Integrating farming and scientific knowledge in adaptation technologies to climate change:

A technographic analysis of the Tradeoff Analysis model for semi-subsistence agriculture in Kenya

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Disclaimer

The views expressed in this thesis are those of the student and do not necessarily express the views of any of the affiliated persons or organizations, and therefore I take responsibility for its contents.

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Asante

ABSTRACT

Ng'ang'a. T.W (2010) Integrating farming and scientific knowledge in adaptation technologies to climate change: A technographic analysis of the Tradeoff Analysis model for semi-subsistence agriculture in Kenya

The study contributes to adaptation science the adaptation activities on the ground of agricultural farmers. It analyzes the mode of integrating them with scientific modelling for future anticipatory adaptation. This is discussed as a mean to facilitate adequate development and deployment of technologies designed to reduce current and future vulnerability of the farmers.

It analyzes the farmers' perception on climate variability and change and the strategies they were engaged in. Twelve (12) Focused Groups Discussions and 42 household formal interviews were administered. The scientific response analysed was the process of making Tradeoff Analysis (TOA) model where participatory observation & informal discussions were used as methodology.

The farmers perceive local micro climate change as a reality. The consequences are decreased agricultural productivity impacting on food security. Their adapting techniques are embedded in their individual livelihood strategies. The TOA model is testing technologies in potato and sweet potato production for their economic, environmental and policies sustainability. A comparison of the two practices resulted into synergies, Tradeoffs and modes of integrating the two practices. It demonstrated the value and the need of integrating the practise of farmers with the practise of science through the approach of social shaping of technology (SST).

Keywords: Farming practices, scientific practises, perception, climate change, adaptation strategies, Tradeoff Analysis

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ABBREVIATIONS AND ACRONYMS

CIP	International Potato Centre
COP	Conference of Parties
CO_2	Carbon dioxide
FGDs	Focused Group Discussions
IARC	International Agricultural Research Centres
IPCC	Intergovernmental Panel on Climate Change
IK	Local Knowledge
ITCZ	Inter-Tropical Convergence Zone
KARI	Kenya Agricultural Research Centre
MOA	Ministry of Agriculture
NARS	National Agricultural Research Systems
NEMA	National Environmental Management Authority
SST	Social Shaping of Technology
TOA	Tradeoff Analysis
UNFCCC	United Nations Framework Convention on Climate Change
WUR	Wageningen University Research

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To my sons: Noel & Newton

Executive summary

In this study the notion of adaptation to climatic change was examined between two groups operating on different spatial, temporal and social scales. The aim is to contribute to adaptation science by exploring the adaptation activities on the ground and analysing the modes of integrating current farmers' responses to scientific long term projections. This is the TOA adaptation technologies designed to address impacts of climate change and reduce vulnerability of the local community in Embu District, Kenya. It looked at practice of adaptation science among the scientific community as well as adaptation strategies among the community of farmers. It established a detailed analysis of local social realities as experienced and performed by the local farmers as well as the contribution and efforts of science in adaptation to climate change.

Chapter one introduces the international debates on climate change and adaptation. The idea of climate change and variability is defined and analysed in relation to what adaption mechanism is taking place. Two types of adaptation are conceptualised reactive, autonomous and private among the farming community and anticipatory, planned and public among the scientific community. The idea of developing adaptation technologies is discussed first as a dynamics process and embedded in livelihood practices of the farmer. Secondly as a result of techniques of environmental manipulation that has been long present within the human systems and culture. The chapter also presents the research objectives with the three main research questions. It also introduces the technology being observed, the Tradeoff analysis.

Chapter two has two sub sections. The first starts by discussing the technography methodological design used in the study. The four elements of technography used in the study are defined and their purpose stated. These are materiality, modality, sodality and the task group. The research design is expounded giving the timeframe, site selection, data collection tools, language used, implementation and finally the challenges experienced. The second subsection gives the background of the study area. It starts with climate change projection in the country, geographical location of the area and later singles out the two crops that are of interest in this study as they are the crops used in the model as information sets.

Chapter three begins with a preliminary step which explains how farmers conceptualize both global and local climate change discourse. This gives way to exploring how they perceive their own micro climate data, predict it and how they relate with scientific weather forecasts. The second part of this chapter analyzes perception of farmers on climate change as a local phenomenon and captures the indicator of climate change, cause and the impact. This is

linked to adaptation strategies they have innovated whose details are given in chapter four. This data was collected during the focused group discussions.

Chapter four analyzes the farmers' adaptation strategies. It is divided into two subtopics. The first one gives the technical view of adaptation as experienced in the farming practices. The second explains how adaptation can also occur as a result of other multi stressors. This therefore explains adaptation as it is integrated in the technical, social and economic activities. The data feeding this chapter was collected during household interviews.

Chapter five, the final result chapter uses four dimensions of technography defined in chapter two to analyze the process of technology development. This involves two main crops, potatoes and sweet potatoes as interacts with two actors, the scientists and the local farmers. It helps identify the commonalities and diverging practices in their interaction with the two crops. This is used to analyze the social shaping of technology. This is where the interaction of the two actors affects the design and development of technology. Data was collected through formal household interviews, participatory observation and informal discussions. In the formal household interview, the process of production and processing of the two crops was sought. Within the scientific community, "being there" in the layout and implementation of the experiments opened chances to acquire details of the practice of science.

Chapter six and the final chapter give a discussion, conclusion and recommendation of the entire thesis. The chapter emphasizes on three issues that are advocated for adaptation technologies. Firstly the reality of climate changes as a local phenomenon, and how the local communities are responding to these changes. It argues that farmers' actions are not only reactive, triggered by past or current events, or anticipatory based on assessment of future conditions, but they are equally based on micro climate change phenomenon they are observing and experiencing. Secondly the analysis of the synergy and point of divergence between the practice of farming and scientific practice helps identify the modes of integrating current farmers' responses to scientific long term projections. This hypothetically will facilitate adequate development and deployment of adaptation technologies designed to address impacts of climate change thus reduce vulnerability of the local community in Embu District, Kenya. It opens up the black box of the TOA model and discusses the social technical elements that were filtered out due to the quantitative nature of the model.

1.0 CHAPTER 1: INTRODUCTION

1.1 **Human adaptation and Environmental changes**

The "world wide climate is changing" this is according to the fourth assessment report of the Intergovernmental Panel on Climate Change (2007 P.4). While this is being debated there are already some scientific consensus like changes in average climatic conditions, increased frequency and intensity of weather hazards, and variable climate becoming less predictable (Lemos et al 2007).

Globally there is increased concern on climate change, which has reinforced the importance of timely action to mitigate its cause and adapt to its adverse effects (Boyd et al 2008). This both actions call for adjustment to behaviour of the society (Adger et al 2005). This study reviews the nature of adaptation in relation to spatial, temporal and social scales and the implication in developing adaptation technology.

1.1.1 Climate change and climate variability

The concern on climate change is due to the drastic increase of global atmospheric temperatures by 0.3-0.6$^{\theta}$C over the last 100 years, its average rate of increase during the 21century is predicted at 0.3$^{\theta}$C per decade (IPCC 1990). This is as a result of increased concentration of carbon dioxide (CO_2) in the atmosphere and other green house gasses, (methane, nitrous oxide). Scholars have referred to these changes as human-induced or anthropogenic climate change. In 1992, the United Nations Framework Convention on climate change (UNFCCC) in Rio de Janeiro established two actions to deal with this kind of climate change, mitigation and adaptation (Schipper 2006); Mitigation referring to actions designed to reduce green house gas emissions or enhancing their sinking. Adaptation to the impacts of climate change was then not defined. It was overlooked for a long time as priority and discussions focused on mitigation to lower the source of climate change, rather than on adapting to it (Schipper 2006). The meaning and interpretation of the term adaptation ever since became an academic and policy debate causing conflicts especially between the north and the south governments, where adaptation was regarded as a "developing country issue" (Schipper 2006). A new focus on adaptation as a policy option to climate change was given in 2001 during the Marrakesh Accords under the UNFCCC. This recognised adaptation as a necessary objective and not an alternative to mitigation (Schipper 2006). This called for an adaptation policy, linked with UNFCCC and at par with mitigation policy. Adaptation in the climate change arena is faced with lots of uncertainty in definition, and in meaning as well as in implementation (Schipper 2006).

The term “Climate variability”, is used to refer to climate fluctuations that are non-anthropogenic (Orlove 2005). Some body of literature suggests that there is nothing new about climate change, and the way the society adapt to changes (Boyd et al 2008). These adaptations by the societies have been refereed to as coping to climate variability. Orlove notes the difficult in distinguishing between climate change and variability especially at regional specific climatic conditions due to earlier societies negatively affecting their environment (Orlove 2005).

This study reviews the nature of adaptation in relation to spatial, temporal and social scales and its implication in developing adaptation technology

1.1.2 Adaptation Theory

This study analyses the theory of adaptation using two communities operating on different spatial, temporal and social scale. The first is the scientific community, whose focus is at a higher regional level and bases their adaptation strategies on future climatic condition using climate focusing models. The second are the local farmers whose adaptation is viewed in the context of local micro climate change and whose adaptation is integrated within individual livelihood strategies as well as within non climatic social economic factors. This results in two types of adaptation which are based on adaptation discourse of purposefulness and timing. The purpose of this study is to contribute to adaptation science by systematically discussing adaptation activities on the ground, and opening the black box of the Tradeoff analysis model, bringing in what has been filtered out during its development process. Adaptation science was defined by Meinke as a “process of identifying and assessing threats, risks, uncertainties and opportunities that generates the information, knowledge and insight required to effect changes in systems to increase their adaptive capacity and performance” (Meinke et al 2009 p.69). It is seen as the intermediary or sitting at the boundary of science and the society. Activities of adaptation science refer to the TOA model that is supposed to inform policy for adaptation decisions. The objective of this study is therefore to look at both societies that are informing the model, and contribute to what could have been filtered out due to its scientific protocol and quantitative need of information.

Foundation of the term adaptation and definition

The term adaptation to environment has its roots in and developed from the natural sciences especially population biology and evolutionary ecology (Winterhalder 1980). Adaptation here is considered as genetic characteristics, response mechanism which allowed individual organisms to adjust or change in behavior, physiology, demographic and structure to survive, reproduce and become more suited in the environment they inhabited (Winterhalder 1980).

The adaptation paradigm has found its way in social science and by extension to ecological anthropology where ecological concepts and principles are applied in the context of human-environment interaction (Smithers & Smit 2009). Here human systems can and do adapt to changes in environment. The application of the term adaptation in human systems can be traced to the anthropologist and cultural ecologist Julian Steward. In his principle of cultural ecology he used human cultural groups as systems of ecological adaptation (Smit & Wandel 2005). This is through their behavior, techniques applied, social organization, institutional frameworks, and how the human systems think and implements decisions. Cultural practices are in this case equated with genetic characteristics in natural sciences. In recent social science studies, adaptation is distinguished by society behavior and technological innovations, (Denevan 1983). It is also widely used in many disciplines like cultural geography, natural hazards research, and ecological economics and more recently in climate change studies.

The term adaptation has been defined by Adger and Arnella (2005 p. 78) “adjustment in ecological, social & economic systems in response to observed or expected changes in climate stimuli and their effects and impacts”. The definition of the term adaptation used in this thesis is borrowed from Lemos, (2007 p. 26) who refers to it as “action taken to adjust to the consequences of climate change, either before or after impacts are experienced”. Adaptation is therefore any activity taken by the human systems to reduce the negative effects of climate change and/or takes advantages of new opportunities presented by the changes.

Adaptation as integrated in the Livelihoods Strategies

Adaptation through the lens of livelihood strategies gives the linkage between human and environmental. The two are taken as interacting with each other with the distinction that the humans are both reactive and proactive. This is due to the ability to plan and manage they own adaptation, as well as incorporate environmental perceptions and evaluate risks (Smithers & Smit 2009). The human systems indicated refers to people, their land, farming systems, their knowledge in regard to their environment, climatic conditions and global views on agriculture and climate change. Ecological system in the conventional sense, refers to natural environment where topography, soils, rainfall, temperatures, Flora and Fauna, are the key elements observed (Raufflet et al 2000).

