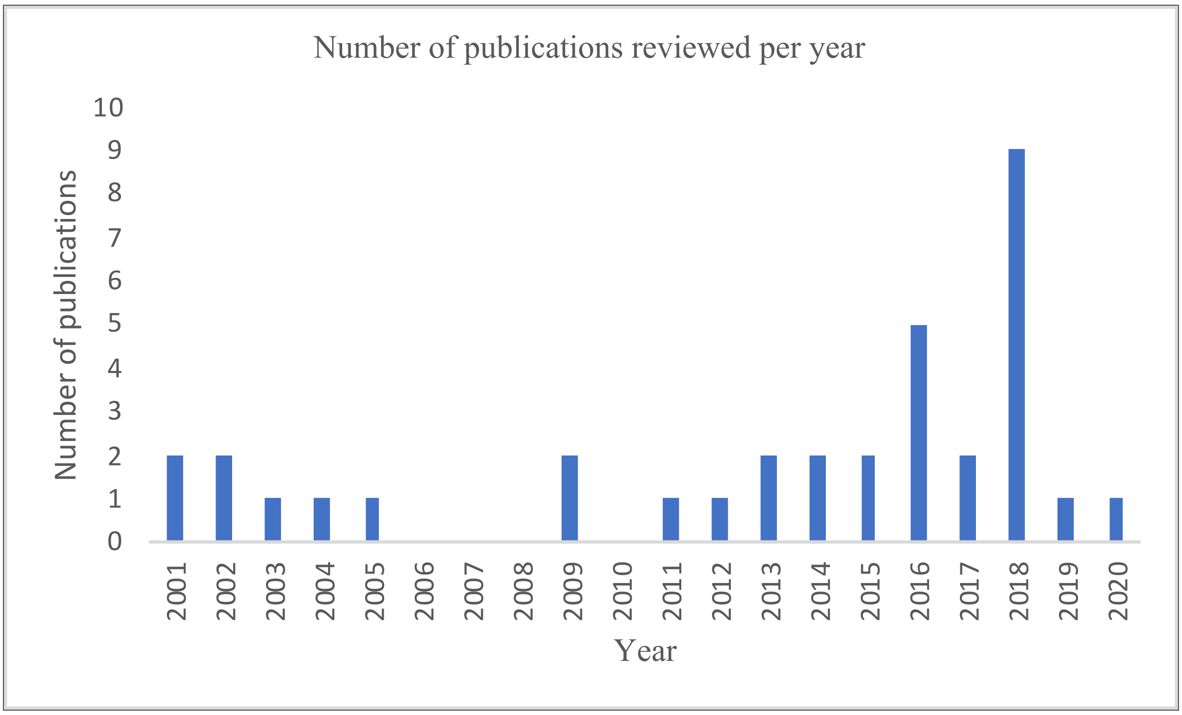


Figure 4.1: Number of publications reviewed per year

Using the keywords, the search result yielded 35 peer reviewed articles for the final review as shown in Prisma diagram in Figure 4.3. There were many non-peer-reviewed pilot project literature in form of reports, working papers and brochures. However, as was indicated in the methodology section, the study chose to use only peer reviewed articles in order to make the study results authoritative. As illustrated in the Prisma flow chart, the search process followed several phases with elimination of articles at each phase until only eligible articles were realized.

Annex II shows the publication citations of the 35 studies that made it to the final review. These publications were thoroughly reviewed to seek answers to two review questions as was discussed in section 3.4.1.1. In this regard, review sought to find out how climate services have contributed to climate risk management in the context of smallholder farming systems and the good practices that led to their success and which can inform future efforts aimed at enhancing adoption.

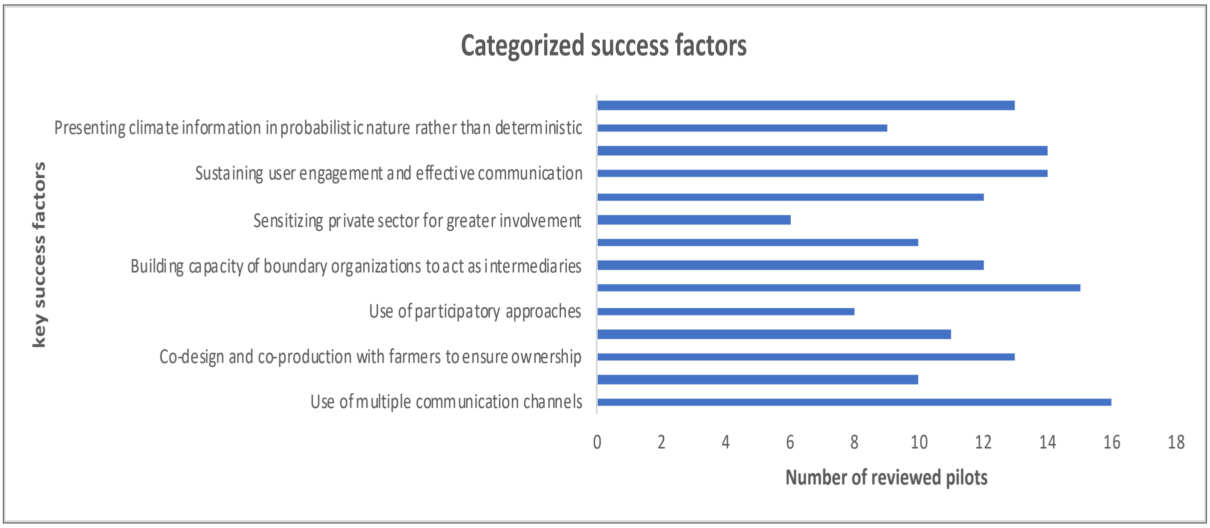


Figure 4.2: Key categorized success factors extracted from the reviewed pilots

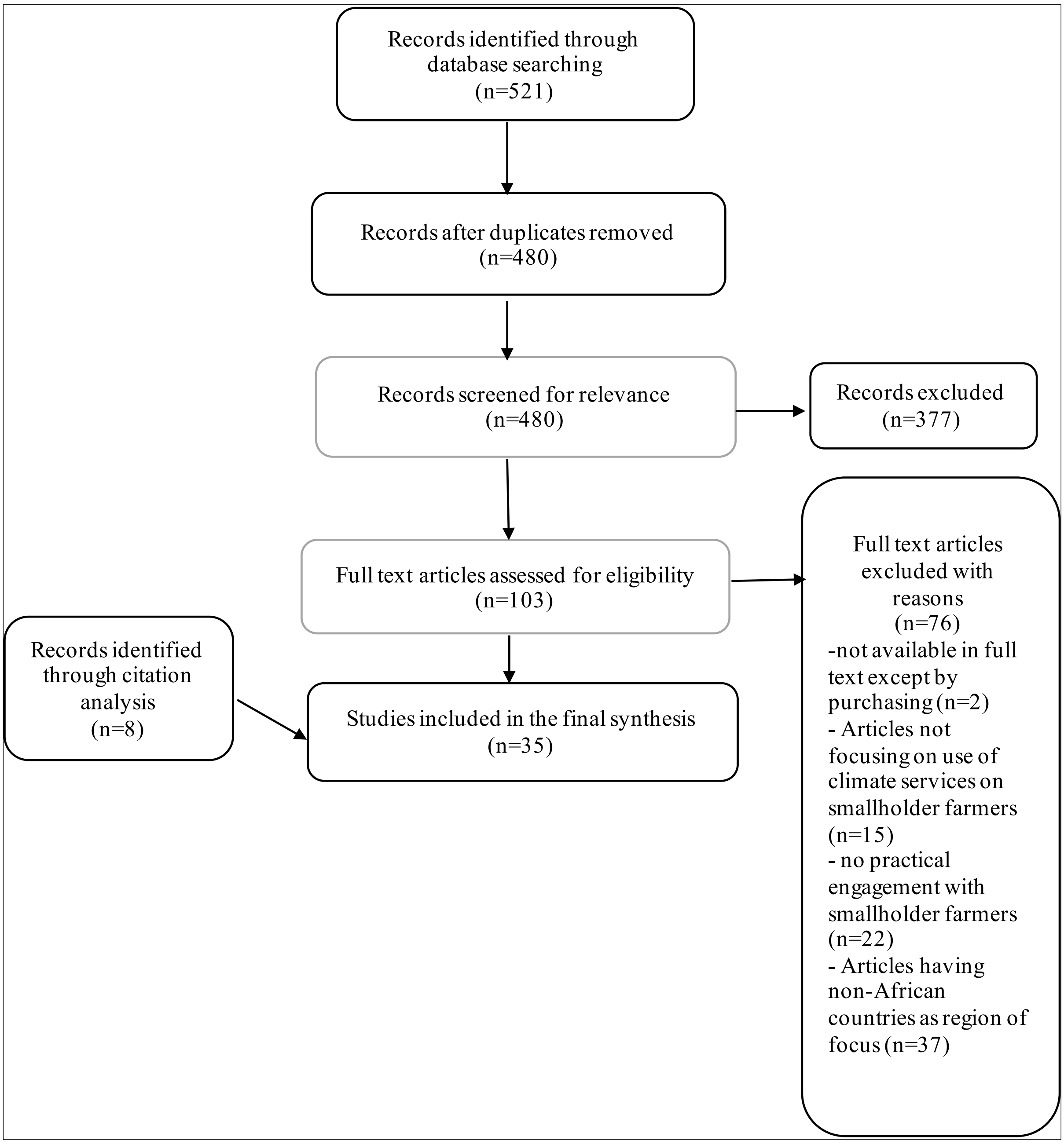


Figure 4.3: Adapted Prisma (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow chart based on Moher at al., 2009.

4.2 Contribution of past climate services pilot projects to climate risk management in Africa smallholder farming systems

It is evident from the reviewed articles that through effective use of climate services smallholder farmers are able to manage (in other words, anticipate and prepare for) agricultural related climate risks through improved decisions. While these studies employ a wide range of approaches, they collectively demonstrate the utility of climate services in helping smallholder farmers manage climate risk. Several of these experiments have shown climate supported advisories to be instruments that can be used to reduce the impact of climate danger and instability on crop production and improve the resilience and adaptability of smallholder farmers in future (Ouédraogo *et al.,* 2018b; Carr *et al.,* 2016; Roudier *et al.,* 2014, Mabe *et al.,* 2014, West *et al.,* 2018). Other studies show that precise and timely use of climate services influence a repertoire of improved pre-season farm management decisions such as input purchase, and land management (Ouédraogo *et al.,* 2018b; Tarchiani *et al.,* 2017; Singh *et al.,* 2018; Partey *et al.,* 2018; Barihaihi and Mwanzia, 2017; Roncoli *et al.,* 2009; Patt *et al.,* 2005; Hansen *et al.,* 2009; Dilley, 2000, Caine *et al.,* 2018; Murgor *et al.,* 2018). As a result, participating farmers in these pilots were able to make better management decisions to confront any kind of climate risk throughout the cropping season.

In addition, after the start of cropping season, climate services provided in dekadal format (10-day forecasts) enables farmers to adjust day to day farm practices such as adjusting dates for ploughing, sowing, and fertilizer use (Roudier *et al.,* 2014; Tarchiani *et al.,* 2017; Ouédraogo *et al.,* 2018b; Carr *et al.,* 2016; Dayamba *et al.,* 2018, Roncoli *et al.,* 2009; Partey *et al.,* 2018; Ziervogel and Calder, 2003, Tarchiani *et al.,* 2018, Bacci *et al.,* 2020, Mpandeli and Maponya 2013). Adjusting the timings of day to day farm management activities enabled farmers to manage short term climate risks throughout the season. Other changes in farm management in response to dekadal forecasts included refraining from weeding on the eve of a rainy day to avoid regrowth of the weeds and early harvesting before a rainy dekad to prevent climate risk associated damages, cropping and labor costs as well as losses normally caused by climate variability (Tarchiani *et al.,* 2017; EwBank, 2016; Roncoli *et al.,* 2009). Climate services also enables farmers to capitalize on anticipated favorable conditions in ways that reduce risks and increase opportunities (Roudier *et al.,* 2014; Hansen *et al.,* 2011; Dayamba *et al.,* 2018).

While effective use of climate services empowers the smallholder farmers to make informed farm level decisions and thereby manage climate risks and uncertainty, it also results into other co-benefits such as increased yields (Patt *et al.,* 2005; Tarchiani *et al.,* 2017; Aura *et al.,* 2015; Roudier *et al.,* 2012; Carr *et al.,* 2016; EwBank, 2016; Barihaihi and Mwanzia, 2017; Phillips *et al.,* 2002; Murgor *et al.,* 2018). As demonstrated in the reviewed articles, the increased crop productivity has been attributed to the willingness to invest in the right crop varieties, more expensive inputs, adoption of improved technology and intensified production by the climate informed farmers. Other pilots have demonstrated that use of climate services results in even more associated benefits such as increased household income, enhanced family welfare, improved livelihoods, enhanced climate change resilience and improved food security and health (Tarchiani *et al.,* 2017; Aura *et al.,* 2015; Roudier *et al.,* 2012; Roudier *et al.,* 2014; Singh *et al.,* 2018; Barihaihi and Mwanzia, 2017; Zongo *et al.,* 2016; Ouédraogo *et al.,* 2018a; Dilley, 2000), while still supporting smallholder farmers to manage climate risk.

Overall these findings, albeit coming from pilot experiences, add to the growing body of literature that underscores the potential of providing climate services to smallholder farmers in managing current climate risk which in turn leads to other co-benefits. This demonstrated importance adds worth of climate services to vulnerable smallholder farming systems and justifies the advocacy to enhance and sustain their adoption and use. However, as it was stated in the introduction section and as it emerges from the reviewed experiences, use of climate services has been promoted majorly through pilot projects, which are limited in scale and lifespan. Despite the nature of pilot projects, the findings show that they have been successful in promoting use among beneficiary communities many of whom are smallholder farmers.

However, other authors (not in the list of final review papers) indicate that making forecasts useful to decision makers, especially subsistence farmers in developing countries, remains a significant challenge (Blench, 2003; Meinke *et al.,* 2006; Cash *et al.,* 2006; Ingram, 2002). According to these authors, these challenges arise from issues surrounding salience (tailoring content, scale and format to farmers' decisions), legitimacy (ensuring farmers have a voice in production and design), credibility (ensuring forecasts are as accurate as possible), access (ensuring timely and widespread reach) and equity (ensuring that climate services support the needs of all farmers). The means that the reviewed studies used to overcome these inherent challenges so that they could stimulate use and demand for climate services can be borrowed as good practices to inform future efforts towards enhancing and sustaining adoption among a wider population. This forms the main discussion of the next section.

4.3 Key insights emerging from the reviewed studies

Research was carried out differently across the reviewed studies, which offered lessons as to how different practices impacted on issues of salience, credibility, legitimacy, access and equity, to the extent that they stimulated use and demand of climate services among the beneficiary communities. This section discusses the different practices employed to address these issues.

Several studies ensured salience of information to farmers needs and usability through downscaling climate information, (Patt *et al.,* 2005; Dayamba *et al.,* 2018; Singh *et al.,* 2018; Roudier *et al.,* 2012), which helped to match the forecasts geographical scale with scale of farm level decision making. This is important since farmer decisions depend on information at a very local scale. However, downscaling and interpreting climate forecasts requires historical observations, which are riddled with many gaps in Africa. Combining the station observations with satellite rainfall estimates can help overcome the problem of missing data (Hansen *et al.,* 2011), which increased relevance of complex climate information to agricultural decision making. These pilots imply that there are thin chances that smallholder farmers will understand and use technical climate forecasts that is not bundled with agro-advisory messages. Adoption of climate information can therefore be enhanced when climate information is downscaled and combined with relevant farm management advisories.

Other studies illustrate the importance of ensuring that smallholder farmers own climate services process form design to delivery (Tarchiani *et al.,* 2017; Dayamba *et al.,* 2018; Ouedraogo *et al.,* 2018b; Roncoli *et al.,* 2009; Patt and Gwata, 2002; Phillips *et al.,* 2002). Good practices identified from these studies include systematic involvement of smallholder farmers in the production and dissemination, which can not only ensure relevance of information content but also appropriateness of the channels used for dissemination (Ouedraogo *et al.,* 2018b; Roncoli *et al.,* 2009; Patt and Gwata, 2002; Tarchiani *et al.,* 2017). Smallholder involvement can be done through forums such as participatory workshops where farmers are treated as equal partners, creation of champions or facilitators, participatory scenario planning and roving seminars (Roncoli *et al.,* 2009; Patt and Gwata, 2002; Ouedraogo *et al.,* 2018b). These forums can enable integration of local and scientific knowledge, which can generate trust in the climate services. Participatory processes can also facilitate better understanding of climate services by smallholder farmers in terms of its capabilities and limitations, which can help farmers attain a balance between caution and confidence during farm decision making process. For instance, participation workshops promoted improved understanding, confidence and use of climate services in Burkina Faso (Roncoli *et al.,* 2009).

However, participatory involvement and continuous interaction with smallholder farmers should be extended beyond a single event to sustain the trust. Several authors note that one-time interaction with farmers is not effective and illustrate the importance of renewing participation and dialogue year after year to promote more co-learning and mutual trust (Ouedraogo *et al.,* 2018b; Tarchiani *et al.,* 2017; Roncoli *et al.,* 2009; Patt and Gwata, 2002). This indicates that disconnect between climate services users and producers can undermine large-scale uptake. As evidenced by the reviewed studies, farmers participated more the second year of pilot projects than first since they had gained more trust. In addition, one-time interaction with farmers was not enough to enable facilitators learn and address communication failures. They were only able to do this through repeated facilitation. This could be an indication that a culture of continued climate services use can be self-reinforcing since it promotes trust. This may point to a significant opportunity to enhance adoption through increased and sustained farmer participation in climate services process. Another good practice to increase legitimacy is through the use of existing farmer local networks such as farmer groups as well as farmer identified village champions and facilitators to act as dissemination conduits (Dayamba *et al.,* 2018; Aura *et al.,* 2015). This points to an opportunity to enhance adoption of climate services through giving smallholder farmers a larger role in the dissemination activities, which can promote ownership and trust.