Adaptation as integrated in the non climatic social economic factors

Adaptation can also be influenced by other factors other than climatic stimuli. These are often referred to as “intervening conditions” as they determine the resilience of the system. For example two regions could be affected by a series of drought periods that result in crop failure, but due to different economic and institutional arrangements, the impact varies (Smit et al

2000). Adaptations decisions are not isolated from other decisions made by the human systems. They occur in the broader and narrow context of demographic, cultural, economic change, technologies, governance and social conventions. It can therefore be difficult to separate climate change adaptation strategies and decisions or actions triggered by other social or economic events (Adger et al 2005).

Adaptation types

The phenomena of climate change and climate variability will provides a framework to understand how these ecological systems have changed over time and actions being taken. The unit analysis in this study is not only the individual farmer in his/her position as a decision-makers in adaptation, but the entire "ecological population" (Denevan 1983). This includes the dynamics of individual farmer, the Embu farming community and the scientists and their culture as they react to a changing environment. It will focus on climate change as what the human system (who) is adapting to and how adaption is taking place, referring to the types of adaptation (Smit et al 2000). In the discourse framing of adaptation, several types of adaptation have been identified. Adger (2005) talks about reactive and anticipatory adaptation based on their triggering factors. The former is triggered by past or current climate variability; Hug and Reid (2009) referred to it as adaptation to naturally occurring climate variability. Ian Burton (2009) referred to it as "adaptation type I". It occurs spontaneously without considering climate change and its activities are reactive responses after impact has been manifested. It does not require intervention of a public agency (Smit et al). For example a farmer experiencing crop failure, may change his selection of crop varieties.

Anticipatory adaptation is based on assessment of future climate conditions (Adger et al 2005) before the impacts are observed. Burton categorized and referred to this action as adaptation type II. Hug and Reid (2009) refers to it as adaptation to anticipated human-induced climate change. They are planned adaptation measures with conscious and deliberate policy decision or response strategies. It is often multi-sectoral in nature and aims at improving the adaptive capacity of the system (FAO 2007). For example, deliberate crop selection and distribution strategies across different agro-climatic zones. Practically it is difficult to distinguish the two types, but policy wise, under the context of UNFCCC, adaption is defined as "adjustment of a system to climate change (including climate variability and extremes) to moderate potential damages, or to take advantages of opportunities or copy with consequences" (IPCC 2007a). Within this broad IPCC definition different types of adaptation can be recognised. Anticipatory and reactive adaptation, between private and public adaptation, and between autonomous and planned adaptation (Orlove 2005).

This study conceptualises the adaptation actions taken by the farmers as reactive, autonomous and private, while adaptation by the scientists as anticipatory, planned and public. The distinction is made because of the fact that adaptation by the scientific community is based on long term future climate projection model. It also utilises the TOA model as a long term decision making tool which can specify the costs and benefits of various adaptation strategies, giving both economic and environmental development. The TOA model can inform policy makers on the optimal climate adaptation strategy based on its analysis. This type of adaptation is viewed as an exogenous decision variable, planned by the modeller. The farmer's adaptation is considered autonomous and endogenous as it is often independent, not controlled by other people and developing from within. They are private in nature and not regarded as a decision making variable as do not lie in the hands of the region leaders (Tol & S 2005). The question is as scientists working on anticipatory adaptation will develop a public adaptation strategy, how will be hosted under the hospice of private adaptation if not integrated from the beginning?

Adaptation and Technology development,

Steward principle of cultural ecology referred to the relationship between environment, technology and task as a useful group that man needs for climatic and biotic factors to be useful to him (Netting 1965). Lack of technology will hinder communities' capacity to implement adaptation options as limits the range of possible options (Smit et al). Denevan (1983) recognized adaptation as being dynamics and embedded in livelihood strategies and in land use management. It is technical and social. The adaptive capacity of local farmers to engage in this dynamic process depends on the availability and access to technologies at various levels, from local to national sectors (Smit et al).

Technological innovations and options exist within the human systems as he/she deals with the environment (Denevan 1983). These options could be in use by the society or dormant based on ecological situations experienced. Denevan (1983) disagreed on attributing new mode of adaptation to an external origin, or to a technological innovation. This is where intervention is associated with the state, research organizations, NGOs, private sectors or the community (Denevan 1983). Within the adaptation literature this is referred to "building adaptive capacity". This is not a new phenomena but re-emerging in the context of climate change due to the multiple stressors the already vulnerable communities are going through (Lemos et al 2007). This study does not equate adaptation to interventions, but as an integration of techniques of environmental manipulation by the local communities with those being utilized by the scientific community for anticipatory adaptation.

The study takes on board the suggestions of Denevan, and looks at adaptation as a dynamic process, integrated in livelihood strategies and also coming from within as well as from external. It also looks at TOA technology development process as a participatory, involving the farmers and therefore not as an intervention from outsiders.

1.2 Problem Statement

This study is based on a hypothesis that if current farmers' responses to climate change are highly integration with scientific long term adaptation plans, this can facilitate adequate adaptation of technologies designed to address future climate change. This is expected to reduce the vulnerability of the local community if adoption rate is high. This study was conducted in two divisions, Nembure and Runyenjes of Embu District, Kenya. It focused on adaptation strategies of the scientific community and the farmers' community. Adaptation strategies for the farmers community was identified through focused group discussions and household interviews. The scientific community response was determined through participatory observation and informal discussions.

The working problem statement is lack of an analysis of how these two communities can combine their efforts and shape a future adaptation technology to climate change. For example the scientific community is using maize stover as mulching material for potato production. The farming community although historically used maize stover, it is in competition with its increase need as animal fodder and therefore another alternatives leaves like grevillea are in use.

This thesis aims are conducting an analysis of the practice of farming and the scientific practice aimed at developing technologies to address the challenge of climate change. It identified issues that can hinder this realisation due to high levels of trade-off and identifies synergy points and proposes modes of reducing diverging issues in the development. The analysis reveals a recommendation for developing a socially shaped adaptation technology.

1.3 Research General Questions and Objectives

The objective of this study is to contribute to adaptation science by exploring the on-going adaptation activities in the field of the farmers in Embu district and to analyse the modes of integrating current farmers' responses with scientific long term projection. Hypothetically this will facilitate adequate development and deployment of adaptation technologies designed to address impacts of climate change thus reduce vulnerability of the local community in Embu District, Kenya.

The objective is guided by three main questions firstly, *what are the perceptions of local farming communities to climate variability and change, and how does this influence their adaptation strategies?* This question is supported by five sub questions, how do the local farmers describe their own climatic conditions and experiences? Are they adapting? What are they adapting to and how? And what is the role of technology in the adaption process? The importance of this question in the adaptation theory is to investigate if there is any adaptation to climate change happening in the face of the farming community.

The second main question *what are the processes, synergies and divergences in the process of making TOA model?* This is an adaptation technology being developed by two research organisations based in Kenya, International Potato Centre (CIP) and Kenya Agriculture Research Institute (KARI) to address climate change. CIP is classified as an International Agricultural Research Centres (IARC) while KARI as a National Agricultural Research Systems (NARS). The two are the most prominent in the potato and sweet potato technologies in Kenya. This main question is supported by three sub questions, what is the stakeholder involvement and organisation during the technology development process? What are the potatoes and sweet potatoes practices used by the scientists to develop the technology? Finally, how different are these practices to performance of the farming practice.

Finally, the third question, *how can the individual farmer's adaptation options and strategies be integrated in the TOA model for effective development and deployment of anticipatory and public adaptation.* This is an integrating question that connects the analysis of question one and two. The aim is to bring both exogenous and endogenous decision variable as a common factor in shaping technology and influencing policy options.

1.4 The Tradeoff Analysis Model: -Adaptation technological tool

Tradeoff as a concept and a tool

The concept of tradeoffs is a basic principle in economics and derives from the idea that resources are scarce. The relationship between the resources can be in the form of competition and therefore tradeoffs. There can as well be a win-win outcome, but this as well comes at the expense of some other desired attributes. They show that to obtain more of one scare good, an individual or society collectively must give up some amount of another scarce good. This is fundamental to economists who refer to it as the principle of opportunity cost. Therefore for a given set of resources and technology, to obtain more of a desirable outcome of a system, less of another desirable outcome is obtained. (Stoorvogel et al 2004). According to Stoorvogel (2004), TOA model is not per se a model, it is a software package that is used by a team of scientists to integrate disciplinary data and models for Tradeoff Analysis. The CIP project leader referred to it as an "excel spread sheet".

Tradeoff Analysis for adaptation options

Tradeoff analysis has been used in exploring the economic potential for soil carbon sequestration in the Nioro region of Senegal's Peanut Basin. The study analysed the linkage between site-specific biophysical models and economic simulation models using the Tradeoff Analysis System. This was to simulate farmers' participation in soil carbon sequestration contracts. The results analysed an increase in quantities of carbon that could be sequestered in the soils of the region if farmers increased fertilizer use and incorporated crop residue. Other elements investigated were labour costs involved to incorporate crop residues, the value of crop residues, and the transaction costs of implementing carbon payment schemes. The researcher recommended need for better data on these variables and for an accurate assessment of the capabilities of local institutions to implement carbon contracts (Diagana et al 2007). Another form of "minimum-data" methodology was used by Lieven in Vihiga district, western Kenya. The purpose of the study was to assess the economic viability of adopting dual-purpose sweet potatoes in the region. This methodology integrated socio-economic and bio-physical data on farmers' land use allocation, production, input and output use. The results indicated that the local community could benefit economically from adopting dual-purpose sweet potato. The use of minimum-data methodology in this study also proved that analyzing specific adaptation strategies like crops can help determine which option will improve the livelihoods of smallholder farmers operating in mixed crop-livestock systems (Claessens et al 2009).

Tradeoff Analysis in the CIP/KARI adaptation Project

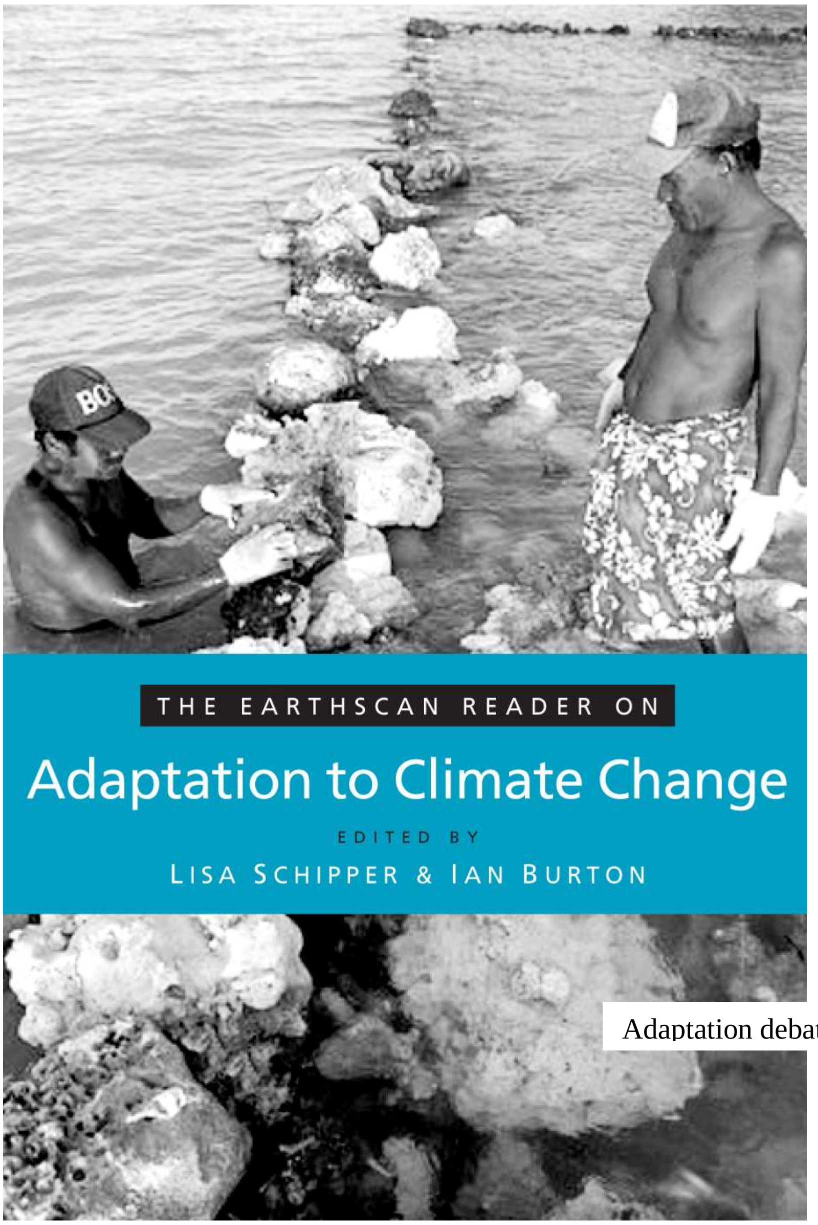
This study explores the process of making an adaptation technology by research organisations under the project title "*Participatory development and testing of strategies to reduce climate vulnerability of poor farm households in East Africa through innovations in potato and sweet potato technologies and enabling policies*" (CIP 2007). This project links the teams from the IARC and various NARS. CIP is the lead organisation with experimental projects in Kenya, Uganda and Ethiopia. In Kenya CIP is in collaboration with KARI. My focus is in Kenya, Embu district, Nembure and Runyenjes divisions.

There are three expected outputs from this project, (1) regionally-specific technology and policy strategies to reduce vulnerability of farm households to climate change; (2) enhanced national and international capacity to utilize new research methods for analyzing impacts of technologies and policies affecting farmers' adaptation to climate change; (3) identified policy impact pathways with assessed actual and expected policy changes (CIP 2007). The project activities aim at assessing the economic and environmental sustainability of technologies and policies. This is referred to as “modelling adaptation to climate change using the Tradeoff Analysis methodology” (CIP 2007). The research relies heavily on lessons learnt from previous studies in Kenya, Peru, Senegal and Uganda that proved reduction of farm household poverty and vulnerability to climate change if a few things were considered; farm size increased and household dependence on rain-fed agriculture reduced, through appropriate technology adoption and economic development policies; Improving system sustainability by increasing soil nutrients and organic matter and finally increasing crop and livestock resilience by improving their tolerance to drought and pest (CIP 2007).

The Kenyan field experiments are hosted by KARI-Kabete under the supervision of the director who is a soil scientist. The actual implementation is by a PhD student who is responsible of biophysical modelling, livestock modelling and climate downscaling. I conducted participatory observation at the student’s level where field experiments are being conducted. The scientific community in Kenya was composed of the CIP project leader, the director KARI-Kabete and a PhD student. I had an opportunity to interact with the three of them in their different capacities. In the field, farm experiments are laid out in four divisions of Embu District. Various potato and sweet potato planting strategies are being used and tested for yield, soil nutrient and moisture content.

The direct beneficiaries of this project are the scientists from the NARS and IARC and policy makers as they have access to the tool under development. It is expected that their participation will increase the capacity to utilize advanced research methods of analyzing climate vulnerability. Policy makers can apply the results of the model to develop specific adaptation strategies and policy options. The final beneficiaries are the farmers who will benefit from improved adaptation decision made (CIP 2007).

The development of the TOA model started with a participatory workshop process, where key stakeholders were invited. These were the scientists, farmers and government officers from the three countries and International scientists from Wageningen and Montana Universities. The vulnerability indicators and adaptation strategies were determined through group processes but are implemented based on country specific conditions (Sietz et al 2009). In Kenya experiments are conducted in farmers’ fields on cost sharing bases where there is an agreement on who contributes what. The scientist collects data in the field and modeling is done through the networking of the scientists involved. The recommendation after three year of the project will be used in policy formulation for effective adaptation strategies that will reduce the vulnerability of the local communities in Embu district (CIP1997).



Adaptation debates from scholars

UNFCCC

Adaptation science debates

Figure 1: Photographic representation of the research objective

CHAPTER 2: - ANALYTICAL FRAMEWORK

2.1 Methodology used in the study

This study is based on an interdisciplinary approach where the process of adaptation is observed between the local community and the scientific community. Among the local community, it is informed by local realities and everyday practices of the farmers. The concept of adaptation is viewed first from the broader angle of how the community is relating to climatic changes they have observed. Secondly at a household level where different decision making processes are involved and finally how the local farmer is integrating potatoes and sweet potatoes in the adaptation process. At the scientific community, the studies are informed by processes of developing the Tradeoff Analysis (TOA) model. In this process the technical and social-economic process of using potato & sweet potato as a source of data collection for feeding into the model is observed. The scientists utilize data that is quantitative in nature and can fit into the spread sheet model. This study integrates technical, social and economic aspects of these communities giving a qualitative description of how they are approaching adaptation. This could be easily filtered out due to its qualitative nature. The analytical framework adopted is technographic analysis embedded in the "social shaping of technology" (SST). This is an instrumental tool as it characterize human systems (technology, knowledge and skills), and the interaction with the relevant environment features, (topography, soils, rainfall, temperatures, flora and fauna).

2.1.1 Technographic analysis

Technography is categories as a realist methodology due to its ability to determine the causal mechanism in an object, unpacking the complexity in techniques (Richards & Vellema 2009). It is a body of practices and procedures to study the relationship between society and technology and was chosen to explore various actors and how they describe their techniques. How these techniques have been developed over time, and how they interact and combine with other elements. It addresses and describes details of the real circumstances as it unveils the performance of the technology and the observed object. This is importance in the study as it allows observation of techniques in the TOA as well as out of the box to the real world of the farmers where broader elements and general adaptation strategies are integrated through their livelihood practices. The four (4) dimensions of technography are used; materiality, modality, sodality and the task group.

Materiality, as used in technographic analysis helps define technology not in terms of tools alone but also in terms of other elements like skills and techniques that help humans to make things work. Climbing of trees and swimming vertically requires the bodily comportment of both skills and knowledge (Richards & Vellema 2009). The main material objects used by the scientists in their TOA experiments are the potatoes and sweet potatoes. They use their professional training to handle the crops as instruments of information. These two crops equally play a role in the livelihood of farmers in Embu district. The way the farmer interacts with them is based on their experience and practice. The element of materiality is therefore used to describe how the material objects is this study is linked with the social and the technical value of the different users.

Modality, was associated to the structure and organization of the local or universal church Richards and Vellma (2009) where knowledge was hidden in the parish. It goes beyond family relations to institutions that are bound either by kinship or locality. The element of modality in Embu district is quite visible in the language and the culture of the Aembu people. Adaptation to climate change among the Embu people is materialized in a variety of institutional modalities. These strategies and techniques will be discussed in chapter 4 where the internal dynamics of adaptation is integrated in the livelihoods strategies. A more focus in the use of the materiality identified will be discussed in chapter 5, in the TOA model development process as it fits in the local social reality.

Sodality as used in technography is a specific professional group of people who perform a specialized task (Richards & Vellema 2009). Skills are therefore important in defining them as they try to improve on material utilization. It is usually a non-localized group united by specific specialism or ethics which conforms to collective aim. The name in history of this professional group is “the guild” (Durkheim 1957 p. 17). The formal Roman guild group only fulfilled the utilitarian functions as they could only serve the material interest of the profession. They had exclusive rights and were like one family. The professional group from history share same ideas, interest, sentiments and occupations which the rest of the population does not have (Durkheim 1957). The scientific group is identified as sodality due to the clear protocols and procedures followed during experimental set up. These included rules, routines, and standardization. This was observed as participant observer in field experiments

Task group as a concept in technography is used to study small groups as units of analysis accomplishing a specific task. The group relates to the environment with its challenges as they perform the defined task. The group is organized to look at technologies and solve community problems (Richards & Vellema 2009). Two task groups were identified, the scientists’ group which was composed of the CIP project leader, scientists from IARC, NARS soil scientists and the PhD student with the task of developing an adaptation model. The second task group identified are the selected farmers that worked with the scientists. They were already in existence before the scientists invited them and were already engaged in different agriculture activities. The task of the farmers group was to test the various potato mulching strategies and indentify the one with the best results during this era of climate change. In the experiments, the organization and functioning of the group was observed as well as how the group interacts with the scientists. The experiments were laid in the farmers' farms and allowed the scientists to collect the data needed to feed the TOA development process. It is also a learning point for farmers and links local communities to research scientists who add facts to techniques. They understand global discussion on effects of climate change and downscale it to local levels.

This studies reviews the body of research that utilizes and addresses the "the social shaping of technology" (SST) MacKenzie and Wajcman, (1999). It examines the content of technology and the particular processes involved in the development. MacKenzie and Wajcman, (1999) in their introductory essay argued that technology is embedded in social organisation. He warned on the notion of "technology determinism", which assumes that technological change is independent; it shapes and impacts the society from outside. This notion is unsatisfactory because, in reality technologies follow some predetermined course of development, research and development decisions play a significant role (Hughie & Gareth 1992). The SST facilitates the opening of the 'black-box' of technology to allow the social-economic patterns embedded in both the content of technology and the particular processes involved in the development to be exposed and analysed (MacKenzie & Wajcman 1985).

2.2 Research design used in the study

2.2.1 Timeframe:

The data collection period was August 2009 – February 2010, a complete season to observe the main crops (maize, beans, and potatoes) planted and harvested. Potatoes and beans are harvested in December and January, while green maize based on variety is harvested green in February and dries in March and April. This period was selected to allow observation of the entire production season of the local farmers in Nembure and Runyenjes division.

2.2.2 Site selection:

The CIP/KARI climate change project is working in four divisions, out of which two were selected for this study. These are Nembure and Runyenjes. This was after a general tour and observation of the entire project area, and in consultation with the scientist (PhD student) doing the field implementation. The following justification was used; Runyenjes division hosts the only sweet potato experimental plot in the entire project. Nembure district was chosen on bases of own perception that there are a large number of sweet potatoes growers unlike the remaining division. "Own perception" as was based on field observations, and recommendation from the scientist but not on any statistical findings. In each division, two villages were selected and for logistic purpose they were close to each other. Rwangondu and Gachutheri in Nembure division are separated by a murram road, but they share common public facilities like hospital, shopping centre and schools. In Runyenjes division, Kiarangane and Kaveti-Kiarangane are divided by a tarmac road that joins Nairobi to Meru town. There is a history of both being under one village called Kiarangane; Kaveti was therefore born out of Kiarangane. Unfortunately the Kaveti villagers fear losing their initial identity, leaning to the former name referring to their village as Kiarangane-Kaveti.

Table 1: FGD and Household Interview Sites and Administrative Units

	Village	Sub-location	Location	Division
1.	Rwangondu	ENA- West	Githimu	Nembure
2.	Gacutheri	ENA- West	Githimu	Nembure
3.	Kiarangane	Njerure	Kieni North	Runyenjes
4.	Kaveti -Kiarangane	Njerure	Kieni North	Runyenjes

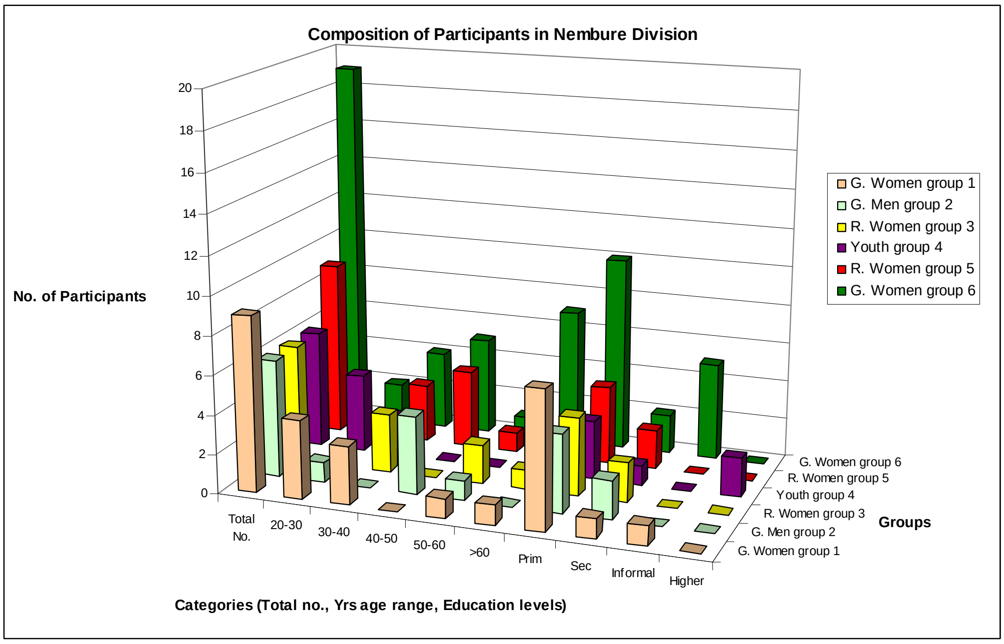
2.2.3 Focused Group Discussions (FGDs):

A total of twelve (12) Focused Group Discussions were held, six (6) per division with an average of two per village. The youth groups combined members from both villages. The average number of participants was 8, ranging from 5-19. The group with the minimum number of participants (5) was the men group in Kaveti village. The group with the highest representation (19) was the women group Gachutheri village. In total 100 farmers participated. The officer from the Ministry of Agriculture (MOA) was present in the respective meetings.