Reviewed studies provided an overview of gender role in smallholder livelihood systems and the associated constraints to equitable access to climate services (Partey *et al.,* 2018; Barihaihi and Mwanzia, 2017; Dayamba *et al.,* 2018; Carr *et al.,* 2016, Jost *et al.,* 2016). An overarching finding from these pilots is that there exist disparities in access between male farmers and female farmers. Women overall had lower access. For instance, Ghana and Uganda pilots indicated that men and women had different preferences as far as receiving information was concerned (Barihaihi and Mwanzia, 2017; Partey *et al.,* 2018, Jost *et al.,* 2016). In Ghana pilot, where dissemination was through mobile phones, men adopted climate services use for climate risk management more than women since they had the financial capacity to acquire mobile phones (Partey *et al.,* 2018).

In a Uganda pilot project, women preferred dissemination through community groups, markets and churches while men preferred radios and newspapers (Barihaihi and Mwanzia, 2017). To overcome issues of gender disparities in access, several studies demonstrated the importance of ensuring wide representation in village trainings and discussions to avoid leaving out the majority, which can create information asymmetries (Partey *et al.,* 2018; Barihaihi and Mwanzia, 2017; Dayamba *et al.,* 2018). These experiences indicate the importance of targeting women in communication efforts through employing gender sensitive dissemination channels and designs. This points to an opportunity to enhance adoption and use of climate services through targeting women in communication efforts and trainings.

To overcome credibility challenge, several pilots suggest presenting climate services in probabilistic rather than deterministic form (Hansen *et al.,* 2011; EwBank 2016; Patt, 2001; Roncoli *et al.,* 2009, Unganai *et al.,* 2013, West *et al.,* 2018). Patt (2001) documents forecast communication in Zimbabwe in deterministic form (at a cost to credibility), which resulted in loss of trust. This indicates the importance of expressing forecast uncertainty in transparent tercile probabilities. However, communicating forecasts probabilistically to smallholder farmers may be difficult. Nevertheless, research suggests that farmers are able to make decisions from probabilistic forecasts if provided with adequate training on how to understand and interpret them into farm management decisions (Hansen *et al.,* 2011; EwBank 2016; Patt, 2001; Roncoli *et al.,* 2009). In addition, it is also important to give short term update forecasts, for example, dekadal forecasts as the growing season progresses (Roudier *et al.,* 2014; EwBank 2016; Patt, 2001, Roudier *et al.,* 2016).

Reviewed pilots indicate that regions with highest awareness of climate services were the same regions where a greater diversity of communication channels had been used (Tarchiani *et al.,* 2017; Patt *et al.,* 2005; Dayamba *et al.,* 2018; Hansen *et al.,* 2011; EwBank, 2016, Bacci *et al.,* 2020). This suggests that employing a wide range of communication channels does not only meet varieties of preferred communication methods but is a more effective strategy than focusing on one or just a few channels. This points to an opportunity to enhance adoption of climate services through choosing the right mixture of communication methods to ensure wide reach even to those less easily reached in rural areas. EwBank (2016) and Dayamba *et al.,* (2018) highlight the risk in concentrating only on new information and communication technologies such as mobile phones, forgetting that the vulnerable communities may have no capacity to acquire or use them. Instead they suggest incorporation of more traditional methods, which can even use local language along with modern communication methods.

Modern technology for instance use of SMS in the local language and voice calls through cell phones has the potential to boost traditional modes of communication (Mabe *et al*., 2014;

Rasmussen *et al.,* 2015; Oladele *et al.*, 2019). This is due to their broad cellular network that can offer extensive reach. The short messages for instance can be sent in local language to legitimate farmer representatives chosen by the farmers and to extension agents who can then share the same with other farmers creating a multi-branch chain of information flow (Oladele *et al.,* 2019). Choosing the most effective communication channel is crucial. However, as is evidenced by the reviewed pilots, farmers have different preferences and there seems to be no magic bullet when it comes to communication methods. Hansen *et al.,* (2011) demonstrated success in using mixed communication methods designed through consultation process with the farmers. This did not only ensure taking into consideration the divergent user and gender preferences but also ensured extensive reach of the information.

There is also potential to enhance climate services access by leveraging farmer social networks, such as farmer groups, which can play an active role in dissemination within the community through which other farmers can be influenced to use climate services (Dayamba *et al.,* 2018; Hansen *et al.,* 2011). In addition to farmer social networks, Tarchiani *et al.,* (2017); Patt *et al.,* (2005); Dayamba *et al.,* (2018); EwBank, (2016); Oladele *et al.,* (2019) tapped into agricultural extension services and used them as communication channels, which increased adoption of climate services by smallholder farmers. However, efficiency of agricultural extension services acting as dissemination conduits can be constrained by the high farmer to extension agent ratio. Dayamab *et al.,* (2018) and Tarchiani *et al.,* (2017) suggest tapping into the potential of farmer to farmer extension in order to scale up dissemination of climate services. This points out to an opportunity to enhance access through strengthening extension services and seeking ways to support and facilitate use of farmer volunteers/champions and farmer to farmer extension.

Ouedraogo *et al.,* (2018b) highlights the importance of private sector involvement such as farm input suppliers in the climate services production, delivery and training. This can ensure farmer access to the appropriate seed and fertilizer by involving input dealers as stakeholders in the co-production process, which can enhance use. Last but not least, there is need to establish feedback mechanisms, such as interactive communication processes, which enable users to ask questions and raise issues regarding the climate services provided (EwBank, 2016; Dayamba *et al.,* 2018; Ouedraogo *et al.,* 2018; Patt *et al.,* 2005). Through feedback mechanisms farmers were able to understand uncertainty of forecasts provided and how best to manage it. On the other hand, producers of the services were able to address communication failures and understand the complementary information to include in future.

The review indicates that climate services offer great opportunity to help smallholder farmers manage impending climate risk, which contributes to building their adaptive capacity to climate change. Managing climate risk is integral to larger strategies for helping smallholder farmers adapt to the changing climate. Reviewed pilot projects have been successful in raising farmers' awareness and use of climate services and they present transferrable good practices. As long as pilot projects exist, beneficiary farmers are fully engaged in the information flow chain starting from data collection (in some pilots) to co-production, delivery, use and evaluation. However, this engagement ends with the end of the pilot projects, which may leave unmet demands as far as climate services are concerned. As a result, the provision, awareness and use of climate services among beneficiary farmers continue to drop soon after the pilot projects end especially when the provision of these services is not institutionalized.

Provision of climate services should be supported by continued engagement of the farmers as well as all relevant stakeholders to develop a locally viable climate services information system informed by key lessons uncovered in this review. With this in place, smallholder farmers can cease to use conservative farm management practices and instead change the way they manage day to day farm practices guided by tailored climate services. As a result, farmers will be able to confront climate related risks, reduce their vulnerability, improve their resilience to climate risks and increase adaptive capacity to climate change. Despite the fact that pilot projects are limited in scale and donor driven and hence short lived, they contribute enormously to climate risk management through facilitating farm level decision making. These contributions justify advocacy to enhance their adoption among more smallholder farmers. This adds up to the long-term desired climate change adaptive capacity in future. On the other hand, factors that contributed to the success of the projects can be used as good practices to inform future endeavors seeking to enhance wider adoption among smallholder who are the most vulnerable to climate risk and climate change impacts.

CHAPTER FIVE: VULNERABILITY ASSESSMENT TO CLIMATE RISKS AND COPING STRATEGIES OF COMMUNITIES IN KITUI COUNTY

5.0 Introduction

The previous chapter has presented the contributions of past climate services pilot projects to smallholder farming systems as well as the good practices that can inform enhanced adoption of climate services. This has set a base for the advocacy of climate services as climate risk management options for smallholder farmers. However, before introducing these services to smallholder farmers, it is imperative to assess vulnerability levels of a community/group prior to introducing adaptation interventions. In this regard, the study endeavoured to investigate the vulnerability of communities in Kitui County as a first step before introducing any adaptation intervention. This chapter therefore presents the results for the Kitui county vulnerability assessment and the strategies adopted by farmers to cope with climate risks. The results for each component of vulnerability are addressed first. This is followed by overall vulnerability results. Lastly, the existing local coping strategies that farmers have adopted over time in response to climate risks are presented.

5.1 Individual component vulnerability maps

Specific feature maps illustrate the area's vulnerability profile in terms of how each component relates to overall vulnerability. These specific maps make it easy to find places where the components have high scores. Different classes were used throughout the maps to display the magnitude of the factor being assessed, with 0-20, 20-40, 41-60, 61-80 and 81-100 indicating lowest, moderate, medium, moderately high and very high (maximum) vulnerability, respectively. As previously mentioned, certain metrics where high values were correlated with low vulnerabilities, such as access to sanitation, market access and women literacy, were reversed. Because of this inversion, the lowest class across all variable maps corresponds to the lowest vulnerability scores and the top class corresponds to the highest vulnerability scores.

5.1.1 Exposure component

Annual average precipitation, trend in annual average precipitation, coefficient of variation in the same, annual mean temperature as well as its trend made up the exposure map (Figure 5.1). The eastern areas of the county have the highest exposure, while the western and central parts have the lowest to moderate exposure. As one would imagine, the exposure pattern has an effect on the societies' socioeconomic structures. Marginal mixed farming is practiced in the eastern area of the county while parts of a remote adjacent portion practice better mixed farming.

As would be expected, this pattern of exposure component influences the livelihood systems of the communities. The eastern parts of the county (where exposure score is the highest) practice marginal mixed farming while western parts and a small adjacent central part (where exposure scores range from lowest to low respectively) practice better mixed farming comparatively.

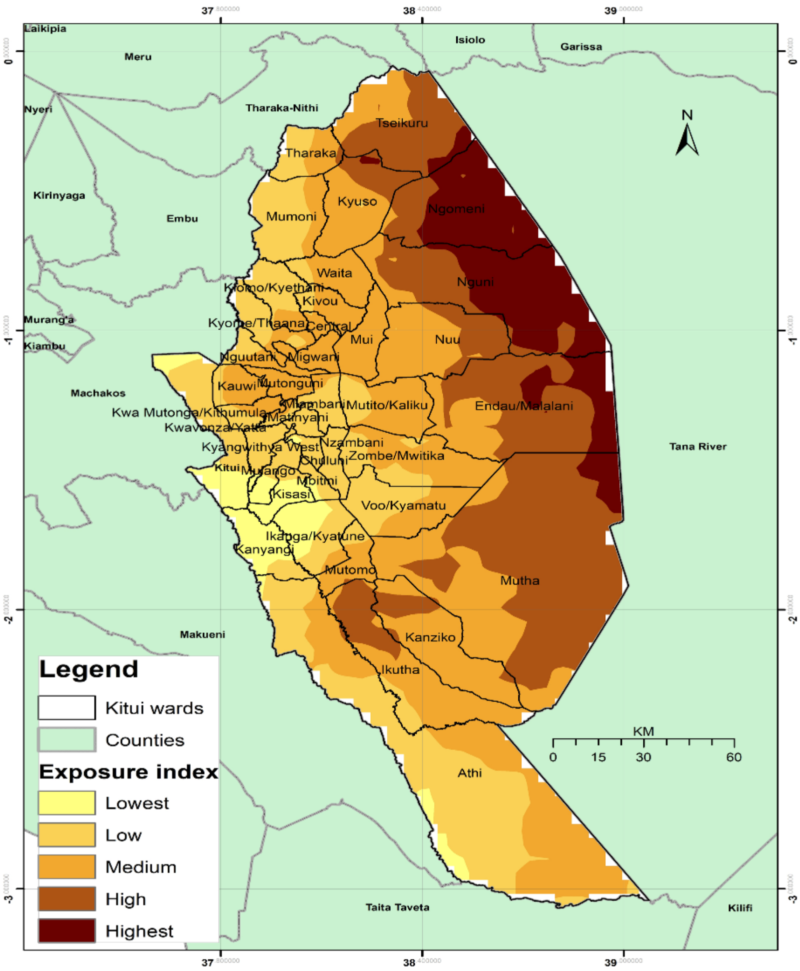


Figure 5.1: Exposure index map for Kitui County

5.1.2 Sensitivity Component

The sensitivity map (Figure 5.2) depicts a pattern that reveals high sensitivity in the county's central areas and a few areas in the east. High sensitivity in these areas can be attributed to the influence of a dense population in the central parts of the county. The county's western regions have the lowest to moderate sensitivity.

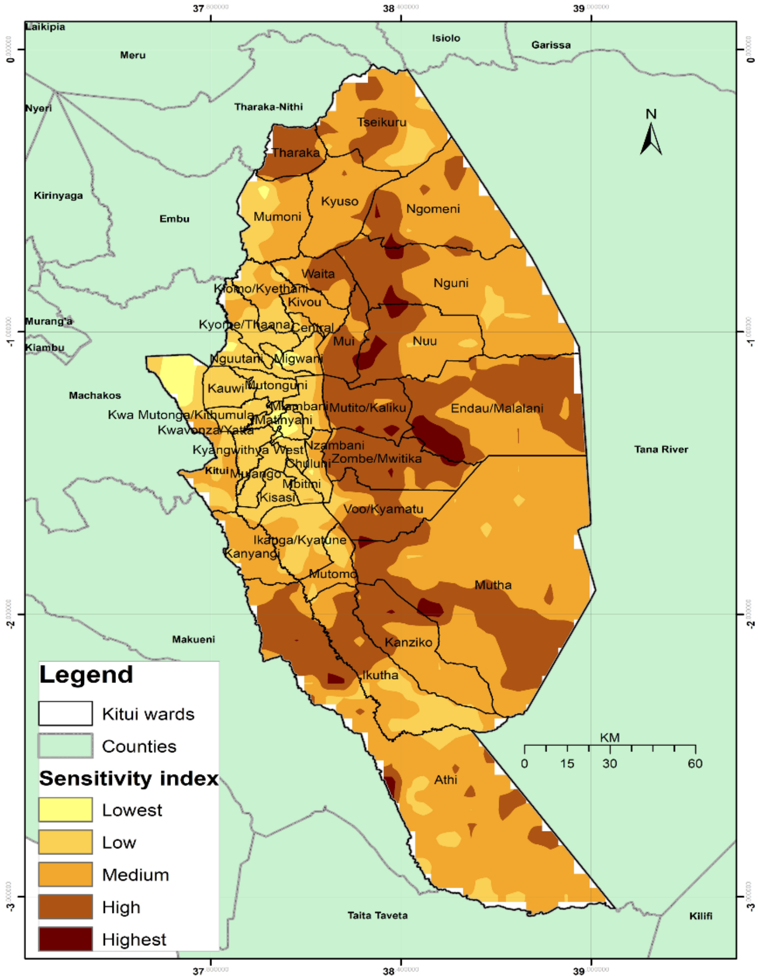


Figure 5.2: Sensitivity index map of Kitui County

5.1.3 Adaptive capacity component

Improved water and market access as well as female literacy made up the adaptive capacity map (Figure 5.3). With increasing distance from Kitui town (the headquarters of the county) and the next major town (Mwingi), the map reveals an increasing pattern of lack of adaptive capacity. In comparison to other areas, urban areas have high adaptive capability, which can be due in part to the provision of clean drinking water and the density of road networks in the region, as well as consumer accessibility. The drier lowlands of Tseikuru, Ngomeni, Endau, parts of Kyuso and parts of Tharaka have low adaptive ability.