The points of discussion were guided by a set of key questions with sub questions and were referred to as a protocol that had four (4) tools (appendix 1). This protocol was developed based on the research proposal, literature review, and consultation with both the field and University supervisor. It was replicated in all the 12 groups. The first tool triggered the discussion on historical and current climatic information. It sought to find out how the local farmers understood the term and debates around climate change, how they defined their own local climate and what guided them in making agronomic decisions plus the role of weather forecast in the process. The second tool aimed at exploring the adaptation strategies the farmer was using to ensure agriculture remained a source of livelihood. The third tool looked at various agro-technologies the farming communities had access to and were utilising. This involved the changes in farming systems as well as hybrid crops from the research organisations. The last tool raised the debate on the role of potatoes and sweet potatoes as adaptation crops.

The guiding principles that were followed were; allowing the participants to move on with the discussion without over facilitation. The process was recorded allowing everything to be captured from the beginning of the discussion to the end. This procedure allowed writing of separate notes on the flip over as the participants interacted. Some probing questions were used like “why, who, when and how”. Participants were also encouraged to demonstrate their idea either by writing on the flip over or telling a story, or reiterating a previous discussion. All this information was typed and became the primary data of this research.

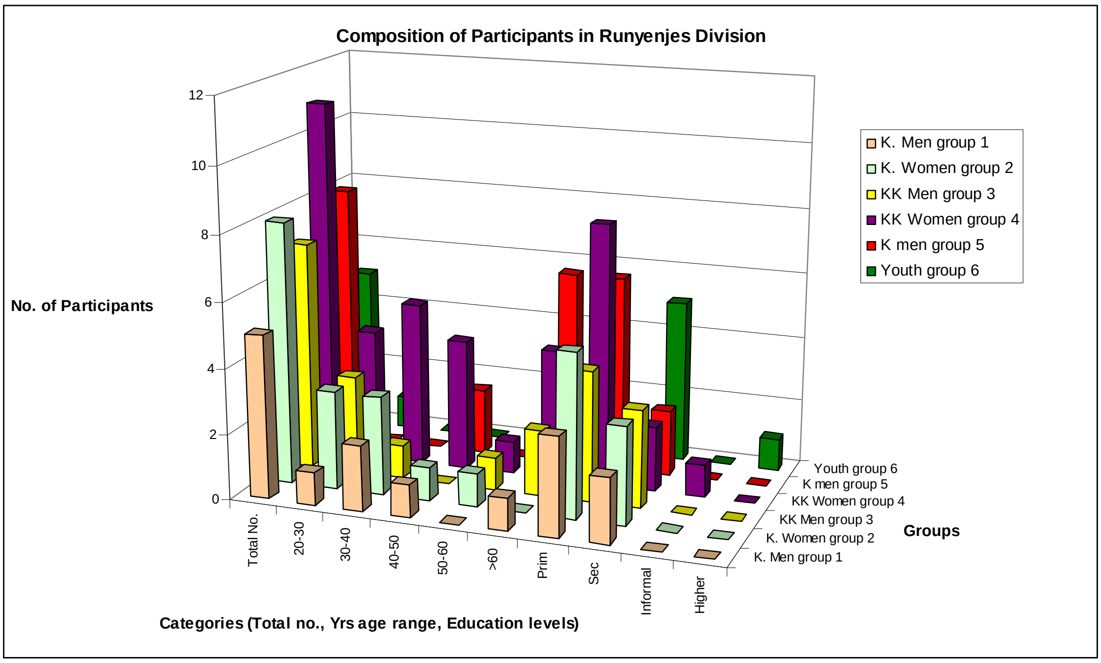
Graph 1: Composition of the 55 participants of the FDGs Nembure division



The group were numbed based on how they were carried out. Letter “G” stands for Gacutheri and “R” Rwangondu village. Youth members came from both villages. Women group 6 from Gachutheri village had the highest number of participants. The highest age bracket represented was 30-40 years with 27%, followed by range 40-50 (24%). 64% of the participants had only basic primary education, with only 4% with above secondary education.

Figure 2: A photo of the G. women group 6 during FGDs in Nembure division

Graph 2: Composition of 45 participants in Runyenjes Division



The group were equally numbered based on when they were conducted. Letter "K" stands for Kiarangane village while "KK" Kaveti-Kiarangane village. Youth members also came from both villages. Group 4 composed of women had the highest participants and came from Kaveti- Kiarangane village. The age group highly represented was above 60 years with 28%. The highest education level attained by 58% of participants was primary education. Unlike 20% participants in Nembure who had secondary education, Runyenjes division had 38%. Some participants from "KK" group 4 were participating in the CIP/ KARI project and therefore the concept of climate change was not new to them. They were already in the preparation stage for their first field experiments on potatoes and sweet potatoes. The FDGs took a period of three (3) weeks inclusive of preparation and appointments.

Figure 3: A photo of men group with MOA official in Runyenjes Division

2.2.4 *Formal household interviews:*

These were a follow-up of debates generated during the Focused Group Discussions. The list of names of the 100 participants formed the population upon which a sample of 42 respondents were randomly selected and successfully interviewed. Adjustment in the field was done where necessary, for example a case where the selected person had left the village, another one from the group list was selected. Of the 42 interviews, 19 came from Runyenjes and 23 from Nembure Division, village representation; Gachutheri 13, Kaveti –Kiarangane 12, Rwangondu 10 and finally Kiarangane 7.

The interviews were structured into four sections triggering specific discussions and answers (appendix 2). The first section asked general information on the main sources of livelihood income. The second part explored decisions that were made by the farmer at the onset of the planting season, October 2009. Section three looked at the harvesting period and experiences of the farmer in the outgoing season. The last section was zoomed into production of potatoes and sweet potatoes crops as crops within the farming practices. The interviews were all conducted by the researcher and took a time range of 2 – 2.5 hours.

2.2.5 *Participatory observation & Informal discussions:*

This is a type of observation, where a researcher takes part in the daily interactions and activity within a study situation. He/she is not merely a passive observer but an active participant (Yin 1984). This way the researcher learns the explicit and tactic aspects of the people’s lives, routine and culture (Kathleen & Billie 2002). While Focused Group Discussions and formal household interviews were used among the local communities, participatory observation was used within the scientific community. This was from August 2009 to February 2010. I assisted in research and outreach for the project under observation: “Participatory development and testing of strategies to reduce climate vulnerability of poor farm households in East Africa through innovations in potato and sweet potato technologies and enabling policies” (CIP 2007). This was in experiment layout, and data taking as well as represented CIP at scientific workshops and meetings. This methodology unlike the first two was not confined within the two districts of this thesis, but participated and assisted in all the experiments in the four divisions of the entire CIP/KARI project, but what has been used as data is only data from the two divisions.

2.2.6 *Language:*

Nembure and Runyenjes division is inhabited by the Aembu people and speak Kiembu language. They neighbor the Agikuyu, Ameru, Achuka and Akamba, all from the Bantu group. The researcher, originally from the Agikuyu community and with fluent Kamba language, was competent in both written and spoken Kiembu. The officers from the MOA were present in all the respective meetings and assisted in interpretation of terms that were unclear. The language used during the household interview used was Kiembu and for clarification Kiswahili, the national language was used.

2.2.7 Logistics:

During the FGDs two meeting were held per day, each taking a range of 2-3 hours. Men and women had different sittings venues. The location of the meeting was arranged by the contact farmer. For all the women meeting, the venue was at the compound of the inviting farmer. Men's meeting had centre meeting points like in a coffee bush, or outside the church, or under a common mango tree. Household interviews were conducted at individual farmer's homes. Some discussion led to farm visits where the farmer could explain for instance how and where the short rain season crops were planted in the farm. In the participatory observation within CIP/KARI project, we either travelled with the researcher from the station in Nairobi or we meet in the field. Our field visits were often duration of two weeks per visit. A total of 3 visits were done, this was during data collection, land preparation and planting and finally during harvesting.

2.2.8 Challenges:

The challenges encountered, were beyond control as were discovered later but they are worthy mentioning. Choosing of participants was left to the prerogative of the contact farmer, and the officer of the MOA. These were people often working with the officers or relatives and friends of the farmer. To overcome this, household interviews were randomly selected and tried to stick to the selection with out being influenced by the contact farmers. Touring the village during the household interview needed a contact farmer to show around and reintroduce the researcher. Due to the sensitivity of the issues being discussed, the farmers could not be open and the contact farmer could help answer questions. Upon realising this, the contact farmer work was reduced to drawing the map, and the researcher could trace the route.

2.3 Background of the study area Embu District, Kenya

2.3.1 Characteristic of the study area

The study area was composed of two divisions, Nembure and Runyenjes both of Embu district (figure 4). Embu district is an administrative region lying in the south of the Eastern Province of Kenya. It lies at the southeastern slopes of Mount Kenya and bordered by Mbeere district to the East, Kirinyaga district to the West and Meru South district to the North. It has two political constituencies Manyatta and Runyenjes, represented by two Members of Parliament. It has five (5) administrative divisions namely, Central, Kyeni, Manyatta, Nembure and Runyenjes, figure 4. These divisions are divided into location, sub-location and villages. Its difference in altitudinal gradient along the slopes of Mount Kenya results in diverse agro-ecological zones from the upper to the lower zones. The district illustrates a typical agro-ecological profile of the windward side of Mount Kenya, from the cold, wet high altitude zone near Mount Kenya (UM1) to middle altitude UM 4, figure 5 with different agricultural systems from the upper to the lower zones table 2.

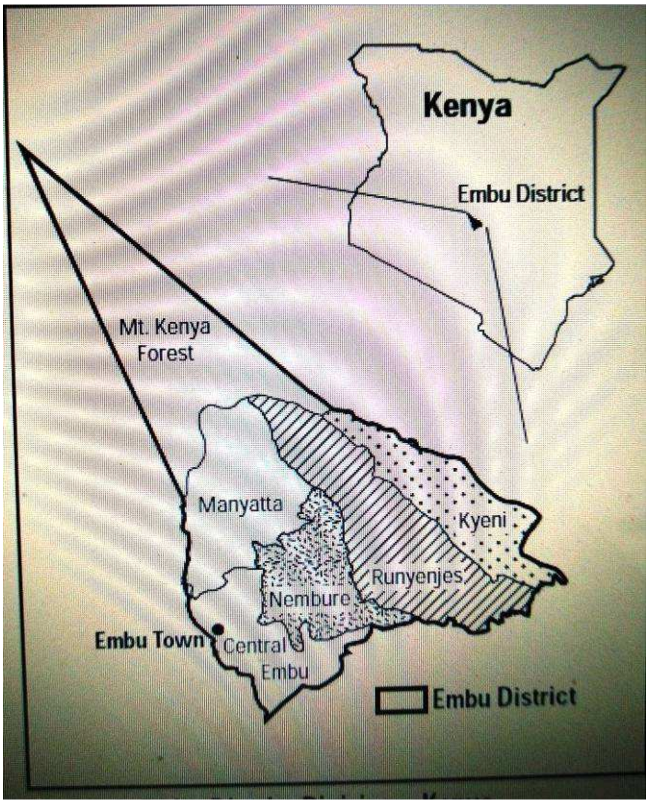
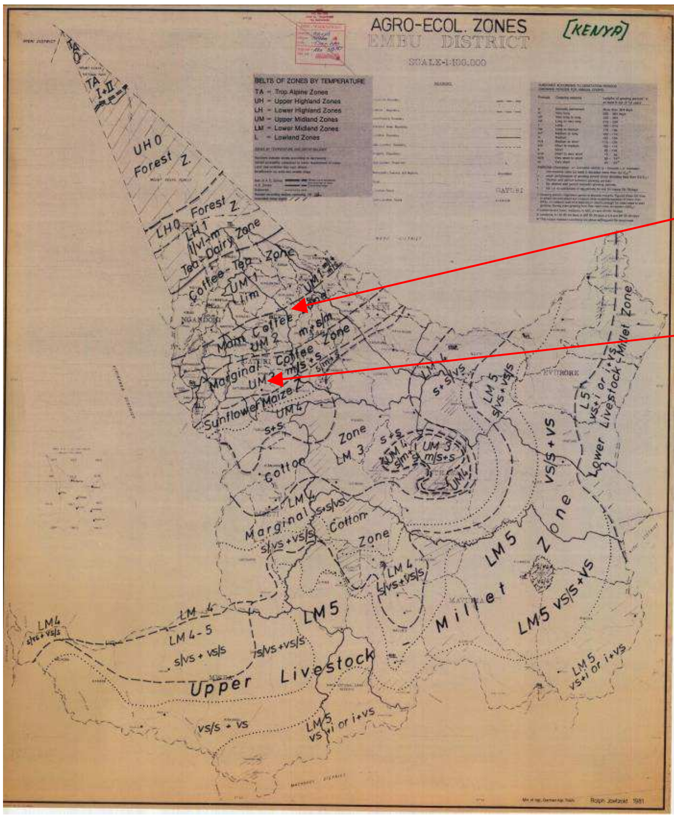


Figure 4: Map of Embu District, in Kenya

The elevation between 1500m and 4500m a.s.l, covers parts of Manyatta, Kyeni and Runyenjes divisions with agro-ecological zone (AGZ) LH1, UM1. The midlands' altitude, ranges between 1000m to about 1500m a.s.l. and covers most of Nembure and Central divisions with AGZ UM2+3+4. Average annual rainfall pattern is bimodal with two seasons, long rains in March- April and short rains October –November. It increases with increase in altitude from 1000 to 2000mm (Ouma et al 2002). Farms in Embu district are well defined and approximately 2-5 acres. Soils are fertile and well drained. Population density averages 472 persons per km^2 (Table 3) (Central Bureau of Statistics. 2001)..

Figure 5 and Table 2: Land use in the different Agro-ecological zone along Embu-Mbeere transect (Gachimbi 2002)



TA0	Snow
TA I-III	Natural Vegetation
UH0	Forest
LH1	Tea and Diary
UM1	Coffee/Tea zone
UM2	Main coffee zone
UM3	Marginal coffee zone
UM4	Sunflower and Maize
LM1-5	Mbeere District

UM1 Runyenjes and UM3 Nembure was the study areas of this thesis

Table 3: Administrative division and population, Embu District, Kenya

Division	Total population	Households (no.)	Area (km2)	Population Density Persons/km2)
Central	52,466	14,726	70.6	743
Kyeni	48,385	10,441	104.9	461
Manyatta	71,332	15,523	197.1	666
Nembure	41,590	8,976	88.1	472
Runyenjes	64,111	13,981	149.0	432
Mt Kenya Forest	332	246	210.2	2
Total	**278,216**	**63,893**	**819.0**	**456†**

Source: Central Bureau of Statistics (2001)
Note: †Excluding Mount Kenya Forest

2.3.2 Characteristic of the potato and sweet potato production in Kenya

Potato production in Kenya

Potato (*Solanum tuberosum*) originated in the highlands of South America and was introduced in Kenya by the British farmers and colonial officials in the 1880s (Waithaka 1976). The colonial government encouraged its cultivation during the First World War as a means to feed troops stationed in East Africa. However African farmers in Kenya, especially at the Rift Valley province began planting potato after the end of WWI mainly for domestic use (Crissman 1989). Seed imports for research purposes and formal variety trials date from this period (Waithaka 1976). By the end of WWII, its cultivation had spread to other areas like Kiambu, Muranga, Nyeri, Elburgon, and Meru Districts (Crissman 1989). These are the original districts and covered a large geographical area, today these districts have been subdivided into smaller districts. Currently the main potato production areas are within the tropical highlands zones, with altitude range of 1200 – 2700 m a.s.l. The mean annual rainfall of 1000mm or greater is experienced in these regions (Kimego 1985). These are lands which straddle the Rift valley, surrounds Mt. Kenya and the Aberdare ranges.

Kenya is the eighth most producer of potato in Africa, with an output of 800,000 tonnes in 2007 (FAO 2008). It ranked as the country's second most important food crop after maize (Ministry of Agriculture. 2007). It is an important food and cash crop in the medium and high rainfall areas where it is grown mainly by small scale women farmers (FAO 2008; Kiiya et al 2006). Some large scale growers produce for commercial purposes (FAO 2008). Over the past 30 years, its production has grown in importance as a stable crop as well as a source of farmers' income (FAO 2008). In the drier parts of the country potatoes and beans are often grown during the short rain season when maize will normally do poorly (Kiiya et al 2006). Potatoes are therefore eaten with beans in most poor rural households during this dry period just before the maize crop is planted and matures in the long rains season (Kiiya et al 2006).

The major constraint to potato production in the Kenya highlands is the rapid decline in soil fertility as a result of continuous cultivation without adequate replenishment of mined nutrients (Kiiya et al 2006). Inadequate supply of certified seeds, as farmers depend heavily on informal seed sources (farm-saved, local markets or neighbours or self-supply) (Kaguongo et al 2008).

Irish potatoes although not the number one crop in the country, It has potential upon improvement for increased production to contribute to the national objective of reducing the vulnerability of farmers as a result of climate change.

Sweet Potato production in Kenya

The origin of sweetpotato, (*Ipomoea batatas)* is believed to be semi-humid regions of Central America, either in or close to Nicaragua. The crop reached the tropical highlands of Eastern Africa in the mid-19th century. Currently sweetpotato is grown in African highlands up to 2200m.a.s.l. with night temperatures close to 5°C (Andrade et al 2009). In Kenya it is an important traditional root crop and its production is concentrated in Western and Nyanza Province 63%, others are Coast Province 30% and 5% in the Eastern Province (FAO 1998; Shakoor et al 1988).

It is grown primarily by small holder farmers either as monocropped patches or intercropped with like maize, or under shade of perennial crops (Mutuura 1992). It is an important food security crop when maize is in short supply or in years of drought (Mutuura 1992). Sweetpotato planting material is often traditionally obtained from previous crops or from other local farmers (Andrade et al 2009). It is a popular food crop, and consumed when boiled or roasted as snack with tea, vine are fed to animals (KARI 1999). Current research and activities are promoting Orange-fleshed sweet potato whose flour is a nutritious food to combat Vitamin A deficiency (VAD) high in beta carotene and source of income (KARI 1999). Other focus of research in KARI and CIP is to produce cultivars which have a high root yield and dry matter content and resistance to diseases and pests.

2.4 Expected climate change projections in Kenya

2.4.1 Recent climate variability and impacts

A report submitted by Stockholm Environment Institute (SEI 2009) in advance of COP 15 reported that Kenya has been experiencing severe climatic variability which has caused major socio-economic impact not only among the local communities but also to the entire country. Recent documented droughts occurred in 1998-2000, 2004/05 and in and in the year 2009. Major floods occurred in 1997/98 and 2006. These severally affected food security in the country, as in the agricultural and environmental sector; it caused loss of crops and livestock, forest fires, and damage to fisheries. Other areas affected were reduced hydro-power generation, reduced industrial production and reduced water supply.

Temperature and Precipitation

The mean annual temperature has been increasing by 1.0°C since 1960 (McSweeney 2008). According to McSweeney 2008, this is an average rate of 0.21°C per decade. He did not observe any statistically significant trend in the rainfall patterns in Kenya, but he reported a proportion increase of rainfall occurring in the long rain period.

2.4.2 Future climate change projections

Temperature

The projections using Global Circulation Models (GCM) indicate future increases in mean annual temperature by 1.0 to 2.8°C by 2060s, and 1.3 to 4.5°C by 2090s (McSweeney 2008). Studies conducted by Stockholm Environment Institute (SEI 2009) using nine GCM models confirms McSweeney finding of increases in mean annual temperature in future years. They reported a rise of almost 1º by 2030 and around 1.5º by 2050 for a mid-range emission scenario but the range of increase in temperature across the different models is wider with projections from 1 to 3.5 ºC by 2050s (SEI 2009).

Precipitation

The different results of models used by SEI (2009) concluded that the future rainfall scenarios are very uncertain as they vary with seasons and regions. Some SEI (2009) models showed a wide variation in relation to average annual rainfall, where the mean rainfall is an indication of increase in annual rainfall (McSweeney 2008). Some showed reduction in rainfall in some seasons while annual rainfall and trend did not change. Some indicated a shift in the timing of seasons, Some models project average increase of rainfall, while others project reduction in rainfall in some months for some regions in Kenya (SEI 2009).

Extreme events: drought and floods

Future projections on these two extreme events in Kenya vary widely (SEI 2009). Some models project an intensification of heavy rainfall during the wet season in some regions, resulting to flood risks; others project the continuation of drought periods with more variations, while some indicate reduction is severity of both events (SEI 2009). SEI conclusion in the study was "…***climate is changing already and the ...the climate of 2030 (and beyond) is very unlikely to be the same as at present"*** (SEI 2009 P. 4)**.**

2.4.3 Climate change effects on Agriculture

Climate change has serious consequences on agriculture which is the mainstay of Kenyan economy. Most of the Kenyan population in the rural areas depend on rain-fed agriculture. This makes it a climate sensitive sector and will be affected by climate change, both positively or negatively (SEI 2009). Positively as the higher temperatures could potentially have a direct CO_2 fertilisation effect (SEI 2009). According to Mati (2000) the increase in temperatures during the short rain period which is more reliable for food production will adversely affect long season crops like maize which is a staple crop in Kenya. "Maize is the dominant crop in Kenya and is a major household staple" (Abigail Amissah-Arthur 2002).

CHAPTER 3: - CLIMATE CHANGE AND VARIABILITY, FARMERS' PERSPECTIVES

The objective of this chapter is to explore the experiences of local farmers as they relate to their own local climate phenomenon. This is an attempt to shift from the idea that farmers are coping to the usual natural climate variability to they are adapting to an experienced local micro climate change. The climatic information from this discussion establishes a foundation for this argument, that indeed some adaptation mechanism is already ongoing at the playing ground of the farmers. Different scholars view current farmers action different, Adger (2005) views the actions as reactive adaptation while Hug and Reid (2009) referred to it as adaptation to naturally occurring climate variability. In my opinion this judgment is not local specific and could face the challenge of wide spatial generalization. The paradigm shift proposed involves reassessing the phenomenon of climate change based on narrow spatial and social scale and the responses taken at this level. This thesis analyzes climate change as viewed by Embu people living in Embu district, at the wind ward side of Mount Kenya. It identifies adaptation responses by the local people for whatever climate change they believe has occurred. The responses are individual, and rely on the person's plans and decisions.

The methodology used included Focused Group Discussions where a total of 100 farmers participated and 42 household interviews. It answered the first question of this research which sought to analyse the perceptions of the farming communities to climate change and variability and how the changes influenced their adaptation strategies. Three steps were used. The first one was to find out if the farmers followed the current debates on climate change. Secondly how they identify their own weather and forecast it and finally the importance of meteorological weather forecast in their farming practice. The second step identified farmers' perception to climate change and three elements were identified, indicators, causes, and impact. The final step sought to find out actions taken by the farmers in response to the observed and experienced climate change. This identified adaptation strategies which being the core of the thesis, more details were gathered during household interviews and form the focal point of chapter 4.