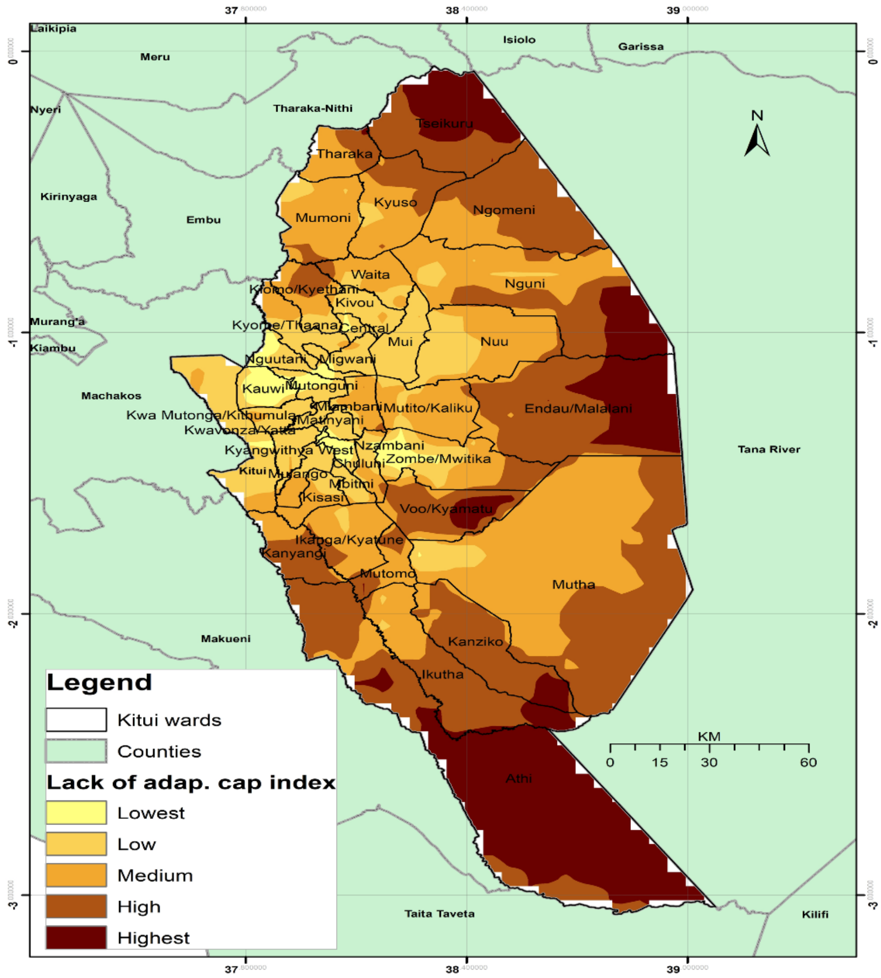


Figure 5.3: Lack of adaptive capacity index of Kitui County

5.1.4 Overall Vulnerability

Averaging the exposure, sensitivity, and adaptive capacity indices yielded the overall vulnerability map (Figure 5.4). As shown in the map, Kitui county vulnerability situation generally follows a west-east slope. The lowest vulnerability is on the western part except in a few areas while the furthest eastern parts have the highest vulnerability scores. These findings are not shocking because they represent the county's livelihoods structures, in that on the eastern regions of the county where vulnerability scores are high, marginal farming dominates and much better mixed farming is practiced on the western parts where vulnerability scores are low. Furthermore, the regions with the highest total vulnerability (the eastern regions of the county) also have the highest exposure and lack of adaptive capacity. The regions of highest vulnerability spread from the north (Tseikuru, Kyuso, Mwingi, Ngomeni, Nguni, and Nuu), across the Yatta plateau, and down to the eastern (Mutito and Mwitika) and southern (Mutomo and Mwitika) regions.

These regions are drier and have more irregular rainfall than the rest of the county. They are also prone to resource use conflict along the Tana River county boundary (ROK, 2005), which increases their vulnerability to climate threats and their inability to respond to them.

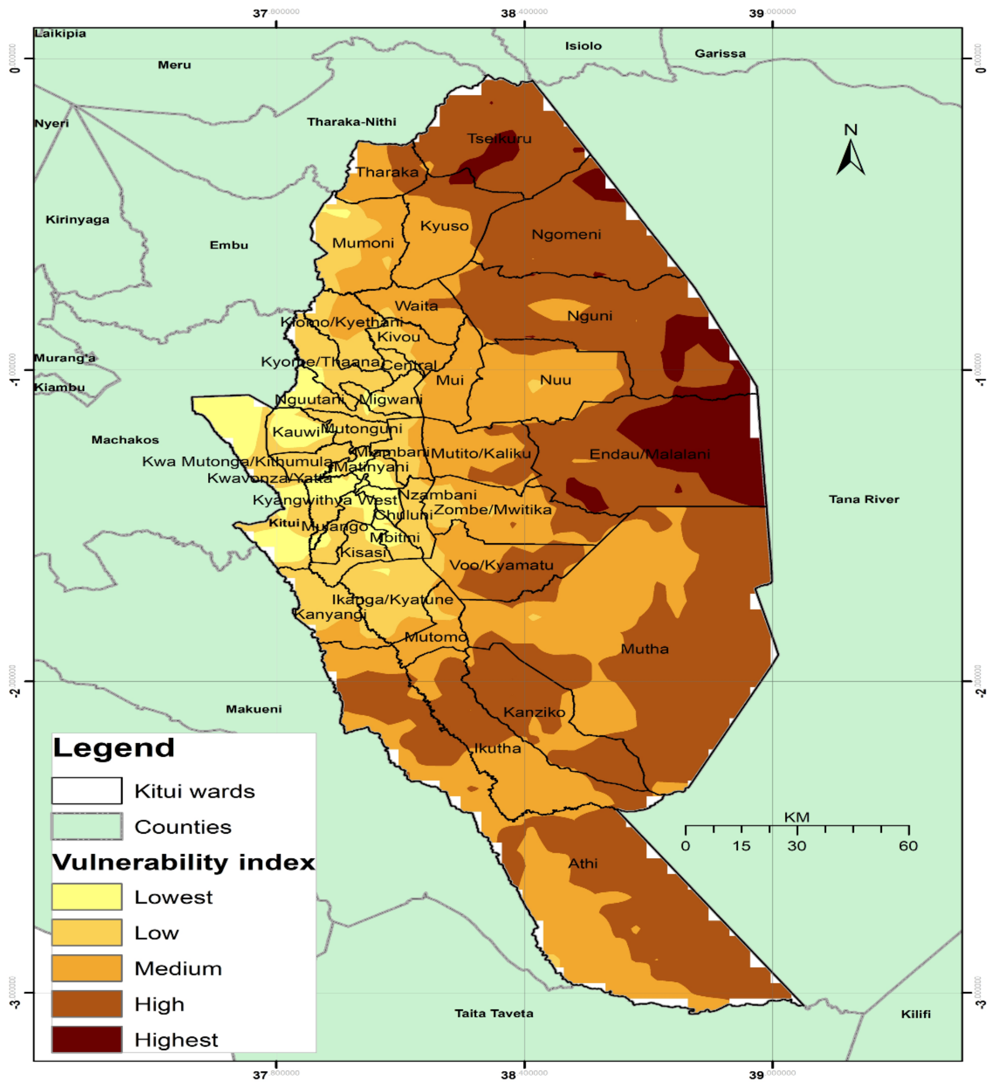


Figure 5.4: Overall vulnerability map of Kitui county

The importance of assessing and mapping risk has been stressed as a first step in assisting adaptation decision-making (Preston *et al.,* 2011). The overall vulnerability pattern and the exposure component map informed the choice of the study area with preference given to highland areas, which receive more reliable rainfall compared to the other regions that receive unreliable and very erratic rainfall. In this regard, climate services which is the focus of this study would have more impact over the highland areas. The findings showed that vulnerability and its components have major spatial variations, demonstrating the importance of mapping vulnerability. The study was focused on vulnerability mapping assumptions, which suggest that each vulnerability variable and its indicators are linearly related. High scores in one index were also believed to compensate for low cores in other indices, but this was not necessarily the case. While these assumptions present limitations of this vulnerability assessment approach, they do not invalidate the results. However, the users of these results should be made aware of the underlying assumptions. The individual variable maps display the causes that lead to each area's vulnerability, which helps decide the adaptation interventions that are suitable. The findings suggest that populations in Kitui county are vulnerable to climate change threats, with differing degrees of vulnerability. The distinct trends of vulnerability illustrate the fact that vulnerability is context-dependent, necessitating local and context specific responses and adaptation strategies.

During the formulation of all adaptation solutions, it is crucial to take into account the county's various primary livelihoods as well as the extent of vulnerability. The reason behind this is that an adaptation approach that works with one type of community does not work for another. The results also demonstrate the potential of vulnerability mapping approaches and use of GIS to support county planning processes when dealing with prioritization of adaptation measures.

5.2 Smallholder farmers' coping strategies in response to climate risks

FDGs revealed that farmers are vulnerable to climate threats, which manifest themselves mostly through seasonal rainfall fluctuations, declining rainfall, rising temperatures, prolonged dry spells, and increasing return time and intensity of droughts. Farmers have implemented different coping mechanisms in relation to these threats in order to help them mitigate their susceptibility to climate risks. During dry seasons when grazing is scarce, the discussants suggested that they trade some cattle to reduce the herd size. In addition, they collect water during time of abundant rainfall and preserve it for use in periods of scarcity. Indigenous knowledge of traditional weather predictors were also cited as useful albeit more so by the elderly participants. In addition, planting a wide range of farm crop types and hybrids was another coping mechanism, which they said helped them reduce total farm losses. Another coping tactic mentioned was decreasing the amount of land under cultivation to minimize the expense of farm inputs as well as losses in the event of a bad rainy season. Farmers also revealed that since certain seasons have been shorter than average, they plant crops that mature within a short time like hybrid bean and maize types as well as cowpeas.

Farmers have also implemented soil management methods, some of which are traditional while others brought to them by NGOs, such as the use of Zai pits for moisture preservation, collection of surface runoff, and soil fertility maintenance are alien. Due to uncertain nature and the short length of the planting season, farmers said they practice dry-planting before the rains arrive to ensure maximum utilization of the seasonal rainfall. Farmers also benefit from small-scale businesses and look for part-time work to supplement their income, particularly during extended dry periods. Farmers also apply pesticides, organic manure and fertilizer to improve agricultural productivity in the midst of climate variability, according to key informant interviews with village elders, which confirmed the data from FDGs. The results matched those of other authors who had conducted similar research in the study field, such as Mutunga et al., (2017), Okumu (2013) and Ndambiri et al., (2012).

In conclusion, this chapter reveals that communities in Kitui county are vulnerable to climate risks and they have devised several coping strategies to reduce the vulnerability. However, as climate fluctuations and duration, as well as the intensity of extreme weather events, have increased, participating farmers alluded to the fact that existing coping mechanisms have proven ineffective, leaving farmers vulnerable. In addition, the vulnerability map (Figure 5.4) showing the overall vulnerability of Kitui county communities supports this fact. As a result, societies' current climate risk vulnerability coping mechanisms should be improved as a primary way of promoting climate change adaptation in to the future. This is due to the fact that factors that form daily coping capacity can reinforce factors that shape long-term adaptability capacity.

As was indicated earlier, measuring vulnerability is considered as a first stage in assisting adaptation decision-making. With the results showing that communities in Kitui county are vulnerable to climate vulnerability and change, and the need to strengthen the existing traditional coping strategies, the study had a basis on which to introduce adaptation intervention. Next chapter describes the results obtained through this intervention.

CHAPTER SIX: THE PROPOSED KITUI COUNTY CLIMATE SERVICES INNOVATION SYSTEM

6.0 Introduction

As was stated in section 2.6, World Bank (2006) defines an innovation mechanism as a network of organisations, companies, and individuals focusing on putting new goods, new methods, and new modes of organisation into economic usage, as well as institutions and policies that influence the systems' actions and efficiency. Innovation systems help to create knowledge, share knowledge and foster learning. This chapter presents findings on the existing climate services situation in the county before study interventions, the proposed Kitui county climate services innovation system including identified stakeholders, their roles in the innovation process and the type of linkages among them. The attained results after operationalizing this proposed innovation system through a crop growing season are also presented. The proposed climate services innovation system was operationalized through implementing key insights that emerged from the systematic review of past climate services pilot projects. It was believed that the reviewed pilot projects had been carried out in regions with similar ecological settings as Kitui.

6.1 Existing stakeholders and nature of climate services flow before the study intervention

Figure 6.1 presents an actor linkage map, which was produced through a participatory process, showing baseline levels of linkage among the existing stakeholders before the study intervention. In this figure, thick and thin continuous arrows depict strong and weak linkages respectively (both of which existed before the study). This study adopted Madukwe and Obiora (2012) definition of linkages as the 'contacts and interactions' between actors in an innovation system. The nature of of linkages existing between stakeholders can be described qualitatively by interrogating the strength of the communications and interactions taking place. As presented in Figure 6.1, the study revealed the existence of various levels of linkage (ranging from strong, weak to sporadic) among the climate services innovation system stakeholders in the county. Strong reciprocal linkages exist between CDM and government agencies such as the National Drought Management Authority (NDMA) as well as research. These strong linkages have been developed over time during pre-season meetings where CDM meets with government agencies and representatives from research to co-produce knowledge. Sometimes this is usually done through two-way email communication to reduce cost. It emerged that budgetary allocation from the headquarter office (Kenya Meteorological Department, hereafter KMD) to the county meteorological office is not adequate to cater for face-to-face co-production process with many stakeholders. The face-to-face co-production of the climate service at the county only happens when there is a donor project hosted at the CDM office. In this case, the CDM office only acts as a host and the donor project pays all the expenses such as meals and per-diems for the participants. The discussion with the CDM revealed that the office rides on donor projects as far as co-production of climate services is concerned since it operates under limited budgetary allocation and yet it is obligated to co-produce climate services.

On the other hand, as Figure 6.1 indicates, there was no flow of the co-produced advisories from the government agencies to the farmers. The NDMA office however, said they sometimes display the advisory on their notice board, which most farmers hardly get to see. In addition, there is a weak linkage between CDM and farmers since the latter is not always invited to the co-production meetings and have no direct interaction with CDM. The CDM communicates the advisory through SMS to only few farmers whom he has had prior interactions with and therefore has their contacts. He does this at his expense and takes advantage of Safaricom bulk SMS offer. However, he doesn’t reach all the farmers and in return receives few feedbacks if any and hence the weak linkages between CDM and farmers as the figure indicates.

In the attempt to disseminate the advisory, the CDM calls the local radio stations and communicates the advisory and hence the strong linkage between CDM and radio. However, since the broadcasters have no much background knowledge on climate services, they cautiously broadcast just what CDM has provided. The linkage between radio and CDM is characterized by weak feedback interactions. However, when finances allow, for instance, when there is a donor project hosted in the CDM office, paid radio sessions are used to explain the forecast. These radio sessions are sometimes short in a manner which denies farmers the chance to call and seek more understanding of the climate services. This notwithstanding, the radio is seen to have strong linkages with farmers thereby playing a key role in providing climate services with strong interactions from the farmers to the radio.

CDM and CBO stand for county director of meteorological services and community-based organizations respectively. Once the farmers receive climate services from radio, they interactively share it with other farmers especially within the CBOs through informal mechanisms and hence the strong linkages between farmers and CBOs. This farmer to farmer extension leaves out farmers who do not belong to any CBOs or who may not have a chance to interact with a climate services informed farmer. The results in Figure 6.1 point to more top-down and formal linkages where information flows from CDM (scientist) to government agencies and radio and then to farmers without the latter influencing the information.

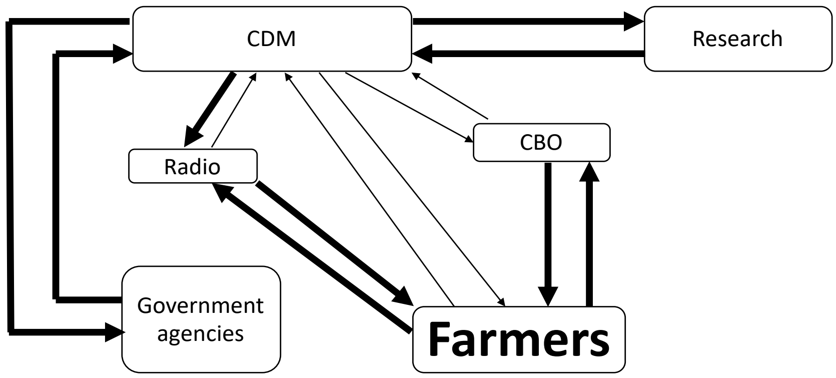


Figure 6.1: Climate services stakeholders and their linkages before the study interventions.

Formal linkage may retard learning and diffusion of climate services due to bureaucracy associated with them. These types of linkages also disregard information from farmers, which is based on practical knowledge (at a cost to salience and legitimacy), and concentrates decision making power at the top. The practical knowledge from farmers could strengthen the capabilities of the other actors. The only active informal linkage is seen between farmers and CBOs. More of these can help break the bureaucracies associated with formal activities and encourage strong levels of linkage. When linkages are strengthened, learning will also be enhanced. In addition, Figure 6.1 revealed the existence of very few stakeholders actively involved in climate services in the county. With this realization, the study sought to identify additional stakeholders who would take intermediary/ brokering roles and with more informal linkages among them. The results of this are discussed in the next section.

6.2 Climate services potential stakeholders identified through the snowball sampling

Desktop review revealed four main pillars in the climate services flow chain: production; translation; transfer and use. These four pillars are represented in Figure 6.2 below. The production pillar entails development of downscaled forecasts from historical data acquired from observation stations, data archives and satellites. Translation pillar entails the interpretation and value addition of forecasts to produce sectoral advisories. On the other hand, dissemination/ transfer pillar includes both widespread dissemination and communication of climate services. Lastly, the information use pillar entails the use of these services for decision making. Recent research emphasizes on the importance of two-way communication between the producers and users of climate services (Hansen *et al.,* 2011; Tall *et al,* 2014; Dayamba *et al.,* 2018). The double head arrow illustrates the two-way information flow.

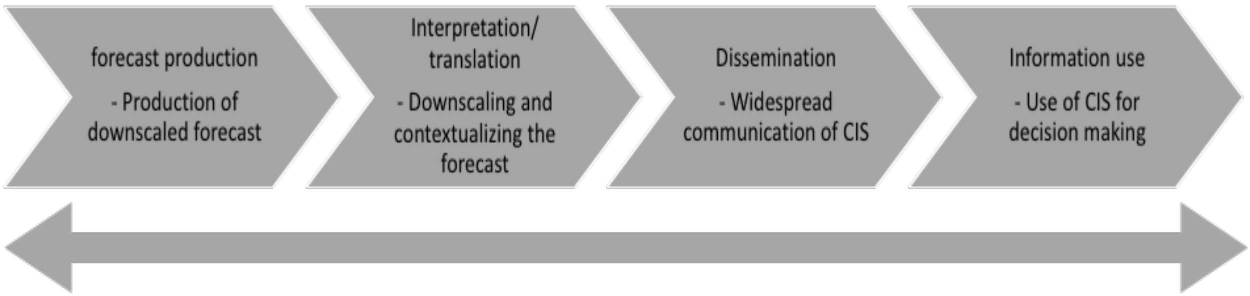


Figure 6.2: Climate services flow chain

These pillars were viewed as the main climate services nodes and were used to group the stakeholders identified through the snowball sampling as shown in Table 6.1. Interestingly, the identified stakeholders were similar in the three study sites. As was stated in section 2.4 an innovation system can be defined as a network of organizations or individuals focused on bringing new products or processes into economic use together with institutions and policies that affect the systems behaviour. In regard to this, the study defined a climate services innovation system as comprising webs of dynamic interactions among several stakeholders such as researchers, extension agents, and farmers at different nodes in the climate services flow chain. In line with this, the gaps identified and the proposals for strengthening innovation systems, both in Table 6.1, informed the design of ideal climate services sub innovation systems at every climate services node.