3.1 First step: Preliminary debates

3.1.1 Climate change as debated by the locals

The awareness of the term "climate change" varied among the different focused groups. In three of the women groups it was a new word. In all the men and the youth groups they had heard the term mostly through the radios. This made a 75% awareness of the term climate change among the local community. The radio programs were on weather forecast, agricultural related programs which advised farmers on planting strategies like early planting and variety selections, discussions on current food shortages in the country, associated with the three consecutive drought seasons, political debates on the destruction of forests like the Mau forest and the effects of exogenous trees like the eucalyptus trees on the water tables and the environment. Some members of the youth had learnt the term in school and followed television and newspapers discussion and they described it as a result of global warming.

Local interpretation

There is currently no direct translation of the term "climate change" in kiembu language. Farmers talk about "*kushejia kwa riera*", this directly translates to "changes in weather" "*riera*" refers also to air, and could be confused to mean "changes in air". Although the term climate change was new to some groups, in their local terms, it was an often discussion among local communities. The main focus was on temperature and precipitation and the influence they have on their farming practices. Temperatures in relation to drought and heat, and precipitation in relation to rainfall amount, its duration and onset. Local discussion on climate change is triggered by farmers' own experience, observations and from information networks, like farmers' agriculture day, radio, development groups' seminar, and churches.

The perspective of farmers is that "local climate has changed". They disagree with the notion that climate change is a phenomenon to come in the future. Their worry is on the magnitude of the expected changes and preparation strategies to overcome it.

3.1.2 Local climatic conditions as known by the farmer community

There are two rainy seasons, long and short rains. The long rains starting from March to April and was historically referred to as "*mbura ya njahi*" (dolichos rain). The name changed after farmers gradually stopped planting dolichos. The new name, still in use is "*mbura ya mbembe*" (maize rain). This referred to the maize planting season which took over dolichos season. It also referred to the long hail storm rains which was associated with little ball like ice material referred to by the local as "maize". The short rains of October to November was referred to as "*Mbura ya mwere*" (millet rainfall). This was associated with the planting of millet which required short rains as it is a short seasoned crop. This term is now not used as maize is planted in both seasons.

June to July was often a foggy a very cold season in the Kenyan highlands. It is usually described as "the highland winter". This was more pronounced in regions near the mountain than in the lowlands. The rest of the months, January, February, August and September were often hot seasons. The next step was to find out how the locals forecast their weather and if the method used are reliable and if still use.

3.1.3 Farmers' responses to seasonal climate forecasting

This sub topic helps explain the challenges experienced with large spatial scale climate information at the local micro level. It compares the modern science metrological weather forecasting to local knowledge weather forecasting. It is a narrow tool to break down the limitation bound to happen if the concept of climate change is debated at high levels in terms of large spatial temporal and social scales. It brings in the importance viewing climate change and adaptation options in narrow spatial, temporal and social scales.

Local knowledge (IK) of climate forecast,

This study discovered that the farmers have access to and combine both local methods of weather prediction with meteorological forecasting. Their interpretation was however skeptical towards modern science, which they claimed did not give accurate seasonal climate forecasts. 80% of the farmers interviewed use local knowledge to predict the onset of rainand when to perform important agricultural activities like planting. This happens however with the information from the meteorological department behind their mind. This local knowledge is often vested upon animals and plants whose existence is challenged by current human activities as well as climate change. These two ways of predicting weather conditions therefore need to complement each other with the increased challenges of climate change.

This subsection explores how the farmers forecast rainfall patterns which are the most importance weather element in their agricultural practices. They rely on observation and interpretation of specific phenomena that exists at the surrounding of the local people (Roncoli et al 2002). It includes the moon, trees, dragon flies, wind and birds. The discussion will give the local name, how it is used or what is observed, what it predicts, its reliability and if still in use in the face of climate change.

The shape and behavior of the moon

It is a reliable indicator of the onset of rainfall and how the season will be. It was mentioned and discussed by 42% of the FGDs. It was often brought up by the aged men and women.

Description of the moon and its importance

The day the moon appears from the west direction, in the month of September it rains. This rainfall is said to be washing the moon. The importance of this indicator is that; if it does not rain on that day, the onset of rainfall in both seasons' shifts from 15th March and 15th October to 25th March and 25th October. If it rains and continues as the moon moves to the east, the rain for the season will increase in amount and in duration. If it rained and stopped before the moon reached the east, the season will have reduced amount of rainfall and not enough for the growth of the crops. The appearance of the full moon in the east, 15 days after its appearance in the west means the rains are in a short range and farmers can start planting.

The shape of the moon as it appears in the west is crescent. Gertrude Giciku, 55, demonstrated the shape of the moon and the meaning. The region facing the inside part of the crescent is believed to expect good rains, and therefore the harvest. The region which the back of the crescent is facing is expected to have low rainfall and famine and starvation can befall the region. Short seasoned crops are recommended. If it is full moon, or "U" shaped bumper harvest is expected for the entire country.

Figure 6: photo of a farmer showing shapes of the moon

Juanina Ruguru, 90, gave an example of a dialogue she had with her son during the long rains of 2009. *"I told my son, this season we are going to go hungry, my son asked, "mama why", look at the shape of the moon"* she said. That season according to her very few people harvested. Testing this spectacular observation, the focused groups agreed to observe the moon in the month of September. They confirmed that it was "U" shaped. This meant the entire country could have bumper harvest. During the household interviews conducted in February 2010, after the short rains, all the respondents (100%) were happy with the yields. It was also announced in many media houses of bumper harvest all over the country.

Curious of the source of this knowledge among the local, I asked Juanina in an informal discussion where she had learnt from. She explained that in the older days, farmers could distinguish the two seasons mentioned above very well, the long rains (*mbura ya njahi*) and the short rains (*mbura ya mwere*). For confirmation the local people then used to observe the moon. Repeated observation confirmed to them that during the short rains the back of the curve could be facing the people and could therefore plant millet. When the inner part of the curve was facing them, they knew it was the season to plant dolichos or maize as the rains are heavy.

Table 4: Summary of how the moon is as an indicator of rainfall seasons

Indicator	Description	Observations & actions
Rain at the appearance of the moon in the west	If rains only that day	expected rainfall dates remain 15th March and 15th October,
	If it does not rain on that day	Onset of rains shifts from 15th to 25th of March and same with October
Does this rain continue for 15days	If Yes	The rain in the season will be a lot in amount and duration
	If No:- stops	The rainfall will be short
Full moon appearance in the east after 15 days from appearance in the west.	When appear in the east as full moon	Rains are near and farmers can start to plant
Crescent appearance	Side facing the inside part	Good rains and high yields
	Side facing outer part of the crescent	Low rainfall, low yields

Behavior of Indigenous trees

Mivuti (*Erythrina abyssinica)* is local tree that blossoms with red flowers. It was mentioned by all the groups and declared an important and reliable method of predicting the onset of rain. It produces and blossoms twice in a year with red flowers as the key observable indicator. It is therefore used in both seasons to predict the onset of rainfall.

Description and importance

The shedding of the leaves starts during the dry period as well as flowering. When all the leaves are shed, and it is fully and brightly blossomed, the onset of rainfall is at medium range. When the flowers start dropping down it is an indicator that the rains will start in a short time, 1-2 weeks and farmers start dry planting. In some groups they mentioned that when the tree drops its seed it rains within a day.

Figure 7: A photo of muvuti in the mid of other trees, taken in September

Other trees with almost similar characteristics are "*mugomo", muringa*", and "*mutondo*". The challenge befalling this indicator is that many have been cut down, and only traces remain in different farms.

Miembe (Mangifera indica L.) are traditional mango trees. They are a reliable indicator of the onset of rain and how the rainfall season will be.

Description and importance

Flowering of mango trees starts in September, this is an indication of medium range, mainly 2-3 week to the onset of rain. As the infant fruits starts to appear the rainfall is at a very close range, and it can rain within a week. Farmers associate the rain with dropping of the infant fruits.

The blossoming of the mango trees is also an indication of how the season will be. This is based on the interpretation of how much yield is expected. If it blossomed a lot and high yields are expected, the production of other food crops is expected to be low as the rainfall amount will be low. In such a season, mangoes are said to be a natural way of providing food security to the people.

***The presence of dragon flies* (*miyeri*),**

These are type of insects which appears in the regions just before the onset of rain. There were mentioned by 83% of the focused groups. Their reliability is currently challenged due to changes in climatic conditions. They have reduced from huge swam to some unnoticeable sizes. They also occasionally come late, after the onset of rain and therefore not useful.

Description and importance

The presence of the flies is an indicator of the onset of short rains in October. They appear twice in a season. The first appearance in the month of September, they fly from the east, indicated by the sun set, or low lands "*weru*" going to the west, or to the mountain. They fly high, fast and calm. Farmers interpret this as "flies are going to get the rain". At this stage the onset of rainfall is still far and farmer start to plough their land.

Two weeks after their first presence, they come back from the west going to the east. They fly low and in a particular noticeable pattern. They touch the ground and then fly up again. Farmers interpret this as a message to cover their seeds in the soil; others say it is too heavy to fly due to the rain it is carrying. The rains come 1- 2 weeks after the flies have disappeared. The second presence is an indicator that planting can start.

Wind

The swirling wind is known by communities around Mt Kenya as "*ndoma sya aka*" (devils of women), they are winds that spin at phenomenal speeds usually over the land with no vegetative cover and they draw up dust and light debris, (dry leaves and papers). This was said by all the six focused groups. Although the wind is considered dangerous as they cause soil erosion and damage roofs of houses, they are also viewed as important in clearing land for planting. They usually come during the day and if they increase in frequency the rains are about and dry planting is done.

Strong winds were considered a very reliable method although only mentioned by 17% of the Focused Group Discussions. They blow from the mountains to the low lands. When they change the direction they were coming from, blowing from the low lands to the mountains, it starts to rain in less than 3 days. Unlike the swirling wind, these winds comes at night, making it difficult to stay outside, the bananas plants fall as well as the leaves and branches of trees, and the rains can come any time.

Sighting special birds

The sight of the swift birds (*thungururu)* is an indication of rainfall in less than two days and beginning of planting time. It used to be reliable, but not currently in use, as the birds have disappeared with the decreased flowering trees. They are said to be looking for mud to construct their houses. Making of noise by "ma*kanda njuki*" birds, bees predatory as the name suggest and are found in the flowered trees is a sign of onset of rain. The English name of these birds was not identified.

Others

Seasonal dates where farmers know when to expect the rains based on calendar seasons. This is very unreliable due to the current climatic changes. The *morning dew* meant the rains are quite near, the *mating period of frogs* as they croaked a lot at the river banks. The smell of the soil or of the rain "it smells like the dry soils if water is poured on it". Increase in temperatures at night. Safari ants and termites (*thua*) once they come out from the hiding place is an indication of the rains are about to come.

Modern science/meteorological weather forecast: perception of farmers

The research noted that farmers have access to modern science of predicting climate forecast, however many rely on local knowledge to make decisions on agricultural activities like planting. The broadcasting of radios in local languages allows the farmers to follow discussions and debates on climatic conditions clearly. Farmers are however skeptical about the information given especially in relation to precipitation. For example they narrate the information they received during the short rains of 1997. They explained that a low rainfall season had been communicated to them and that is what they expected. The short rains came as expected but did not end at the expected month. It continued in January, February and joined the March long rains of 1998 and turned out to be El Niño as was announced later.

During the period under this study (October 2009– February 2010), farmers explained during the FGDs that the information they received was that; it was going to be an El Niño season. Farmers knew that this was going to start in the month of October. During the household interview 95% of the respondent knew the season was forecasted to be El Niño. In conducting household interviews farmers were asked the preparation and decision they made in regard to the El Niño projections. In Nembure division, 52% of the respondent used the information in making planting decisions, while only 33% in Runyenjes used it. From the 1997 El Niño experience, they prepared themselves by digging terraces, keeping stock of firewood in the house and some purchased and planted long seasoned crop varieties like the hybrid maize variety 6 series and reducing the amount of beans planted as they are known to be destroyed by long rains. For those who did not use the information (Nembure 48%, Runyenjes 67%) claimed uncertainty, and mistrust of the information. Another element however affected majority of the farmers' decisions was the MOA responding to the country food insecurity and anticipating long rain gave the farmers hybrid maize variety 513.

Identifying the gap of the practice of science using meteorological weather information

Farmers describe the 1997 El Niño as "total confusion". They were not prepared in advance; they therefore planted without this consideration. The consequences were that many of their crops got spoilt, due to wet harvesting. Harvesting and second planting took place the same time, again without clear information of how long the rains were to continue. They attributed this confusion to lack of precise and accurate information given by the weather forecast.

In the 2009 El Niño projection the farmers again expected it to be like the experienced one in 1997. According to them, they experienced the short rains as usual which had a break of three weeks that gave them a panic. Unlike the usual short rains that end in December this ended in January. In terms of duration it was longer than usual but not as heavy as expected and they did not consider it as El Niño. They however acknowledged the presence of El Niño in some part of the country based on flooding information they received through the media. According to them, the meteorological department had once again failed to give them accurate local specific information on their local weather forecast.

3.2 Second step: Perception of the local community on local climate change

The second step identified farmers' perception to climate change using four elements, indicators of climate change, causes, impact and actions taken.

3.2.1 Indicator of climate changes

Indicators of climate change are based on the increased climate variability that the farmers have observed over the past years. The three main anomalies mentioned are precipitation, temperatures and foggy season.

Changes in rainfall patterns

Through the extensive discussions during the FGDs, the farmers explained how changes in rainfall patterns had taken place. These changes were mentioned as the key indicators of climate change by the twelve groups. The changes listed were; changes in the usual onset of seasonal rainfall, reduction of long rains and increase of short rains, a general decline in rainfall amount, reduced offseason rain showers, and finally unpredictable rain pattern.

Changes in the onset seasonal rainfall,

The farmers explained that they had always known when the long rain and the short rains start. This was 15th of March and 15th of October respectively. Any change to these dates was a delay of 10 days and the rains could start on the 25th of the month. The current onset of rain can either be too early or too late. In the year 2009 for example, rainfall started in January. There was a lot of confusion in the season as was explained by the farmers. They planted thinking it was the onset of long rains, but it failed seedlings withered and dried. It resumed again in March, and farmers' replanted again for the second time and the rains failed. The April rainfall when farmers replanted for the third time was considered better of. However many had given up and no much investment in terms of seeds and fertiliser was used.

Reduction of long rains and increase of short rains

The distinction between the old known long rains and current short rains is blurring. Farmers explained that the old categories of long rain based on high magnitude and its duration and short rains in terms of reduced magnitude and short duration had changed. This had confused the traditional way of naming the season and changed their farming practice. For example maize is grown in both seasons and millet is no longer a main crop planted in the region. Planting of maize in both seasons is a risk adaptation mechanism as they never know which season it will do well. Giving the above example of the 2009 long rains, could not be compared with short rains of the same season. Short rains started in October and ended in January a very unusual scenario, and farmers expected good maize harvest.

A general decline in rainfall magnitude

Farmers expressed their observation that there is a general reduction in rainfall. They gave an example of the long rains which could be continuous rain for 3 months, March, April and May. This could easily join in with June, and July the cold foggy season. This has however changed and farmers are adapting to this reduction. The long rains were also associated with river Kamburu, which was very dangerous to cross during the season as it could get full; break the river banks, and carry the bridge. The last time it happened was during the 1997 El Niño. The long rains currently experienced do not fill this river, and reduces very fast after the rains. During the dry season, the river could be used as a local swimming place for boys. This has ceased due to reduced level of water in the river.

Reduced offseason rain showers

July been a cold season, it could end with 8 days of rain before the August dry period. This was helpful to crops planted in foggy season, boosting them to withstand the dry period. In September again two days of heavy showers was experienced after every harvest season especially beans. This was mentioned by four groups. This was in the months of February and September. There are the same showers associated with the shooting of the moon, as discussed above. The showers were referred to as "*mavuria matongi*", translated as rain to put off bush fire. The fires were set to burn the beans stover, and clear the land in preparation for the re-germination of pasture. Smoke from different farms was visible and the rains could put them off. These showers were equally beneficial to the seedlings planted during the June – July foggy period and could endure till the short rains of October. The rainfall showers are not reliable any more as they either does not rain as expected or rain with reduced amount.

The foggy period "Highland winter"

The months of June- July are cold and foggy periods in the Kenyan highlands. The locals referred to this period as "*gathano*" others referred to it as the winter of the Kenyan highlands. In the regions observed, little showers of rain and foggy conditions could limit visibility. For example the locals could not see Mount Kenya from a distance. This period has changed to being, cold, dry and the visibility of the mountain is clear even in the morning, before the sunset. The local community could use the showers to plant long seasoned maize crop, and sweet potatoes. The last foggy season experienced was in the year 2006. Farmers claim that since then things have changed. In the month of September, historically maize crop could be in the farm, awaiting green harvest in December. The FGDs were held in September, the farmers showed their frustrations while discussing this point. They expressed that there was no maize in the farm since they had not even planted. This has changed their farming practice as they no longer plant maize or the sweet potato in this season.

Increased temperature

Farmers noted that temperatures had been increasing over the years and complained of very hot seasons. They used examples of drying trees which to them is an indication that the trees are affected by the high temperatures with reduced rainfall. Rivers are drying up very fast even after heavy downpour, this is due to high evaporation rates. The soils are bare and hot, making even walking without shoes very difficult. They however associated this with the cutting down of trees which could provide the shade, and regulate the hot air.

3.2.2 Farmers perception on causes of climate change

The global climate change is associated with both natural and human induced activities. The local community however discussed the causes of local climate change as a result of local human activities. Four main causes were identified; cutting down of trees, cultivation along the river banks and wetlands, increased population pressure on land, and industrialization.

The cutting down of indigenous trees and planting of exogenous trees

The cutting down of trees was in reference to the indigenous trees. These are *mivuti, migumo, mikuu, miiria, mitondo, and miringa.* These were trees often found at the water catchment areas. In their place, exotic trees have been planted especially the grevillea and eucalyptus. Paul Njiru, 82, viewed the cause of climate as the destruction of the wilderness forests (*ititu*), the wilderness conservation efforts based on pristine wilderness (Kalamandeen 2007). The forests were preserved under spiritual ethics and were viewed as sacred and homes of their god (*mwene nyanga*). The Embu community had 5 shrines that were believed to trap the moving clouds which could bring in rain. This form of conservation did not allow utilisation of forest products, game and grazing. Breaking this rules resulted to sacrifice of a goat to cleanse the sins caused to the forest.

Modernisation and land demarcation allowed allocation of the forests to individuals and private investors. This resulted to over exploitation of the forest resources as well as its conversion to school playing ground and agricultural land. Christian religion and new beliefs left the taboos ideology which was viewed as traditional and demonic. Fear of the god and sacrifices became things of the past and exploitation was with no spiritual connection.

Deforestation is not the problem. The farmers view their region as having many trees everywhere than was there previously. It was possible for example to see landscapes positioned very far. This was because the indigenous trees were positioned only on strategic places, at the slopes, near the rivers, water swamps and springs. The new tenure and land ownership made individual farmers to plant the exotic trees to act as farm boundaries and for timber and firewood production due to their early maturing. The eucalyptus whose local name is "*munyua mai*" (drinker of water) was referred to as the "wrong" tree for the region and the main cause of climate change. This is due to the effect the farmers have observed in the area they are planted. For example, drying of rivers, the area 30m around the tree becomes very unproductive and reduced water table of boreholes.

The purpose of their introduction in the region as the farmers explain was to reclaim swamps and wetlands, and they were planted in specific areas. They are now planted every where and increased tremendously in number due to their high economic value to the individual farmer. They have however increased vulnerability of the community as the roots have no boundary.

The over exploitation of the wetlands and irrigation along the river banks

This was seen as a cause to climate change as it is drying the wetlands and the rivers. The increased cultivation in the wetlands and irrigation plots near the rivers and streams is seen as a farmers' response for lack of land, severe drought and the pressing domestic needs. The drying of the wetland was explained by giving an example of a cow which could be attracted to go and graze at the green grass that was visible from a distance. The wetlands were then impassable due to high water table, the cow could get stuck. Several strong men were required to pull it out and this could result to a cow with broken legs and could be slaughtered. The wetlands were sources of reeds for making baskets, and farming of arrow roots.

Cultivation in the wetlands started by digging drainage trenches and making raised beds to create room for production of other crops. This expanded over time, artificial fertilisers were introduced for soil fertility and all this resulted to rapid deteriorated of the wetlands. The irony behind this practice is that trenches then were dug for drainage purposes. Currently they are dug for irrigation purposes. Farmers associated the drying of wetlands with reduction of water table and drying of streams and therefore responsible for climate change.

Increased population pressure on land

High population pressure and land subdivision has resulted to over utilization and degradation of agricultural land. These has resulted to an over sensitive soil system that cannot sustain a crop in an event of reduced rainfall due to climate change. Shift cultivation historically practiced could allow resting and revitalizing of soils. With small pieces of land and over dependence on few crops planted (maize, beans, potatoes) crop rotation is as well challenges. Continuous cultivation characterises the farming practices in the region. One lady illustrated that since she was married 10 years ago and shown where to farm by the in-laws, she had continued to farm there and never missed a season.

Industrialization

This was mentioned by 5 focused groups. The youth talked about industrial pollution as the main cause of climate change due to green house gases destroying the ozone layer. The men blamed the tea industry in Runyenjes division since they are the main market of eucalyptus trees as they use firewood for their factory boilers. Eucalyptus trees as discussed above are an additional challenge to agricultural productivity.

3.2.3 Impacts of climate change as perceived by the local farmers

Local communities experience reduced agricultural productivity

Agricultural productivity was mentioned as the most important impact of climate change by the 12 focused groups. Cash crops like tea and coffee were said to have reduced in yield and therefore reduced income. This was associated with low rainfall and prolonged drought periods. The productivity of bananas had equally reduced. Bananas used to be in plenty due to high rainfall amount and were a source of food sovereignty. The reduction in banana productivity has resulted to scarcity and increased prices unaffordable even to the locals.

Water sources and storage strategies

Sources and storage of water were never a worry among the local community. Simple drums were used to store either rain water or fetched water. With the experienced of reduced rainfall, farmers are investing on rain water harvesting using huge tanks, either plastic or concrete made. The challenge is that the reduced long rains under the face of climate change, do not harvest enough water to do irrigation. It is only therefore for limited domestic use, like cooking and drinking. Alternative sources are boreholes which capture underground water, but also dry off during prolonged drought periods.

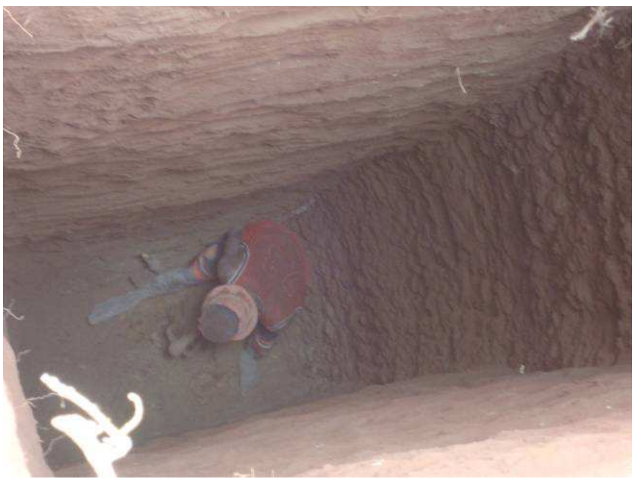


Figure 8: manual search of water, digging of boreholes

Increase of pest and diseases

Farmers complain of increased crop pest and diseases. Mango trees and especially grafted ones need to be sprayed which is a new practise. Sweet potatoes weevil (*gathua) is* a pest whose increased impact has resulted to farmers abandoning the crop or adapting to new growing methods. Maize is also being sprayed for pest control. The short rain season of 2009, although had good rainfall, it was associated with increased pest which destroyed maize and beans. This pest was not identified.