Table 6.1: Stakeholders identified through the snowball sampling process and who formed the climate services innovation system

Climate Services node	**Active Stakeholder(s)**	**Functional roles**	Gaps for ideal climate services innovation system	Norms/policies that could improve or strengthen the ideal climate services innovation system at each node
Forecast Production	– Kenya Meteorological Service – County Director of Meteorological Services	– Generation of forecast	– Farmer representatives are missing – Representatives from the county ministries are also missing	– Give farmers an active role in this process – Enlarge the mandate to include all other relevant stakeholders in the county

Translation/ Interpretation	– County Director of Meteorological Services – Agricultural extension workers – NDMA staff – County agriculture ministry head (sporadic engagement) – County water and environment ministry head (sporadic engagement)	– Downscaling of forecast from national scale to county scale – Integration of scientific and indigenous forecast and consensus building – Development of local advisory – Value addition of climate information i.e. integration of sector specific (e.g. agriculture) in the forecast	– Farmers participation is missing at this node – Suppliers of agriculture and livestock products are missing – Research institutions are missing – Existing stakeholders are engaged sporadically based on availability of funds	– Give farmers an active role in this process – Enlarge the mandate to include all other relevant stakeholders in the county – Government should avail enough budgetary allocations to facilitate stakeholder engagement every season

Dissemination/ Communication	– County Director of Meteorological Services – Agricultural extension workers – NDMA staff – County agriculture ministry head – County water and environment ministry head – Suppliers of Agricultural and Livestock products – Sub County, Ward and Village Administrators – Religious leaders – Village elders (Atui) – Mbaitu FM radio – Musyi FM radio – Kitui Red Cross branch volunteers – Farmers	– Wide spread communication of climate information services	– Farmers are not actively engaged at this node – Suppliers of agriculture and livestock products are missing – Engagement of civil society groups is also missing (Farmer groups, Women groups and religious leaders) – – Research institutions are missing – Existing stakeholders are engaged sporadically based on availability of funds	– Leverage the strong social network of farmers to disseminate climate services – Actively involve private sector (for example, the input suppliers) – Engage civil society groups and local government representatives to enhance ownership and trust in the information

	– Farmer groups, – Women groups		– Government representatives are also missing (chiefs, assistant chiefs, as well as sub-county and ward administrators)	
Information Use	**County level end users** – County development planners – County natural resource managers – Kitui Water Users Associations – Suppliers of Agricultural and Livestock products **Final end users** – Smallholder farmers – Pastoralists	– Use of climate information services for decision making at County and farm level	– No point of authority from which farmers get the climate services – There is no wide reach to all farmers – No feedback mechanisms from users	– Office of CDM to establish itself as the point of authority – Develop feedback mechanisms to support continuous improvement of climate services. – Build capacity of climate services users

6.3 Stakeholder linkages at each climate services node

The study recognized different sub-innovation systems through the climate services flow chain, which function at different times, with different levels of input from diverse stakeholders. With this understanding, it was easy to see the nuances that exist in the roles of particular actors from one node to another across the climate services flow chain from production to consumption. For instance, at production and translation nodes all farmers were not involved in the innovation systems but only a few farmer group representatives. But in subsequent stages, real farmers were involved.

Forecast production node

At this node the sub innovation system consisted interactions between KMD and CDM and among CDM, NDMA, research, county ministry representatives and farmer groups representatives as illustrated in Figure 6.3. To improve actor interactions all stakeholders were regarded as equal partners. In this regard, farmers were given a degree of ownership and a voice in the whole process rather than treating them as spectators or inactive participants. It was also important to ensure the farmer group representatives were picked and agreed upon by the other farmers in the groups to avoid mistrust and conflict. The county ministry representatives were involved at this inception stage in an attempt to buy in political will. The CDM received forecast from KMD and downscaled it together with the other stakeholders. The facilitator at this node was the researcher who ensured sustenance of regular consultations among the stakeholders. The guiding rule here was that all stakeholders were equal and each of them had an authoritative voice in the process.

Translation node

This followed the previous node. The interactions in this node involved the following stakeholders: CDM, agricultural extension workers, NDMA staff, farmer group representatives, county ministry representatives, suppliers of agriculture and livestock products and research (South Eastern Kenya University). This is illustrated in Figure 6.4. Again, at this node, only representative farmers were involved. This sub-innovation system helped to strengthen the roles of actors in translating raw forecast into a climate service that farmers could apply in farm decision making.

Like in the previous node, the actors were regarded as equal partners in order to improve and strengthen the linkages among them. Regular consultations were sustained among the stakeholders. The champion at this node was the extension officer who enjoyed more trust from the stakeholders. The overarching guiding rule at this node was to ensure no stakeholders gave biased interpretations of the forecast (for example on grounds of profit making).

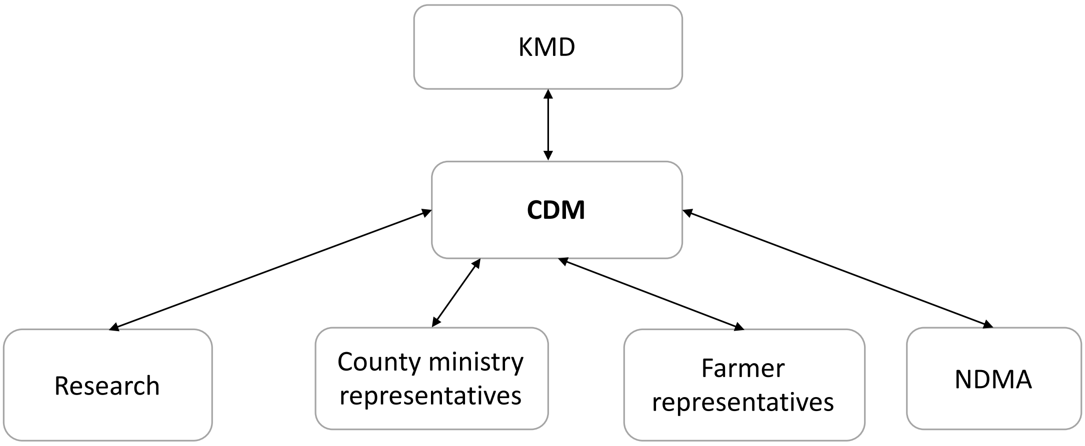


Figure 6.3: Forecast production node sub innovation system

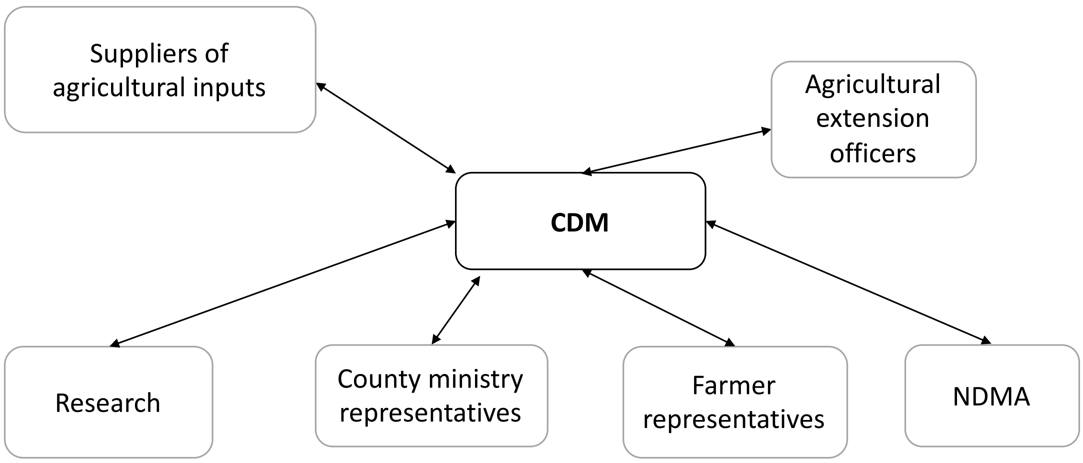


Figure 6.4: Forecast translation node sub innovation system

<u>Dissemination/ communication and information use nodes</u>

The study viewed these two nodes as interconnected in the sense that once the information is disseminated and reaches the farmer, the latter uses the information to influence farm level decisions with chances of communicating the same to his/her peers. These also use the information and passes it on to other farmers. In addition, seasonal updates are disseminated as farmers continue to use the information through the season. In this regard, the two nodes were viewed as cross cutting and therefore hard to separate. This sub-innovation system had the most stakeholders to ensure wide reach of climate services.

The stakeholders included CDM, agricultural extension workers, NDMA, county ministry representatives, suppliers of agricultural and livestock products, Sub county, ward and village administrators, religious leaders, village elders (Atui), Mbaitu FM radio, Musyi FM radio, Kitui Red Cross branch volunteers, farmers, farmer groups, women groups, chiefs and assistant chiefs. This is illustrated in Figure 6.5. Unlike in the earlier nodes real farmers were now fully involved. Informed by Table 6.1, the study leveraged the strong social network of farmers to disseminate climate services, the private sector (for example, the input suppliers), civil society groups and local government representatives to enhance wide reach, ownership and trust and subsequently adoption of the information. The champion was still the extension officer. He ensured regular two-way consultations were sustained through the process.

The qualities of linkages among stakeholders are important conditions for an innovation system to achieve any social impact. As was revealed by figure 6.1, the uncomfortable reality is that although climate services are available and more so through the devolved office of the CDM, it may not have the anticipated impact on the smallholder farmers due to very few linkages or channels for information flow from the CDM to the farmers. These few coordinated channels for information flow can compromise its access, for example, by farmers who do not own radios or whose radios are broken down. In addition, as was discussed in Chapter four, scheduling of radio programmes may coincide with farmer outdoor activities making the farmer miss out on the information aired since they do not carry the radios with them everywhere. On the other hand, the few channels for information flow may not meet gender preferences on information access (at a cost to equity), a point that was well discussed in the said chapter. This can result into serious information asymmetries. Lastly, farmers who do not belong to any CBOs or without strong social ties have high chances of missing out on climate services provided.

Potential formal and informal linkages for climate services flow, which had not been exploited in the county were developed at the dissemination and information use node. These new developed linkages at this node are indicated by dashed lines in Figure 6.5. They included more of intermediary/ broker stakeholder categories who would facilitate climate services adoption through providing it to more audiences (farmers) as well as interpreting it into a more relevant and understandable language. It was necessary, however, to first conduct capacity building to ensure all the stakeholders understand the term climate services, its jargon and interpretation. This was done through two-day meetings but the farmers were trained at separate meetings due to availability issues.

As indicated in the Figure 6.5, the new linkages included linkages between CDM and extension staff, input dealers, NGOs, religious leaders and village leaders; and between farmers and NGOs, research, input dealers, extension staff, religious leaders and village elders. These additional linkages if exploited and coordinated can add to the few existing channels for climate services flow thereby increasing access as well as overcoming issues/challenges surrounding climate services use (salience, legitimacy, credibility, equity and access), which were extensively discussed in Chapter four. For instance, exploiting the linkage between farmers and extension officers, input dealers and NGOs may not only improve access but also salience and legitimacy of the information. Input dealers would point farmers to the right seed and varieties to purchase and hence make climate services more salient.

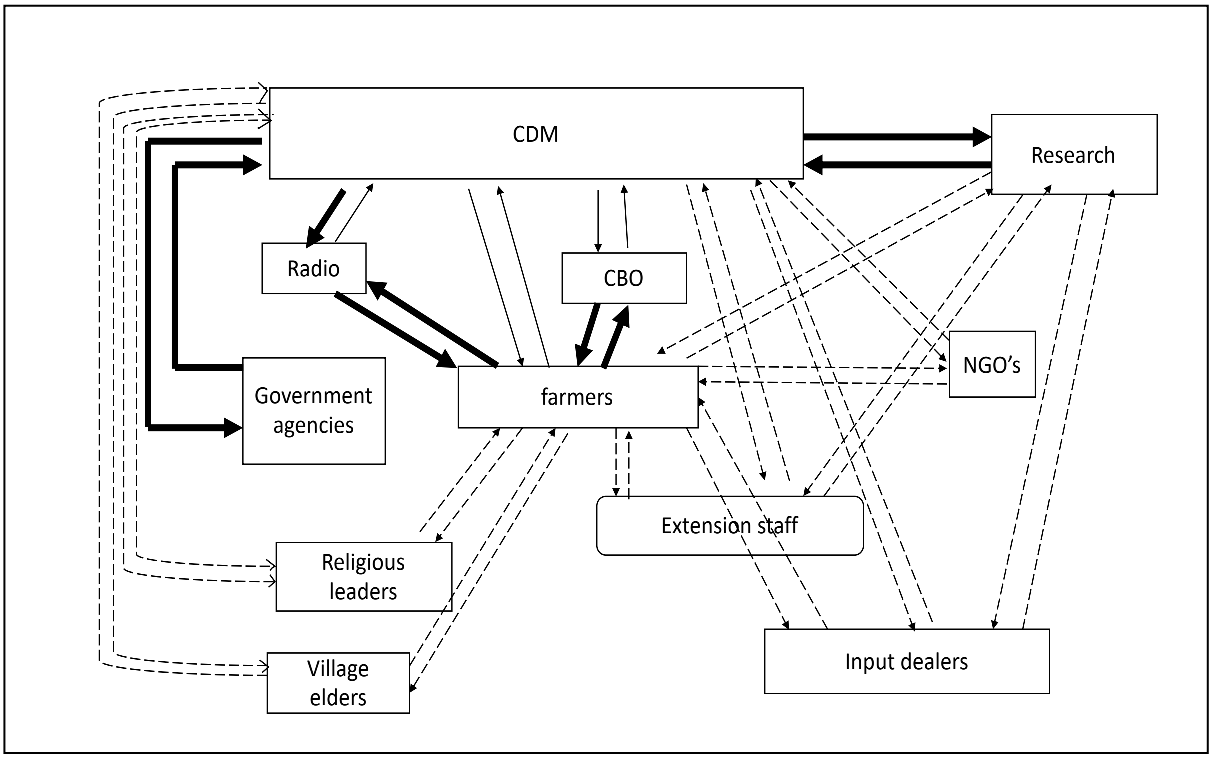


Figure 6.5: Sub innovation system at the forecast dissemination and forecast use nodes..

In figure 6.5 thick and thin continuous arrows depict strong and weak linkages respectively (both of which existed before the study) and dashed arrows depict new linkages that resulted from the study. Exploiting trusted NGOs that already have existing interactions with farmers to act as climate services conduits brings more trust and hence making the services more legitimate. In addition, more coordinated channels for climate services flow may reduce information asymmetries and improve access across all smallholder farmers thereby overcoming equity issues. This indicates that a climate services innovation system has the potential to overcome inherent challenges and lead to enhanced adoption. Having co-designed a county climate services innovation system the study tested its performance in enhancing climate services adoption through a crop growing season and the results are discussed in the next section.

6.4 Governance of the climate services innovation system

The governance of these sub innovation systems entailed the mechanisms by which decisions were made. The governance aspect generally included the presence of effective leadership, which worked by consensus and development of collective learning routines and trust. The study probed all the possibilities for seeking and achieving consensus and a common vision for enhancing climate services adoption among smallholder farmers. Through this, there was a strong element of consensus building among all the actors in the creation and execution of the sub innovation systems. The study also created a common vision through developing awareness of innovation system concept among the stakeholders.

Stakeholder networks were strengthened through joint meetings, which presented some kind of platforms to foster dialogue and co-learning. These dialogue platforms also helped to build trust among stakeholders and encouraged a culture of collaboration among them. Initially these platforms were championed by the researcher but down through the innovation process, extension officer emerged the most trusted facilitator and took over the role. The trusted facilitator ensured all stakeholders upheld a culture that respects the different partners. A spirit of collective action enabled stakeholders who had more influence than others to still consider the interests of other partners in the network.

The study was cognizant of the differing motives with which stakeholders joined the network. For instance, suppliers of agricultural inputs might have been motivated by potential chances of making profit while research organizations may have been motivated by a chance to advance science, and so on, which could be precursors of eventual conflict. In this regard, coordination by the facilitator at all levels was necessary to regulate and certify the contributions of each stakeholder in order to prevent them from providing biased information. For sustainability, the study envisaged that internal factors in the innovation network such as the presence of consensus oriented and effective leadership, and the development of collective learning routines and trust would motivate the stakeholders to continue networking beyond this research.

6.5 Operationalizing the climate services innovation system through a crop growing season

Strong linkages between stakeholders are an essential requirement to promote adoption of information through an innovation process. Studies have pointed to the role of facilitator or network broker to take up intermediary or bridging role to strengthen linkages among the actors (van Lente *et al.,* 2003; World Bank, 2006; Klerkx and Leeuwis, 2008). Literature also explains that the role of innovation facilitators or brokers can take shape in different ways and may be carried out by individual researchers (Klerkx *et al.,* 2009), or by research/ extension organizations, government agencies and NGOs (Kilelu *et al.,* 2011). In this regard the researcher took the initial role of the facilitator and acted as a bridge to facilitate contacts and interactions and hence knowledge among the stakeholders. This was done through: facilitating stakeholder capacity to understand climate services, sensitizing the stakeholders on their potential role/s in the services flow and the need to build coalitions to enhance access; and facilitating meetings for information sharing and encouraging dialogue (especially informal) between stakeholders. These efforts played a role in changing attitudes and setting the innovation agenda.

The use of the baseline actor linkage map (Figure 6.1) to discuss the existing status of the climate services flow system helped to reveal and legitimise previously unacknowledged but vital activities by individuals. For example, one input dealer said they had no interactions with farmers as far as climate services were concerned. However, one of his shop assistants reminded him that he had recently been convincing farmers on what seed varieties to buy or not to buy for the season crop, which had been informed by climate services but without mentioning the forecast to the customers. Similarly, agricultural extension officers with prior knowledge of climate services said they advise farmers to plant more of legumes and less maize albeit without a mention on the forecast. When these activities were marked on the linkage map it emphasised how important the previously unacknowledged work of the input dealers was in the climate services innovation system especially by bridging the divide between CDM and farmers.

The actor linkage maps were found easier to use in discussing the existing and the newly developed climate services linkages with the stakeholders. However, for collecting the information as the innovation system developed through the season, an actor linkage matrix was used to monitor linkage building progress and the level of information flow among the innovation stakeholders. Observations showed that agricultural extension officers had a lot of familiarity and were interacting freely with almost all other stakeholders probably because they had prior interactions with them through other forums. This was confirmed after the stakeholders were prompted to choose one among them who could lead or facilitate the process and they choose the extension officers. The extension officers seemed to possess deep knowledge of the farming community and were seen to have a better ability to manage farmers expectations and bring them within the realm of the innovation system. In addition, they were identified as credible and trusted facilitators who helped to sensitize and broker more linkages between the stakeholders. In this regard, the extension officers assumed the facilitation role and the researcher guided them from the background. Table 6.2 shows an actor linkage matrix developed as the season progressed showing the unfolding innovation process and the level of climate services flow between stakeholders.

Among the outstanding linkages in this table is the farmer to farmer exchange, which was given more attention as far as promoting climate services adoption was concerned. The study also exploited the great potential of strong linkages developed, for instance, between CDM, farmers, radio, input dealers, extension staff, NGO's with other stakeholders in the system and leveraged these to enhance climate services adoption among farmers. In general, additional linkages did not only strengthen the innovation system but also ensured optimal information sharing towards social and economic benefit.

In this table, climate services flow between stakeholders is indicated by * (more stars indicate high level of flow). Linkages that existed before study interventions are dotted while the shaded areas are linkages that resulted after study interventions. The study experience revealed that enhanced climate services adoption by participating smallholder farmers had ensued because through the proposed innovation system: wider access of climate services by farmers was enabled through increasing channels for information flow; climate services were made more salient and credible by involving multi-actors in the co-production process who tailored the climate services to farmer's needs, climate services were made more legitimate by involving farmers in the process and enabling a trusted facilitator to lead the process, and lastly, equity in both access and participation was promoted through leveraging different channels of climate services flow and ensuring equitable gender representation in the process.

Table 6.2: Actor linkage matrix showing the climate services innovation system in progress through the crop growing season.

		1	2	3	4	5	6	7	8	9	10	11
		CDM	Radio	CBO	Government agencies	Farmers	Religious leaders	Input dealers	Researcher	NGO' s	Village elders	Extension staff
A	CDM		**	***	**	*	*	**	**	***	***	***
B	Radio	**				***						**
C	CBO	***				***		*	***	**		***
D	Government agencies	**										*
E	Farmers	*	***	***		***	*	*	***	**	**	***
F	Religious leaders	*				*						
G	Input dealers	**	**	**		*			*			**
H	Research	**	**	***	**	***	*	*		**	**	**
I	NGO's	***		***		**			**			
J	Village elders	**				**			**			
K	Extension staff	***	*	***		***		*	**	**	*	

6.6 Typology of climate services flow from innovation stakeholders to the farmers (final end users)

The row marked E in table 6.2 above indicates the various innovation stakeholders through which climate services reached the farmers. Hall *et al* (2001) defines linkage mechanisms as the procedures, arrangements or events or means that bridge the gap between innovation stakeholders so that communication between them can take place. These linkage mechanisms are the means used to channel information and coordinate tasks in the process of reaching the farmers with technologies. The study attempted to understand the linkage mechanisms and types of linkage that took place between the innovation stakeholders (columns 1 to 11) and the farmers (row E). The types of linkages were identified as either formal, informal, top-down and bottom-up depending on the way communication was done as well as the channels of communication employed. This understanding is summarized in Table 6.3 below.

Table 6.3: Linkage mechanisms and patterns of interactions between the innovation system stakeholders and the farmers

Row/column in Figure 14	Linkage	Linkage mechanism	Types of linkages
Row E column 1	Linkage between CDM and farmer	Joint meeting with farmers, phone calls and SMS to farmer representatives	Formal and bottom-up
Row E column 2	Linkage between Radio and farmer	Radio broadcasts, and paid radio session with CDM	Formal
Row E column 3	Linkage between CBO and farmer	Announcement in meetings and direct person to person contacts	Informal
Row E column 4	Linkage between farmers	Direct person to person	Informal
Row E column 5	Linkage between religious leaders and farmer	Announcement in religious gatherings	Formal
Row E column 6	Linkage between input dealers and farmer	Advices during purchase of farm inputs	Informal
Row E column 7	Linkage between	Joint meetings and phone calls	Formal and bottom-up

	researcher and farmer		
Row E column 8	Linkage between NGO's and farmer	SMS to farmer group representatives	Formal
Row E column 9	Linkage between village elders and farmer	Announcement in village meetings and direct person to person	Formal and informal
Row E column 10	Linkage between extension staff and farmer	Group farm meetings and SMS	Formal and informal

As indicated in the Table 6.3, various linkage mechanisms were used to reach the farmers with climate services. In addition, various linkage types were identified. Formal linkages were those specified by the organizations, for instance, in the CDM office there is a mandate that climate services must be disseminated to users while informal linkage types are the direct person to person contacts based on the need to communicate between stakeholders, for instance, the farmer to farmer exchange. Informal linkages are not only effective but cost-effective and has a great potential to enhance innovation system's performance. Bottom-up linkages include flow of information from farmers to research and science actors. Information from farmers is based on their practical knowledge and could help to strengthen the capabilities of the other actor. The various linkage mechanisms and types helped reach the farmers with salient, legitimate, credible and equitable climate services thereby raising potential for enhanced adoption of the innovation.

6.7 Practical use of probabilistic climate services by smallholder farmers

Participating farmers used OND 2018 deterministic forecast prepared by CDM office (Appendix III) to guide farming activities on their individual farms as was the routine. This deterministic forecast was translated into local language for each of the three group farm sites (Appendices IV, V, VI). The farmers were encouraged to use this forecast to guide normal activities on their individual farms, which would act as controls. However, as was stated in Chapter Four presenting climate information in transparent probability terms rather than communicating forecast category with the highest probability has great potential to ensure credibility of the information. In this regard, OND 2018 forecast probabilities, which were also obtained from the CDM office, were used to guide farming activities on the group farms. This was issued with a lead time of three weeks, which enabled prior preparations as well as adequate flow of climate services through the established innovation system to take place.

Smallholder farmers used probabilistic advisory in making necessary pre-season adjustments such as seed/ variety selection and land allocation on the group farms. The probabilistic advisories were drawn from the three forecast probabilities groups (of above normal, below normal and normal). The study co-developed a forecast summary including both the communicated forecast from CDM office (forecast category with the highest probability) and probability forecasts (forecast indicating all likely probabilities). This forecast summary is indicated in Table 6.4. However, in cognisant that smallholder farmer access to climate services is one thing and actual use is another thing, the study endeavoured to participatorily apply probabilistic forecasts with farmers using the three group farms as demonstration sites. As a routine the farmer groups met one day each week and the members preferred to have the research meetings during their normal meeting day. In line with this, and with a good lead time the meetings days were Tuesdays, Wednesdays and Fridays for Seven-up, Mucerere, and Kanzoya farmer groups respectively over a period of three consecutive weeks.

The group farm sizes were 1 acre for Seven-up and Mucerere and 0.75 acres for Kanzoya. With the help of CDM, extension staff and input dealers and using the local language, farmers were reminded the probability concept. After that they were asked to explain in their own words what they understood by the concept and majority said it meant they avoid “putting all eggs in one basket”. Interestingly, this response emerged in all the three farmer groups. This phrase seemed to have aroused the minority farmers attention and understanding and hence was used all through the demonstrations. After brainstorming on the best way forward as far as interpreting and implementing forecast probabilities were concerned the participants agreed to use the percentages allocated to each probability category (above normal (A), normal (N) and below normal (B)) to guide selection of appropriate seeds types/ varieties and amount of land to allocate to each (Table 6.5). To avoid involving farmers in lengthy mathematical calculations they were encouraged to use their judgement to divide the group farms into three portions equivalent to each probability category.

Table 6.4: OND 2018 forecast for the three study sites

GROUP FARM	COMMUNICATED FORECAST	FORECAST PROBABILITY	ONSET DATES	CESSATION DATES
Kanzoya	Above normal	A 50% N 30% B 20%	2nd to 3rd week of October	3rd to 4th week of December
Mucerere	Above normal	A 50% N 30% B 20%	3rd to 4th week of October	3rd to 4th week of December
Seven-up	Normal to above normal	A 30% N 50% B 20%	4th week of October	3rd to 4th week of December

Table 6.5: Selected seed varieties planted in each group farm to cover all probability terciles

Group farm	**Communicated forecast**	**Forecast probability**	**Proportioning of the group farms to spread the risk**
Kanzoya	Above normal	A 50% N 30% B 20%	50% of the land plant Pioneer P28 30% of the land plant Duma 43 20% of the land plant DH 02
Mucerere	Above normal	A 50% N 30% B 20%	50% of the land plant Nyayo 30% of the land plant Kat X 56 20% of the land plant Kayelo
Seven-up	Normal to above normal	A 30% N 50% B 20%	30% of the land plant Nyayo and DK8031 50% of the land plant Kayelo and Sungura 20% of the land plant DH 02 and Katumbuka

The farmers selected appropriate crops for each tercile and the extension staff helped them narrow down to the best variety of the selected crop as shown in Table 6.5 in order to cover the whole envelop of forecast uncertainty (above normal, normal and below normal). Seed acquisition was not a problem for the Seven up and Mucerere farm groups since they had seed banks into which every member contributed 50 Kenya shillings every month. The study contributed towards the seed varieties for the Kanzoya farmer group.

6.8 Post season survey

Focus group discussion with participating farmers indicated that climate services as well as seasonal updates had become more accessible during the season than it was before. Apart from the study facilitator, they cited to having received climate services from extension officers, agro-dealers, the church, local FM stations, village elders and CBOs. The services had also become more salient, credible and legitimate to the farmers. For the first time, the farmers had received transparent forecast probabilities and understood how to interpret it. Proportioning the group farms to cater for all probability groups brought some balance between caution and confidence unlike before. This was contrary to the individual farms where they planted guided by forecast category with the highest probability. For instance, Kanzoya farm group site whose climate service had been derived from forecast category of above normal actually received normal rains during this season. Individual farmers in this site did not harvest much from their farms since they had used seed varieties appropriate for above normal rains.

On the other hand, it was not a total loss from the group farm (Kanzoya) since farmers had partitioned the farm into three portions to cater for the three probability groups. As a result, they got plenty harvest of Duma 43 (a maize variety) from 30% proportion of the group farm. Mucerere farm group received above normal rains just like the communicated forecast had indicated. In this locality, participating farmers had plenty of harvest from their individual farms and from 50% proportion of their group farm. On the other hand, participating farmers from the Seven up farm group did not harvest much from their individual farms since they used seed varieties for normal to above normal following the communicated forecast but the actual rains received were below normal. However, it was not a total loss from their group farm since they received good harvest of DH 02 maize (a seed variety appropriate for below normal rains) from 20% portion of the group farm.

The question of forecast accuracy notwithstanding, the group farm demonstration helped farmers appreciate the aspect of probability in forecasts as well as how they can interpret it to spread the risk. By doing so, the farmers had a good balance between caution and confidence throughout the season. Most farmers were of the view that climate services availability needed to be extended to every farmer in the county and they believed that other farmers would benefit greatly like they had. Regarding what should be done to make farmers understand and use climate services in planning and managing farm activities, farmers cited the following prerequisites: make climate services available to all farmers, train farmers to understand and use climate services and communicate forecast probability in a transparent manner.

In conclusion, this chapter demonstrated the effectiveness of an innovation system approach in the delivery of climate services. It emerges that climate services flow chain is not linear but composed of complex interactions among heterogeneous actors at every node of the process and can be better represented by innovation system approach. Through this approach enhanced adoption of climate services ensued because: wider access of climate services by farmers was enabled through increasing channels for information flow; climate services were made more salient and credible by involving multi-actors in the co-production process who tailored the climate services to farmers' needs; climate services were made more legitimate by involving farmers in the process and enabling a trusted facilitator to lead the process; and lastly, equity in both access and participation was promoted through leveraging different channels of climate services flow and ensuring equitable gender representation in the process. The chapter also demonstrated the importance of presenting forecasts in their probabilistic nature and formulating probabilistic advisories

This chapter recommends the use of an innovation system approach in the delivery of climate services in place of the top-bottom linear approach. In addition, it also recommends transparent presentation of forecasts probabilities to farmers and formulation of probabilistic advisories in order to avoid the dangers of banking on a wrong deterministic forecast.

CHAPTER SEVEN: ENABLING ENVIRONMENT FOR SCALING UP THE PROPOSED CLIMATE SERVICES INNOVATION SYSTEM

7.0 Introduction

Enabling conditions are essential for effective innovation processes. This chapter discusses several enabling environments that can foster optimum performance of the proposed climate services innovation system and thereby scale up climate services use among wider populations.

7.1 Scaling up concept

Community based climate change adaptation faces major challenges in terms of sustainability and up-scaling of activities. World Bank (2003) define scaling up as to efficiently increase the socioeconomic impact from a small to a large-scale coverage. Linn (2012) define it as the replication or spread of techniques, ideas or approaches in order to achieve an increased scale of impact. It can occur in different directions either horizontally, vertically or diagonally. Horizontal upscaling, also known as scaling out involves replicating proven practices in new geographical areas or target groups (Linn, 2012) in order to disseminate the practices to wider places. Vertical upscaling involves facilitating institutional and policy change in order to sustain efforts in the long-term while diagonal upscaling involves adding more project components according to World Bank (2003). To be effective and to create sustainable impact of proven practices such as climate services, enabling conditions that support especially the horizontal and vertical scaling up (both of which are collectively referred to as scaling up in this study) will be necessary.

7.2 Enabling environment for effective scale up of climate services through the proposed innovation system

Integral to scaling up climate services through the proposed innovation system is institutional framework for interpreting, disseminating and ensuring information uptake. Innovative approaches that support building institutions are important conditions for enabling scaling up of climate services. This underscores the necessity of establishing county institutional frameworks to enable climate producers, agricultural experts, end users and other relevant stakeholders to co-design and co-produce relevant and timely climate services for farmers. Examples of institutional frameworks suggested by the innovation systems stakeholders included effective communication, strengthening capacity of actors, using existing institutions and taking a participatory approach in the whole process. However, institutional arrangements will be limited if the farmers are not fully involved in the process of climate services co-production. In this regard, a supportive institutional structure needs to extend the co-production process's boundaries to incorporate farmers' voices through sustained engagement. Institutional arrangements create platforms that enable and sustain direct engagement across disciplines and with end users. Such engagement is essential for optimal functioning of the climate services innovation system.

Scaling up climate services through the proposed innovation system will require sustained effective partnerships among the multi-stakeholders involved. This can be achieved through memoranda of understanding (MOU) and priority setting among innovation stakeholders as well as establishing contractual agreements among stakeholders. Experiences cited in this research point to the need for climate services to be relevant, participatory and operational beyond a single event. Establishing and sustaining effective partnerships is a key enabler in realizing these qualities. In addition, co-production of climate services requires sustained partnerships among multiple stakeholders to integrate climate and agricultural information to produce farm management advisories. In this regard, strong partnerships in the county defined either through MOUs or contractual agreements among the innovation stakeholders will be necessary for effective scale up of climate services through the proposed innovation system. Important partnerships include those with county government agencies that have reach and finances to support scaling up, NGOs that have a strong link to communities and private companies that can finance and support the climate services innovation system through their networks.

On partnerships, it is also paramount to ensure that county government partners are engaged at inception in the design of the climate services innovation system. This engagement has the potential to lead to long-term sustainability as well as enable largescale replicability by creating ownership and commitment to county budgetary allocation for climate services. In this regard, one way towards upscaling lies in creating linkages for mainstreaming climate services into county government budgets through inter alia involving county stakeholders from an early stage of the innovation system design.

Reviewed literature, expert-led discussions and the research experience with practical use of climate services with farmers note the importance of capacity building along the climate services value chain as a critical factor in successful scaling up. Gebru *et al* (2015) identified lack of capacity as a bottleneck to improving climate services provision. A number of studies also point to the growing need for sustained training of climate services stakeholders (Goddard *et al.,* 2010; Visman 2014). Capacity building activities should be addressed to all stakeholders in the climate services flow chain. Capacity building is critical since the stakeholders involved may not be equal, which can heighten the potential for asymmetry in traits such as power, voice and resources. It is therefore necessary to build capacity especially among the weakest partners to create a common ground for partnering and reduce asymmetries.

Working with farmer group organizations through the study pointed to the importance of building organization structures at the community level, which can enhance horizontal scale up of climate services. Such organizational structures in the county include self-organized farmer groups, village youth groups and community seed banks. These can be included into the innovation system and yield multiplier benefit in climate services adoption. The untapped potential of the county village youth can be tapped effectively when the youths are involved in a kind of organization structure making it easier to be trained and constructively engaged in climate services.

Availability of innovation facilitators/ champions is another enabling factor for upscaling climate services in the county through the proposed innovation system. Champions can play a crucial role by mobilizing communities to demand for climate services or making a case for fund allocations for climate services thus facilitating scale up. This demand can be enhanced by demonstrating climate services importance to end users and county government agencies such as the ministry of agriculture services and planning. The reasoning is that once the climate services demand is created, there will be an incentive for the county government to take responsibility and promote subsidies for climate services delivery.

Last but not least, upscaling climate services in the county definitely needs political and financial support from the county government. For instance, in Mali where climate services was initially promoted through short term pilot projects, upscaling was only realized after political support and budgetary programming from the government (Hellmuth *et al.,* 2010). Reviewed articles in this study pointed to a fact that when there is a buy-in from the government, new initiatives had enhanced reach. In this regard, policies that promote the county government buy-in of climate services can play an enabling role to upscale climate services. Examples are policies that promote integration of climate services into the county government development planning as well as those that create a mandate for county governments to expand its participation and fund adaptation initiatives. For instance, decentralization rather than devolvement of meteorological services to the counties is one form of policy that can play a role in expanding the county government participation in climate services. In addition, policy agenda that promotes stakeholder engagement such as collaboration and linkages development towards a common good, for instance, by defining adequate incentives for participating stakeholders is another enabler for scaling up. With such policies, climate services innovation stakeholders more so the intermediaries in the county would accept climate services as a normal way of working rather than an additional task.

To summarize, providers of climate services need to broaden their mandate, partner with other relevant stakeholders, together deepen their level of engagement, assess and reassess to improve efficiency of the climate services innovation system and seek to influence the enabling environment through policy advocacy. The study hopes that these enabling factors will help scale up climate services through the proposed innovation system as well achieve demand-driven climate services through overcoming the supply-driven inertia with an end aim of improving the resilience of smallholder farmers to climate.

Using the above enablers as building blocks for scaling up of climate services through the proposed innovation system, the conceptual framework in Figure 7.1 below is proposed as the consolidation of requisite modalities and enabling environments. According to this Figure, the emerging theory of change is that IF smallholder farmers (who possess indigenous/local knowledge) interact with other external actors (possessing scientific and technical knowledge on successful climate services from pilot tests) within an innovation systems, and integrate critical cross-cutting issues (e.g. gender, youth, communication) as well as the necessary enabling environment in scale up plans; and if an appropriate monitoring, evaluation and learning system is similarly installed and all these interactions are coordinated by a trusted champion, THEN a rapid scaling up of climate services will occur and, over time, climate-resilient farming systems will be realized at scale.

In conclusion, as indicated in Figure 7.1, a portfolio of good practices together with relevant county stakeholders will form the basis for establishment of the climate services innovation system. However, enabling conditions are a pre-requisite for its optimum performance. In this regard, this chapter recommends putting in place an enabling environment to foster optimum performance of the proposed climate services innovation system and thereby scale up climate services use among wider populations.

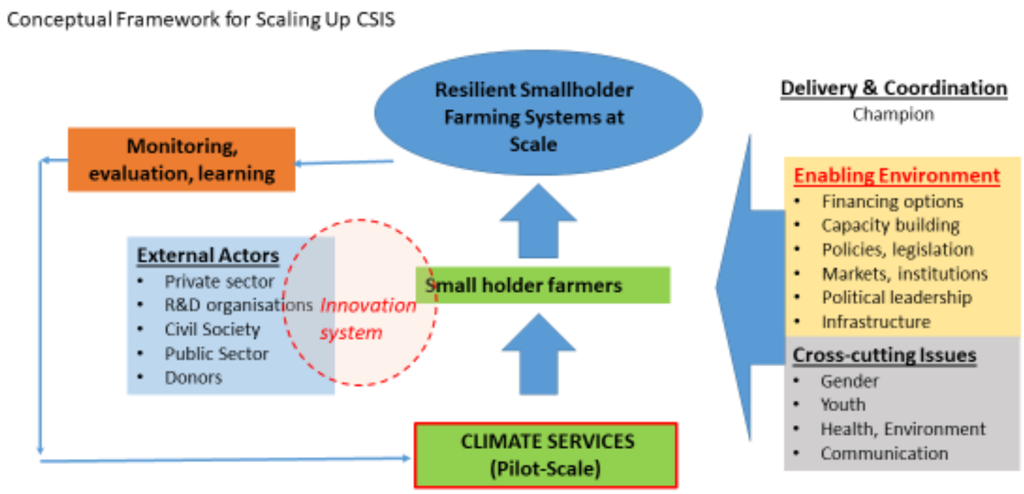


Figure 7.1: Proposed Conceptual Framework for scaling up Climate Services Innovation System (CSIS).

CHAPTER EIGHT: SYNTHESIS AND DISCUSSION

8.0 Introduction

This chapter attempts to tie up the whole study by synthesizing the findings of each objective as well as showing their relationship to the main study objective. The study was made up of four objectives which had been formulated as building blocks to achieve the main aim of the study (towards improved resilience of smallholder farmers in Kitui county through enhanced adoption of climate services). In this regard, the objectives of the study were carried out stepwise in that objective one led to objective two, which led to objective three in that order until the fourth objective. The stepwise relationship among these objectives and how each of them contributed to the general aim of the study is discussed in the sections below.

8.1 Contribution of past climate services pilot projects to climate risk management in Africa smallholder farming systems

This was the first objective of the study ("to review the contribution of past climate services pilot projects in climate risk management in order to establish good practices") and its results formed the discussion in Chapter Four. The objective was achieved through literature review of relevant peer reviewed articles. Google scholar was the main database used to obtain these articles using some chosen keywords. Quite a number of pilot project write ups were in form of gray literature but the study chose to use only peer reviewed literature so that the study results would remain authoritative. The essence of this objective was to establish a research base to support advocacy for enhanced adoption of climate services as was stated in the research title. The research revealed that past pilot projects have contributed enormously to climate risk management of smallholder farmers despite their limited nature in terms of time and coverage. In addition, the past pilots offer a lot of insights regarding good practices that can be employed in future to ensure enhancement of climate services use among vulnerable smallholder farmers.

In summary, timely use of climate services inform a lot of improved pre-season farm management decisions such as input purchase and land management. In addition, climate services provided in dekadal scales enables farmers to plan their farm daily activities such as planting, weeding and fertilizer application in ways that manage risks. Use of climate services also comes with a lot of co-benefits to the smallholder farmers at the household level such as increase in yields, income and welfare. With these results, the study had a firm base to advocate for enhancement of climate services use among smallholder farmers in order to improve their resilience to climate variability and change. However, before introducing any adaptation assistance, it was necessary to first determine the vulnerability of smallholder farmers community in the study area to climate risks, which formed the second objective of the study.

8.2 Vulnerability assessment to climate risks and coping strategies of communities in Kitui county.

This was the second objective of the study and its results are presented in Chapter Five. Indicator approach was used to assess the communities' vulnerability in the study area. Past research advocates for the carrying out of vulnerability assessments before introducing adaptation interventions. The study endeavored to know the vulnerability situation of communities in the study area to determine if indeed introduction of climate services was a befitting adaptation assistance. The results indicated that the communities were spatially vulnerable across the county and practiced different livelihoods and this guided the zeroing down on the specific study areas in the county. In response to the existing vulnerability situation, the research revealed that communities already had their traditional coping strategies to help them cope. However, these had become inadequate with time due to increasing climate variability. There was a need to strengthen these traditional coping strategies to reduce existing vulnerability to climate risks and thereby enhance the communities' resilience.

The study had climate services as adaptation assistance in focus, which was intended to improve the resilience of communities in the study area. Results of objective one had already established that past climate services initiatives contribute to climate risk management of smallholder farmers and also offer good practices that can be transferred in the future. In addition, objective two results established that communities were indeed vulnerable and their coping strategies had become ineffective with time. These results set the base for the study to endeavor to improve climate services use as an adaptation assistance with a general aim of achieving the main aim of the study.

8.3 The proposed Kitui county climate services innovation system

The study established that climate services were not new to the communities but they were not being used to a level which was good enough to contribute to reduction in climate vulnerability and hence contribute to improved resilience. In this case objective three set to improve the use of climate services to the communities since they already had some grassroot knowledge on these services. An overarching finding from the systematic literature review results of objective one was that enhanced use of climate services ensued where participatory approaches had been used with farmers having a degree of ownership in the climate services process. In addition, many insights emerged from this objective on how to overcome inherent challenges surrounding use of climate services: salience, legitimacy, credibility, equity and access. Informed by these results and with the aim of improving the communities' resilience, the study took an innovation system approach. This approach was viewed to be more participatory and systematic than the linear information delivery approach that communities had experienced before.

Multiple stakeholders in the climate services chain were identified in the county to form the innovation network. The identified stakeholders were grouped into climate services sub innovations based on different value chain nodes as follows: forecast production sub innovation system had KMD, CDM, research, county ministry representatives, farmer representatives and NDMA; forecast translation sub innovation systems had CDM, suppliers of agricultural inputs, research, county ministry representatives, farmer representatives, NDMA and agricultural extension officers; lastly the forecast dissemination and use sub innovation system had CDM, research, radio, CBO, government agencies, farmers NGO's, religious leaders, extension staff, village elders and input dealers. Through this network the study endeavored to ensure climate services inherent challenges were overcome using the insights derived from the systematic literature review results so as to enhance adoption. Resilience to climate risks would then ensue with improved climate risk management as a result of enhanced use of climate services. New linkages among the climate services network stakeholders were developed and the weak ones were strengthened in order to improve the network performance. It emerged from objective one results that credibility of climate services improved where they were formulated using probabilistic forecasts rather than deterministic. In this regard, a lot of capacity building was conducted to ensure the stakeholders understood forecast probability nature and how to interpret it into advisories as well as their roles in the process. Farmers were also capacitated to ensure they not only understood probabilistic forecasts but would also interpret it into farm level decisions to realize improved resilience to climate risks.

The performance of this network was tested through a crop growing season and short term updates were provided to all stakeholders as the season progressed. Post season survey revealed that climate services provided through the proposed approach had become more salience, legitimate, equitable, credible and accessible. As a result, more adoption of these services ensued thereby enabling the smallholder farmers to manage climate risks during the season. If sustained and scaled up, this contribution has the potential to improve the communities' capacity to adapt to climate risks. This calls for enabling conditions to be put in place to ensure sustenance and scale up as well as optimal performance of the proposed climate services innovation system.

8.4 Enabling environment to support effective scale up of climate services through the proposed innovation system

The discussion on the results of this fourth and last objective of the study are presented in chapter 7. Having seen the potential of the proposed climate services innovation system in helping farmers manage climate risks, it was imperative for the study to establish conditions that must exist to ensure optimal function of the system and hence guarantee effective scale up. These enablers include capacity building of all the network stakeholders, availability of innovation facilitators/ champions especially those with prior grassroot interactions with farmers, incorporating local institutional environment into the design of the innovation system network, ensuring farmers have a degree of ownership in the climate services process, establishing and sustaining effective partnerships among the innovation stakeholders, employing diversified communication channels, leveraging existing local networks and putting in place mechanisms to improve technical issues of climate services. The proposed climate services innovation system can operate optimally and sustainably if these enabling conditions are put in place. This can support the smallholder farmers in climate risk management and in the long run contribute to improving their resilience to climate risks.

CHAPTER NINE: CONCLUSIONS AND RECOMMENDATIONS

9.0 Introduction

This chapter presents a general summary of conclusions from the study objectives and recommendations based on the conclusions. The study findings have indicated that past climate services pilots have contributed to climate risk management and they offer a lot of insights, which if borrowed can inform climate services provision towards enhanced adoption. The smallholder communities in Kitui county are vulnerable to climate change risks and in this regard enhanced adoption of climate services can enable them manage impeding climate risks. The means used to introduce and/or promote adaptation options among smallholder communities determine the level of uptake of those options. This study the potential of innovation systems approach in raising adoption levels of adaptation interventions among smallholder farming communities.

9.1 Conclusions

Use of climate services by vulnerable communities has largely been promoted through donor driven and time bound pilot based projects. Past climate services pilot projects have contributed enormously to climate risk management through influencing farm level decision making. Through past pilots, farmers were able to adjust farm activities such as when to plant, weed, as well as apply fertilizer and pesticides. As a result of climate services influenced farm level decisions, other co-benefits can be realized such as increased food security and household income. The main shortcoming of these pilots is that they are donor driven and hence time bound. This brings forth the question of sustainability of good practices achieved (as far as use of climate services is concerned) during the life span of the pilots. Sustainability of good practices is a great challenge surrounding pilot projects especially where the pilot activities are rolled out with total disregard of existing local institutions.

Despite the nature of these pilots and their inherent sustainability issues, they do not only stimulate demand driven use of climate services but also offer a lot of insights that can be applied to realize wider use in the future. These insights can be drawn from the various ways through which different past pilots used to overcome challenges that surround use of climate services (issues of salience, credibility, legitimacy, access and equity). Downscaling climate information to match the forecasts geographical scale with scale of farm level decision making can ensure salience of information to farmers needs and usability. Salience can also be ensured through value addition of forecasts by team of experts to tailor or create agrometeorological advisories (climate services) from raw climate forecasts. Wider adoption of climate services can therefore ensue when climate information is downscaled and combined with relevant farm management advisories.

Legitimacy issues surrounding use of climate services can be overcome through increased and sustained farmer participation. In general, adoption of climate services can be enhanced through giving smallholder farmers a larger role in the whole process of development (thereby ensuring legitimacy) such as using local networks as well as identified village champions and facilitators to act as dissemination conduits. On the other hand, equity issues can be overcome through ensuring there exists no disparities in information access between male and female farmers as well as ensuring gender sensitive dissemination channels are used.

Credibility issues can be overcome through expressing forecast uncertainty in transparent tercile probabilities as well as supplementing this with short term updates as the season progresses. This however, necessitates provision of adequate training on how to understand and interpret probabilistic information into farm management decisions. Regarding climate services access, it is evident from the past pilots reviewed that regions with highest awareness of climate services were the same regions where a greater diversity of communication channels had been used.

Generally, climate services offer great opportunity to help smallholder farmers manage impending climate risk, which contributes to building their adaptive capacity to climate change. Managing climate risk is integral to larger strategies for helping smallholder farmers adapt to the changing climate. Reviewed pilot projects have been successful in raising farmers' awareness and use of climate services and they present transferrable good practices. Factors that contributed to the success of past pilots can be used as good practices to inform future endeavors seeking to enhance wider adoption of climate services among vulnerable smallholder communities. However, the importance of carrying out a vulnerability study on communities before adaptation assistance cannot be overstated. It is evident from the results that Kitui county communities are vulnerable to climate change risks with differentiated vulnerability scores. The differentiated patterns of vulnerability emphasize that vulnerability is context specific and hence context specific responses and adaptation strategies are required at local levels.

The approach taken to introduce adaptation assistance to vulnerable communities has great potential to influence the level of uptake of interventions. Top-down approaches hinder participation of local actors and regards them as spectators in the whole development process, which prevents adoption of adaptation interventions. This necessitates introduction of participatory approaches, which view knowledge adoption more systematically and interactively. An example of these is the innovation systems approach. Taking such an approach supports understanding of the social networks, including identification of key information nodes as well as existing and potential pathways to disseminate information effectively to all farmers.

The results of this study indicate that through an innovation systems approach, enhanced climate services adoption by smallholder farmers would ensue since: wider access is enabled; climate services are made more salient and credible by involving multi-actors in the co-production process, climate services are made more legitimate by involving farmers in the process and enabling a trusted facilitator to lead the process, and lastly, equity in access is promoted through leveraging different channels of climate services flow. However, several enabling factors must be put in place for the innovation systems approach to work effectively in order to ensure enhanced adoption of climate services.

9.2 Recommendations

The study has shown that pilot projects have been successful in raising farmers' awareness and use of climate services and they present transferrable good practices. However, farmer engagement ends with the end of the pilot projects, which leaves unmet demands for climate services and hence a drop in the provision, awareness and use of climate services among beneficiary farmers. This brings about sustainability challenges in the provision and use of climate services. To overcome these challenges the study recommends factoring in sustainability enablers into the pilot design before intervention. This notwithstanding, a lot other recommendations on how to overcome inherent climate services challenges can be drawn from the good insights emerging from past pilots and from the research experience throughout this study and these are discussed below:

1. Need for probabilistic forecasts: In ASALs where farming is almost a matter of do or die, forecasts should be expressed as probabilistic rather than deterministic in order to ensure credibility. These forecasts should then be used to formulate appropriate probabilistic advisories to evade the danger of banking on a wrong deterministic forecast, which can ruin future trust in the forecasts. This calls for adequate stakeholder training to ensure enough understanding of probabilistic forecasts and how to implement them at the farm level.
2. Case for specific adaptation: The study has shown that vulnerability patterns can be spatially differentiated across a region and therefore recommends carrying out vulnerability studies before introducing adaptation assistance. As a result, it is critical to seek context-specific adaptation strategies to overcome vulnerability. This is because an adaptation approach that works for communities in one primary livelihood may not work for communities in a different primary livelihood. On the other hand, the results demonstrate the potential of vulnerability mapping approaches and use of GIS and therefore recommends the use of these tools to support county planning processes when dealing with prioritization of adaptation measures.

3. Innovation systems approach for science and technology mobilization: An overarching finding from this study is that a more systematic approach is needed to support science and technology mobilization, for instance, climate services in order to deliver benefits. In this regard, in place of a linear climate services delivery approach (one way delivery from the producer to the farmer) the study recommends an innovation system approach, which has the potential to enhance salience, credibility, equity, access and legitimacy of the information.

4. Effective communication and prtnerships: The study also recommends putting in place conditions that foster effective communication, partnerships and working relationships among actors if an innovation system has to achieve any social impact.

5. Involvement of local institutions and organizational arrangements: For sustainability purposes, the study recommends the involvement of local institutional and organizational arrangements in the establishment of the innovation system.

6. Detailed future research to improve the proposed innovation systems stakeholders. Lastly, this study recommends a more detailed research to broaden the proposed innovation system stakeholders in order to consider issues of market and post-harvest for the season crop produce in the event that farmers have a surplus in the harvest.

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APPENDICES

Appendix I: FGD questions for the post-season survey

1. What type of climate services did you receive this season and was it different from what you have been receiving (if any) in the past?
2. Did you find the information useful or not? why?
3. In what ways do you think other farmers in the county can benefit from climate services?
4. What key lessons did you learn from our interaction through this season?
5. Through your experience this season, what should be done to make more farmers understand and use climate services in planning and managing their farm activities?
   END

Appendix II: Publications that made it to the final systematic review

S/No	Publication citation
1	Aura, S., Muthama, N. J., Karanja, F. K., Kahuha, S., Chanzu, B., King'uyu, S., ... & Karanja, F. (2015). Making Meteorological Services More Beneficial to Farmers. *WMO Bulletin*, *64*(1), 55-58.
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5	Carr, E. R., Fleming, G., & Kalala, T. (2016). Understanding women's needs for weather and climate information in agrarian settings: The case of Ngetou Maleck, Senegal. *Weather, Climate, and Society*, *8*(3), 247-264.
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7	Dilley, M. (2000). Reducing vulnerability to climate variability in Southern Africa: the growing role of climate information. In *Societal Adaptation to Climate Variability and Change* (pp. 63-73). Springer, Dordrecht.
8	Ewbank, R. (2016). Increasing small-scale farmer access to climate services. *Food Chain*, *6*(2), 65-76.
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14	Murgor, D. K., Cheserek, G., & Nduru, G. M. (2018). Climate and Weather Informational Services and Products for Maize and Wheat Farmers in Uasin Gishu County, Kenya. *Africa Environmental Review Journal*, *3*(1), 30-42.
15	Oladele, O. I., Gitika, M. P., Ngari, F., Shimeles, A., Mamo, G., Aregawi, F., ... & Olorunfemi, O. D. (2019). Adoption of agro-weather information sources for climate smart agriculture among farmers in Embu and Ada'a districts of Kenya and Ethiopia. *Information Development*, *35*(4), 639-654.
16	Ouedraogo, I., Diouf, N. S., Ouédraogo, M., Ndiaye, O., & Zougmoré, R. (2018). Closing the gap between climate information producers and users: Assessment of needs and uptake in Senegal. *Climate*, *6*(1), 13. (Ouédraogo *et al.,* 2018a)
17	Ouédraogo, M., Barry, S., Zougmoré, R., Partey, S., Somé, L., & Baki, G. (2018). Farmers' willingness to pay for climate information services: Evidence from cowpea and sesame producers in Northern Burkina Faso. *Sustainability*, *10*(3), 611. (Ouédraogo *et al.,* 2018b)
18	Partey, S. T., Dakorah, A. D., Zougmoré, R. B., Ouédraogo, M., Nyasimi, M., Nikoi, G. K., & Huyer, S. (2018). Gender and climate risk management: evidence of climate information use in Ghana. *Climatic Change*, 1-15.
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22	Phillips, J. G., Deane, D., Unganai, L. and Chimeli, A. (2002). Implications of farm-level response to seasonal climate forecasts for aggregate grain production in Zimbabwe. *Agricultural Systems* 74: 351–369.
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25	Roudier, P., Alhassane, A., Baron, C., Louvet, S., & Sultan, B. (2016). Assessing the benefits of weather and seasonal forecasts to millet growers in Niger. *Agricultural and Forest Meteorology*, *223*, 168-180.
26	Roudier, P., Muller, B., d'Aquino, P., Roncoli, C., Soumaré, M. A., Batté, L., & Sultan, B. (2014). The role of climate forecasts in smallholder agriculture: lessons from participatory research in two communities in Senegal. *Climate Risk Management*, *2*, 42-55.
27	Roudier, P., Sultan, B., Quirion, P., Baron, C., Alhassane, A., Traoré, S. B., & Muller, B. (2012). An ex-ante evaluation of the use of seasonal climate forecasts for millet growers in SW Niger. *International Journal of Climatology*, *32*(5), 759-771.
28	Singh, C., Daron, J., Bazaz, A., Ziervogel, G., Spear, D., Krishnaswamy, J., ... & Kituyi, E. (2018). The utility of weather and climate information for adaptation decision-making: current uses and future prospects in Africa and India. *Climate and Development*, *10*(5), 389-405.
29	Tarchiani, V., Camacho, J., Coulibaly, H., Rossi, F., & Stefanski, R. (2018). Agrometeorological services for smallholder farmers in West Africa. *Advances in Science & Research*, *15*.

30	Tarchiani, V., Rossi, F., Camacho, J., Stefanski, R., Mian, K. A., Pokperlaar, D. S., ... & Adamou, A. S. (2017). Smallholder Farmers Facing Climate Change in West Africa: Decision-Making between Innovation and Tradition. *Journal of Innovation Economics Management*, (3), 151-176.
31	Unganai, L. S., Troni, J., Manatsa, D., & Mukarakate, D. (2013). Tailoring seasonal climate forecasts for climate risk management in rainfed farming systems of southeast Zimbabwe. *Climate and Development*, *5*(2), 139-152.
32	West, J. J., Daly, M. E., & Yanda, P. Z. (2018). Enhancing the Salience, Credibility and Legitimacy of Climate Information and Services in Semi-Arid Tanzania: Lessons from the Pilot Phase of the Global Framework for Climate Services Adaptation Programme in Africa. *AGUFM*, *2018*, PA31B-1144.
33	Ziervogel, G. (2004). Targeting seasonal climate forecasts for integration into household level decisions: the case of smallholder farmers in Lesotho. *Geographical Journal*, *170*(1), 6-21.
34	Ziervogel, G., & Calder, R. (2003). Climate variability and rural livelihoods: assessing the impact of seasonal climate forecasts in Lesotho. *Area*, *35*(4), 403-417.
35	Zongo, B., Diarra, A., Barbier, B., Zorom, M., Yacouba, H., & Dogot, T. (2016). Farmers' perception and willingness to pay for climate information in Burkina Faso. *Journal of Agricultural science*, *8*, 175-187.

Appendix III: OND 2018 Deterministic forecast

REPUBLIC OF KENYA
MINISTRY OF ENVIRONMENT, WATER AND NATURAL RESOURCES
KENYA METEOROLOGICAL SERVICE
County Meteorological Office–Kitui County
P.O.Box 205 90200, Kitui, Tel:…………
E-mail: kituicounty@meteo.go.ke: http:// www. meteo.go. ke

When replying please quote Ref. No. MET/KTI/0016 Date: 9 September, 2018

OUTLOOK FOR THE OCTOBER, NOVEMBER, DECEMBER (OND), 2018 RAIN SEASON IN KITUI COUNTY

Highlights

Enhanced rainfall is expected over most parts of Kenya, during the October, November, December 2018 season. This condition is especially so for the northern parts of the country including parts of Kitui County such as Mwingi North Sub-county.

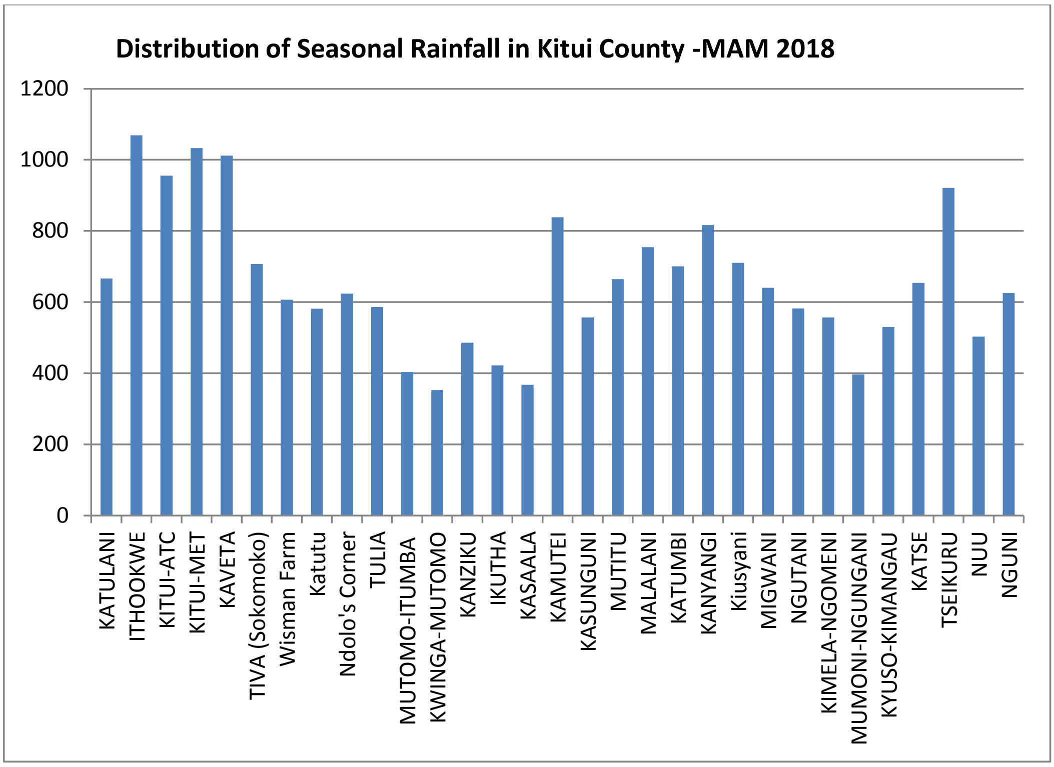
General Synoptic Indications of Climate

The seasonal rainfall forecast for October, November, December (OND) 2018 "Short-Rains" is based on the prevailing and the expected evolution of Sea Surface Temperature Anomalies (SSTAs) over the Pacific, Indian and Atlantic Oceans as well as other Synoptic, Mesoscale and local factors that affect the climate of Kenya in general and Kitui county in particular.

SST conditions are favorable for good seasonal rainfall in Kenya. The predicted Onsets, Cessation and Distribution of rainfall were derived from statistical analysis of past years, which exhibited similar characteristics to the current year. The forecast indicates that much of the country and especially most of the north sector including Kitui County has high probability for experiencing generally enhanced rainfall during the October, November, December 2018 season. The distribution of the rainfall in time and space over Kitui County is expected to be generally good over most places especially during the peak month of November.

Review of the rainfall conditions in March, April, May (MAM) 2018

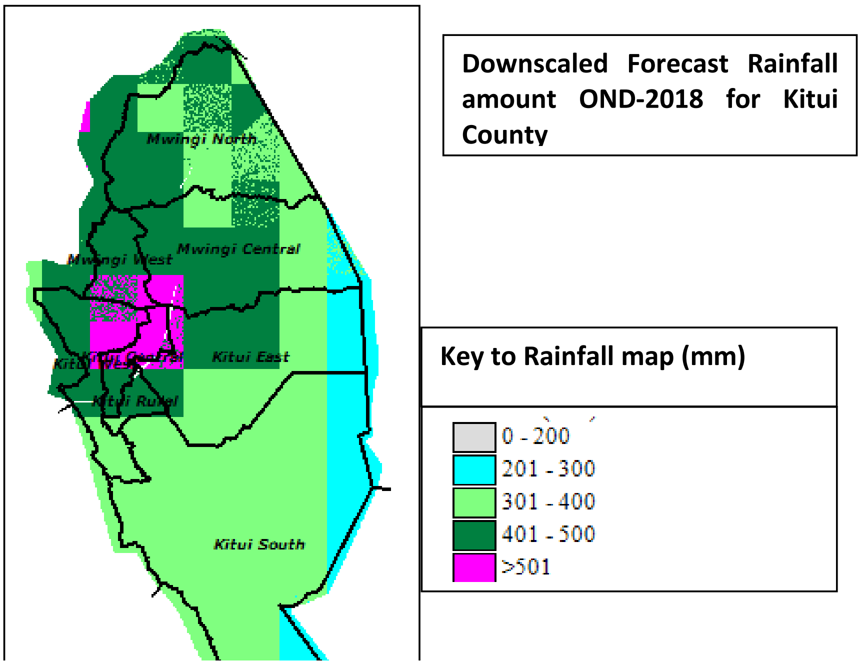
During the March-April-May (MAM), 2018 season, most parts of Kitui County experienced above-normal rainfall that was mainly recorded in the months of March, April and May 2018. This condition of enhanced rainfall was experienced in most places of Kitui County.



Several rainfall stations in the County recorded above-normal (enhanced) rainfall as indicated in the figure above. The season also exhibited high wind and storm conditions.

Forecast for October-November-December (OND) 2018 "Short-Rains" Season

The figure below shows the downscaled characteristics of expected rainfall amounts for Kitui County during the OND 2018 season. Forecast models have indicated high probability for receiving the rainfall amounts shown in the map.



High seasonal rainfall of over 400mm is expected in Kitui Central, Mutito, Kitui West, Kitui Rural sub-county including Mbitini and Kisasi, parts of Kitui West sub-county such as Matinyani, parts of Mwingi West sub-county such as Migwani ward and parts of Mwingi north sub-county including Mumoni and Tharaka wards. The expected rainfall matches amount of water sufficient to support generally high water requirement crops including hybrids. Other parts of the county (parts of Kitui East sub-county- Voo-Kyamatu, Zombe Mwitika, Endau Malalani and all areas to the eastern boundary of the County), have high probability of receiving over 300mm of rain.

EXPECTED RAINFALL ONSET AND CESSATION

- Rainfall onset for OND 2018 season for Mwingi North and parts of Mwingi Central Sub-counties is expected to occur during the 2nd to 3rd week of October 2018.
- Parts of Kitui county including: Kitui West, Mwingi West and Kitui Central sub-counties will experience rainfall onset by the 3rd week of October 2018.

- Parts of Kitui county including: Kitui East, southern parts of Kitui Rural and Kitui South, will experience rainfall onset by the 4th week of October to 1st week of November, 2018.

- **Cessation** of rainfall is expected to occur during the 3rd to 4th week of December, 2018, over most parts of the County.

Expected Rainfall Distribution

The rainfall distribution, both in time and space, is expected to be generally good over most parts of the county.

Expected Impact For OND-2018

October to December period constitutes a very important rainfall season for Kitui County, contributing to over 60% of the food security situation in the county. Relevant sectors (water, agriculture, livestock among others) and communities are advised to take advantage of the expected rainfall to enhance food production. The good rainfall performance expected will impact positively on the agriculture, livestock and water sectors.

Agriculture, Livestock Development and Food Security

Given that rainfall is expected to be enhanced in the season, farmers are advised to liaise with the County Ministry of Agriculture to get advice on appropriate crops in order to make the best use of the anticipated enhanced and well distributed rainfall. Food security is expected to improve over most parts of the county.

Water Sector

Water resources (rivers, water pans, sand dams and boreholes), in the county are expected to improve and probably will recharge to full capacity following the forecasted enhanced rainfall.

Disaster Management Sector

The disaster management institutions are advised to be aware of incidences such as: Health - Disease outbreak (Rift Valley Fever etc), Transport and Public Safety - (Flash floods) are likely to occur over several parts of the county particularly along the seasonal rivers

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William Ndegwa Githungo Phd

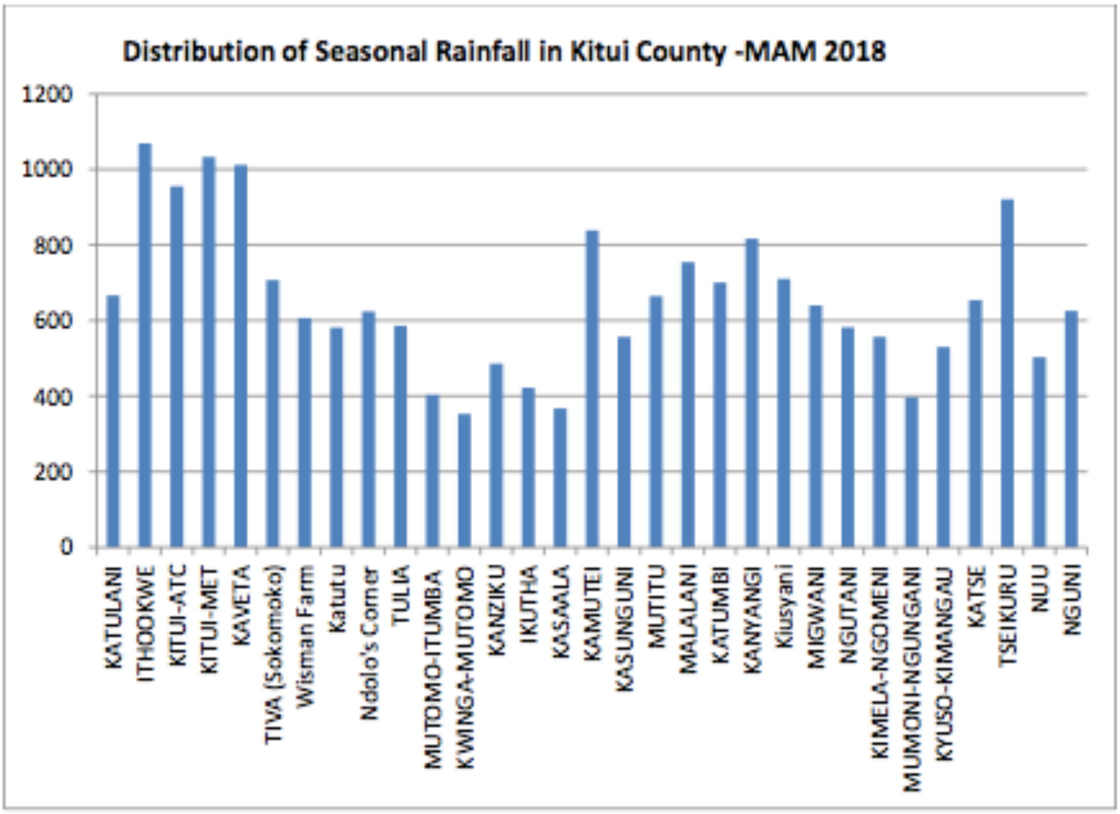
County Director for Meteorological Services

Appendix IV: Translated OND 2018 Deterministic forecast for Kyangwithya Ward

KUWETELA KWA IVINDA YA MBUA YA NZWA (MWEI WA IKUMI, IKUMI NA IMWE, KUVIKA IKUMI NA ILI) 2018 KISIO KYA KYANGWITHITHYA KYA UTHUILONI WA SYUA, KITUI KYA KATI

KUSISYA UNDU MBUA YA UUA 2018 YAUIE

Mbua ya uua 2018, isio mbingi sya Kitui inakwatie mbua mbingi otondu ithimi sya mbua syonanitye vaa itheo.



KUWETELA KWA IVINDA YA MBUA YA NZWA (MWEI WA IKUMI, IKUMI NA IMWE, KUVIKA IKUMI NA ILI) 2018

Kisio kya Kyanngwithya ya uthuiloni wa syua, Kiyui kya kati, kiiikwatiwa kukwata mbua mbianiu kurika mbua mbingi.

Mbua yiikwatiw'a kwambiia kyumwa kya katatu mwei wa ikumi 2018, na ikithela kyumwa kya katatu kuvika kya kana mwei wa ikumi na ili 2018.

Utao ma uvisi wa uimi kumana na kuwetela kwa mbua ya nzwa 2018

Aimi metawa mavande makwasi, manga, malenge na mboka sya kithio ta telele, manaku, nundu wa uima wa mii yoo

Aimi metawa mavande mbeu ila ivitukithitwe ni ataalamu kuma kwa nduka ila inengwete valua wa kuta mbeu

Aimi metawa ingi mavande na kuimia liu woo ivinda yila yailite, na kusaiisya mauwau, na midudu ila itonya kwananga liu woo na moona syindu isu mainengane repoti uvisini wa uimi ula wi vakuvi namo.

Aimi metawa mavande liu wa indo syoo ta nyeki sya mbeetwa, ndaata kivumbu na mbwea

Metawa ingi makethe liu woo ivinda yila yailite na kwanika liu woo wume nesa, na kwikia ndawa ivinda yila yailite. Aimi nomatumie makunia ala mena nylon nthini kusuvia liu woo

Aimi metawa masanze indo syoo nundu wa kusiia mawau ala mokanasya na mbua mbingi.
Aimi nimekutawa kutumia nzia sya kuketha kiw'u miundani yoo, ta kuseuvya mbenzi, kuseuvya tumitalu, kuketha kiw'u kya iala sya nyumba, kuvwika muthanga, kuseuvya tusilanga na kuketha kiw'u kya nziani.

Aimi nimekuthuthwa kutumia vuu wa indo, mbolea ya kuthooa ndukani kwisila utao wa athukumi ma uimi isioni syoo. DAP na NPK wa kuvanda na kutonyea CAN.

Aimi mavande miti ya matunda, ngu na ya mbwau.

Aimi mavande mbeu ii mbua ya nzwa 2018

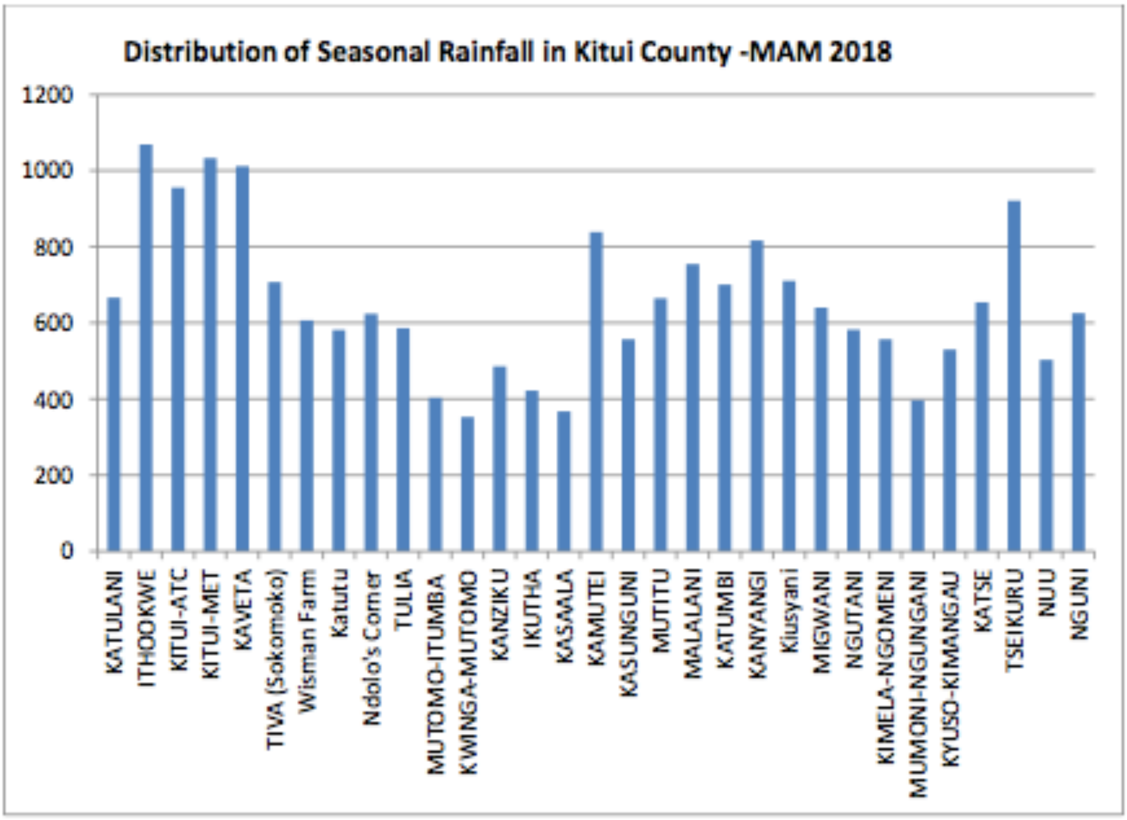
Mbeu	Muthemba (Variety)
Ndakithi	Nylon na Uncle
Mbooso	Ndumu ya maina, Kakuuzu, Nyayo, mwei umwe, kayelo
Nzooko	Ila ina mukea mutune, mukea mweu, kaluki na kalitho
Mbemba	KDV4, Pioneer, Duma 43, Pan 4M-19, DK 8031, Sungura, DHO4
Nzuu	Mbaazi 1, Mbaazi 2, Kat 60/80, Kikamba

Appendix V: Translated OND 2018 Deterministic forecast for Matinyani Ward

KUWETELA KWA IVINDA YA MBUA YA NZWA (MWEI WA IKUMI, IKUMI NA IMWE, KUVIKA IKUMI NA ILI) 2018 KISIO KYA MATINYANI, KITUI KYA UTHUILONI WA SYUA

KUSISYA UNDU MBUA YA UUA 2018 YAUIE

Mbua ya uua 2018, isio mbingi sya Kitui inakwatie mbua mbingi otowelu ithimi sya mbua syonanitye vaa itheo.



KUWETELA KWA IVINDA YA MBUA YA NZWA (MWEI WA IKUMI, IKUMI NA IMWE, KUVIKA IKUMI NA ILI) 2018

Kisio kya Matinyani, Kitui kya uthuiloni wa syua, kiiikwatiwa kukwata mbua mbianiu, kuvika mbua mbingi.

Mbua yiikwatiw'a kwambiia kyumwa kya katatu mwei wa ikumi 2018, na ikithela kyumwa kya katatu kuvika kya kana mwei wa ikumi na ili 2018.

Kunyaaika kwa mbua kwiikwatiw'a kwithiwa kwi kwa kwaila kila vandu na ivinda yonthe ya mbua

Utao ma uvisi wa uimi kumana na kuwetela kwa mbua ya nzwa 2018

Aimi metawa mavande makwasi, manga, malenge na mboka sya kithio ta telele, manaku, nundu wa uima wa mii yoo

Aimi metawa mavande mbeu ila ivitukithitwe ni ataalamu kuma kwa nduka ila inengwete valua wa kuta mbeu

Aimi metawa ingi mavande na kuimia liu woo ivinda yila yailite, na kusaiisya mauwau, na midudu ila itonya kwananga liu woo na moona syindu isu mainengane repoti uvisini wa uimi ula wi vakuvi namo.

Aimi metawa mavande liu wa indo syoo ta nyeki sya mbeetwa, ndaata kivumbu na mbwea

Metawa ingi makethe liu woo ivinda yila yailite na kwanika liu woo wume nesa, na kwikia ndawa ivinda yila yailite. Aimi nomatumie makunia ala mena nylon nthini kusuvia liu woo

Aimi metawa masanze indo syoo nundu wa kusiia mawau ala mokanasya na mbua mbingi.

Aimi nimekutawa kutumia nzia sya kuketha kiw'u miundani yoo, ta kuseuvya mbenzi, kuseuvya tumitalu, kuketha kiw'u kya iala sya nyumba, kuvwika muthanga, kuseuvya tusilanga na kuketha kiw'u kya nziani.

Aimi nimekuthuthwa kutumia vuu wa indo, mbolea ya kuthooa ndukani kwisila utao wa athukumi ma uimi isioni syoo. DAP na NPK wa kuvanda na kutonyea CAN.

Aimi mavande miti ya matunda, ngu na ya mbwau.

Aimi mavande mbeu ii mbua ya nzwa 2018

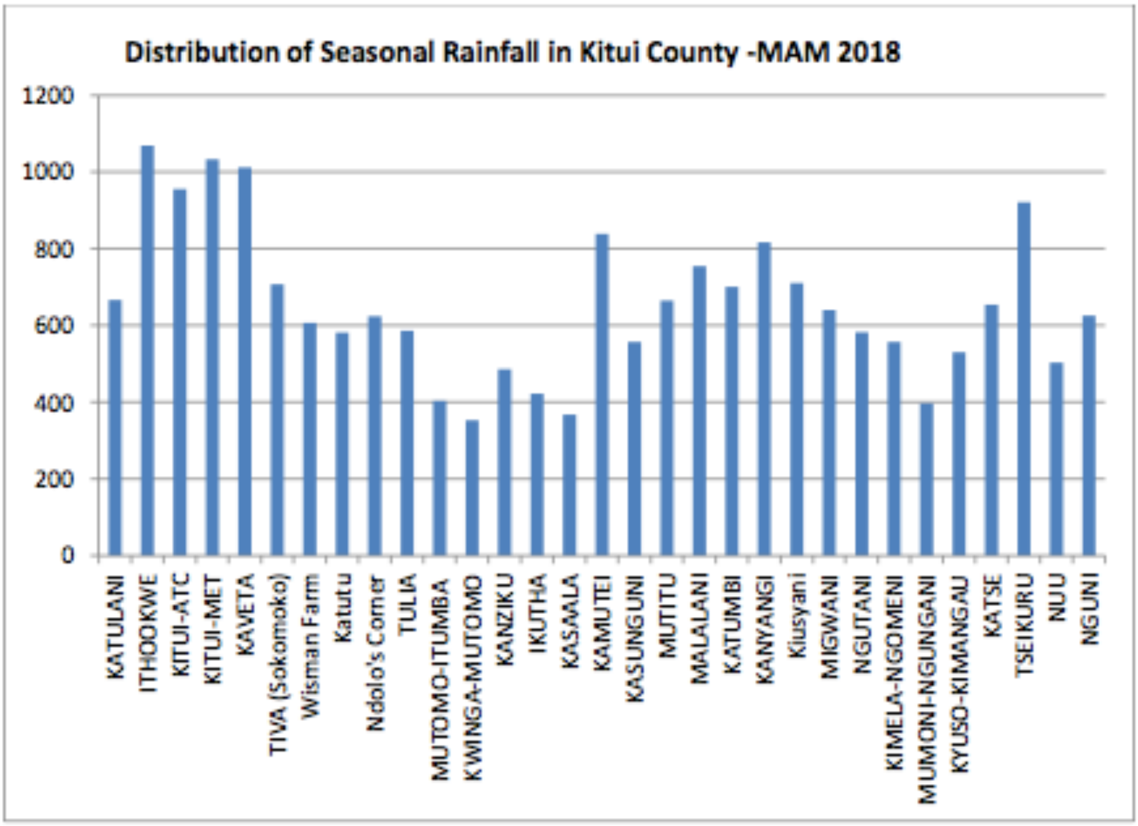
Mbeu	Muthemba (Variety)
Ndakithi	Nylon na Uncle
Mbooso	Ndumu ya maina, Kakuuzu, Nyayo, mwei umwe, kayelo
Nzooko	Ila ina mukea mutune, mukea mweu, kaluki na kalitho
Mbemba	KDV4, Pioneer, Duma 43, Pan 4M-19, DK 8031, Sungura, DHO4

Appendix VI: Translated OND 2018 Deterministic forecast for Kwa-Vonza Yatta Ward

KUWETELA KWA IVINDA YA MBUA YA NZWA (MWEI WA IKUMI, IKUMI NA IMWE, KUVIKA IKUMI NA ILI) 2018 KISIO KYA YATTA KWAVONZA, KITUI RURAL

KUSISYA UNDU MBUA YA UUA 2018 YAUIE

Mbua ya uua 2018, isio mbingi sya Kitui inakwatie mbua mbingi otondu ithimi sya mbua syonanitye vaa itheo.



KUWETELA KWA IVINDA YA MBUA YA NZWA (MWEI WA IKUMI, IKUMI NA IMWE, KUVIKA IKUMI NA ILI) 2018

Kisio kya Yatta Kwavonza, Kitui Rural, kiiikwatiwa kukwata mbua mbianiu kuvika mbua mbingi.

Mbua yiikwatiw'a kwambiia kyumwa kya kana mwei wa ikumi 2018, na ikithela kyumwa kya katatu kuvika kya kana mwei wa ikumi na ili 2018.

Kunyaaika kwa mbua kwiikwatiw'a kwithiwa kwi kwa kwaila kila vandu na ivinda yonthe ya mbua

Utao ma uvisi wa uimi kumana na kuwetela kwa mbua ya nzwa 2018

Aimi metawa mavande makwasi, manga, malenge na mboka sya kithio ta telele, manaku, nundu wa uima wa mii yoo

Aimi metawa mavande mbeu ila ivitukithitwe ni ataalamu kuma kwa nduka ila inengwete valua wa kuta mbeu

Aimi metawa ingi mavande na kuimia liu woo ivinda yila yailite, na kusaiisya mauwau, na mididu ila itonya kwananga liu woo na moona syindu isu mainengane repoti uvisini wa uimi ula wi vakuvi namo.

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Aimi metawa masanze indo syoo nundu wa kusiia mawau ala mokanasya na mbua mbingi.
Aimi nimekutawa kutumia nzia sya kuketha kiw'u miundani yoo, ta kuseuvya mbenzi, kuseuvya tumitalu, kuketha kiw'u kya iala sya nyumba, kuvwika muthanga, kuseuvya tusilanga na kuketha kiw'u kya nziani.

Aimi nimekuthuthwa kutumia vuu wa indo, mbolea ya kuthooa ndukani kwisila utao wa athukumi ma uimi isioni syoo. DAP na NPK wa kuvanda na kutonyea CAN.
Aimi mavande miti ya matunda, ngu na ya mbwau.

Aimi mavande mbeu ii mbua ya nzwa 2018

Mbeu	**Muthemba (Variety)**
Ndakithi	Nylon na Uncle
Mbooso	Ndumu ya maina, Kakuuzu, Nyayo, mwei umwe, kayelo
Nzooko	Ila ina mukea mutune, mukea mweu, kaluki na kalitho
Mbemba	KDV4, Pioneer, Duma 43, Pan 4M-19, DK 8031, Sungura, DHO4
Nzuu	Mbaazi 1, Mbaazi 2, Kat 60/80, Kikamba