3.2.4 Summary: climate change or climate variability

The local ways of forecasting weather are still the major source of information on weather and climate patterns for the local community in Nembure and Runyenjes divisions. However, their reliability is challenged by the increased variability or micro climate change. Scientific weather forecast is based on large spatial scale and their local implication is not well interpreted by the farmers. Giving the examples of 1997 and 2009 El Niño forecasted, farmers in this region experienced a different scenario of what was communicated. This therefore makes it difficult for the farmers to plan the season as crop failure increases the farmers' vulnerability to climate change. It is important to integrate local knowledge within the scientific forecast for a better local interpretation and implementation of climate information.

Climate change as a global consequence is viewed as a phenomenal to come in the future. Based on local community own observation and experience climate change is probable. This is based on the practical reality of their everyday interaction with the environment. This view is given by the anomalies they listed, changes in rainfall pattern, dry highland winter and increase in temperatures. They use this to make a clear distinction between climate change and climate variability. The causes of climate change are as a result of local human induced activities like destructions of natural forests the shrines, the many eucalyptus trees and they consequences, degradation of land, over exploitation of the wetland and over dependency on agriculture land. Periods of drought and periods of bumper harvest have been there from history, but the community had established mechanisms to predict and to cope with the seasons. These changes have resulted to reduced agricultural productivity, increased incidences of crop pests and diseases, and fragile agricultural lands.

This analysis to a large extent has revealed that the local communities are taking the issues of climate change as a concern to their livelihood. They are not only reacting to climate variability, but are responding to changes they have observed, and the worst they anticipate. If the scientific community on the other hand views climate change based on large spatial scale as a future phenomenon, will there be a gap between the two communities in terms of adaptation? What will be the impact of this gap? This discussion and questions are taken further in the next chapters, where I will discuss the action being taken by the farmer community, as well as how the adaptation technologies within the scientific community are socially constructed.

Lower than average rainfall scenario
(Nembure Division)

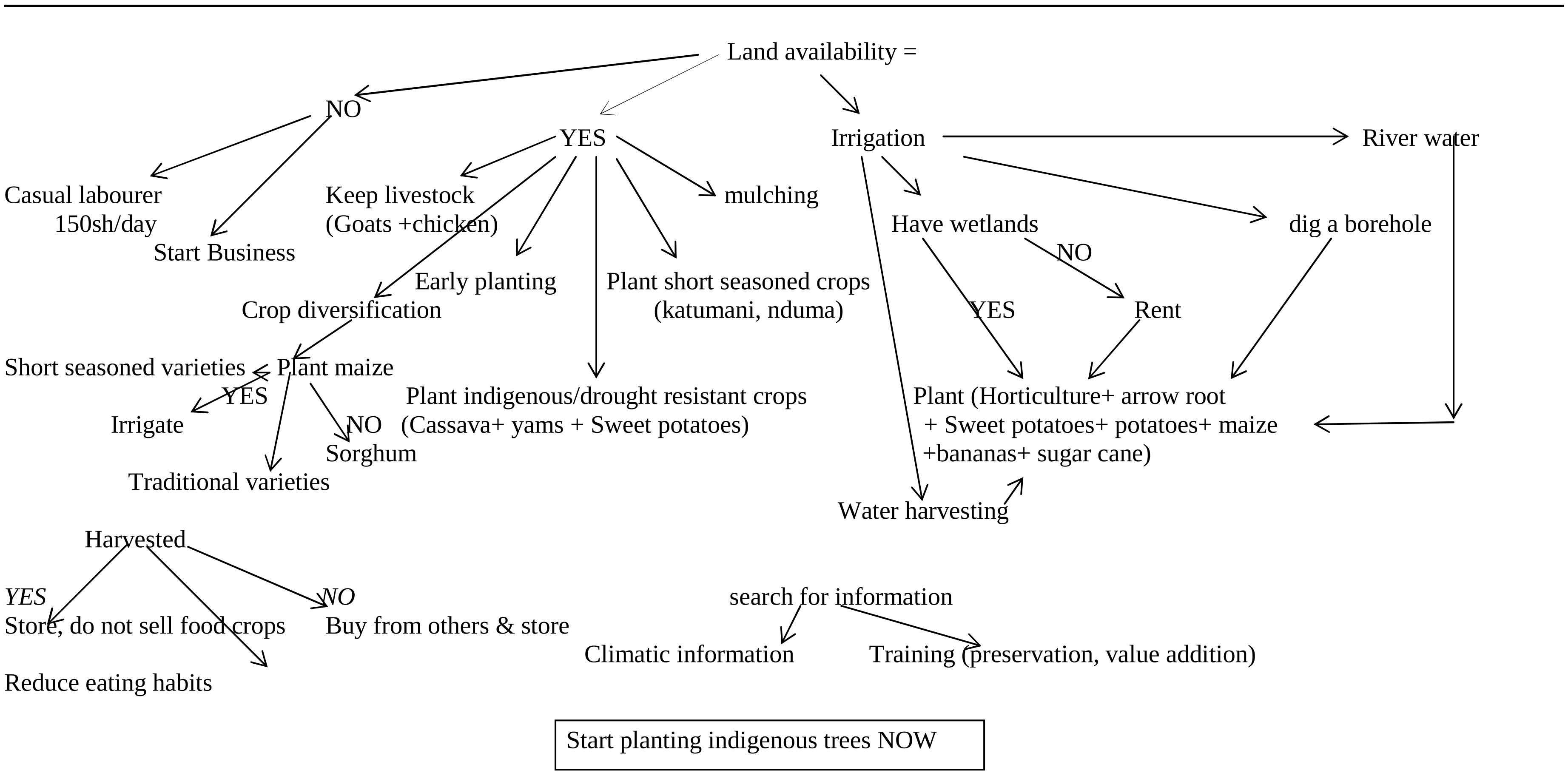


Figure 9: Future adaptation strategies of lower than average rainfall scenario due to climate change

Higher than average rainfall scenario
(Runyenjes Division)

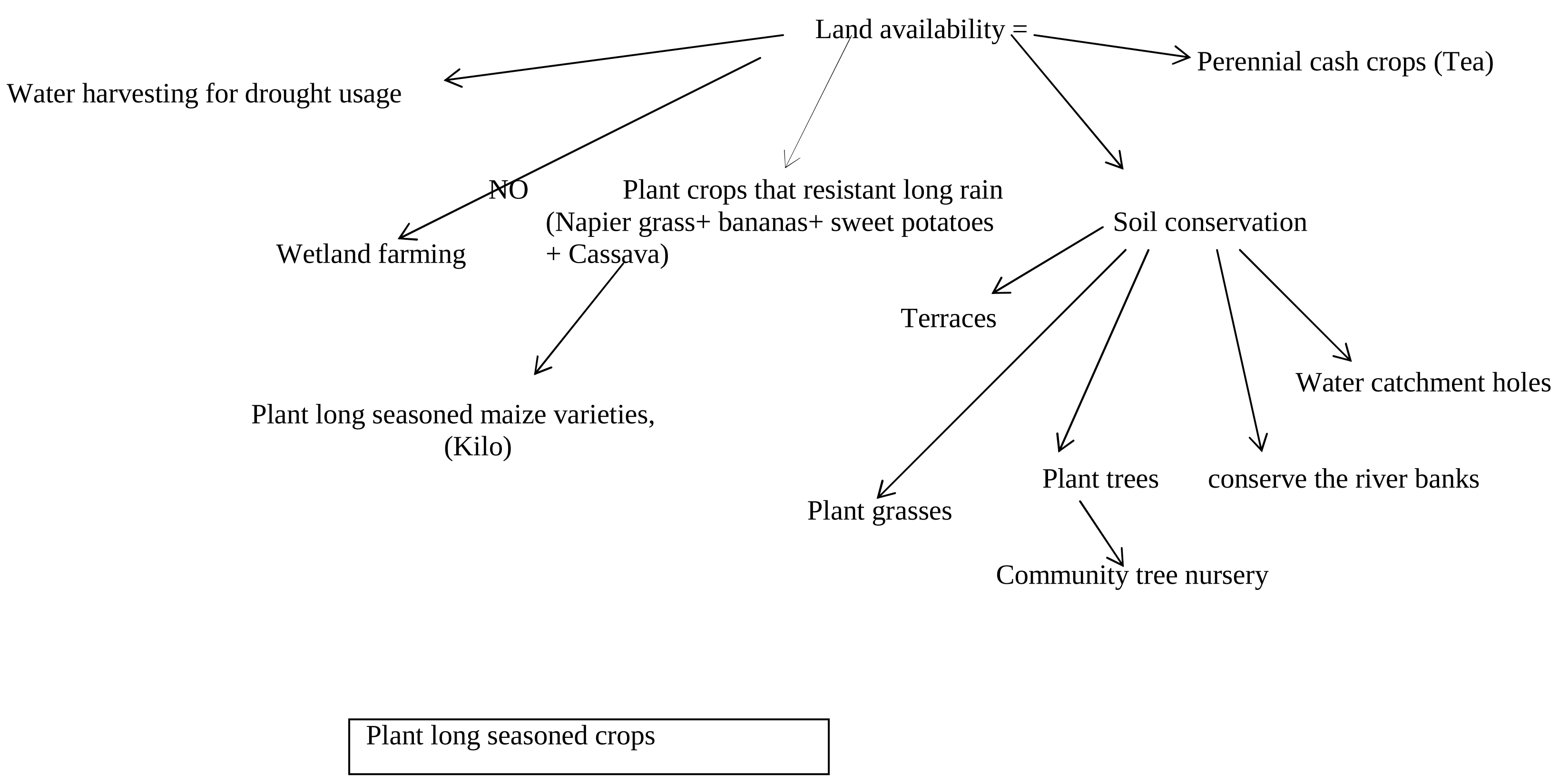


Figure 10: Future adaptation strategies of higher than average rainfall scenario due to climate change

CHAPTER 4: - FARMERS ADAPTATION STRATEGIES

The fourth assessment report to the IPCC (2007a) confirms the changes in climate and that many physical and biological systems are being affected by these changes. This is in agreement with the climate observations and experiences of the farmers' discussed in Chapter 3. This study acknowledges the challenge of identifying local adaptation to climate change since it is an ongoing activity and also under the influence of multiple non- climate stressors. This was the reason behind the discussion on climate change as a starting point in the FGDs. It helped an easy introduction of the adaptation to climate change topic and differentiated specific actions from the normal ongoing diverse livelihood practices. These actions as discussed in chapter 1 have been referred by scholars as reactive (Adger et al 2005), autonomous and private adaptation (Orlove 2005).

The term adaptation to recent global warming was defined as "actions taken to adjust to the consequences of climate change, either before or after impacts are experienced" (Lemos et al 2007). The emerging range of local adaptation is viewed in relation to decisions and actions taken by individual farmer and considered as private adaptation. It is a dynamic process embedded in livelihood practices and observed in the context of farm management and crop production. They are not however taken in isolation of other non- climate drivers which also play a role in adaptation. They occur in the context of demographic, cultural, economic and social changes (Adger et al 2005). This opens a wider horizon to equally look at adaptation in the other context of social economic activities.

Adaptation is explored as actions taken to respond to rainfall changes, increased temperatures and missing foggy season. They were categorized into two based on purpose and mode of implementation (Adger et al 2005; Smit et al 2000). These includes diversification in crop production categories as different types of crops grown, short seasoned varieties selected, early planting preferred to capture the first rain, and the most important crop for domestic food security occupies the large proportions of land. It also includes land management practices like intercropping, mono-cropping, crop rotation, mulching and use of chemical fertilizer in response to the fragile soil conditions due to reduced soil fertility. Non climatic stimuli include management of farm labour, skills and experiences, culture, and other entrepreneurship.

4.1 Diversification in farm management and crop production

This involves practices of farming by the individual farmer to ensure high yield and reduce risk from unreliable and unpredictable rainfall patterns and amount. Local farmers historically practiced mixed farming where they grew crops and kept livestock. They mainly depended on natural resources and rain-fed agriculture for their livelihood. The changing climatic condition is posing threats to the agriculture productivity and the livelihood of the local community. These are actions and strategies being taken by the farmers to reduce these risks. These actions are highly initiated at the level of individual households and a low proportion at government level through local interventions.

4.1.1 Individual adaptation: diversification in type of crops produced

At individual household level most informants highlighted actions taken in relation to farm management and crop production. These are seen in the context of different types of crops selected for planting, crop varieties selected, selected land available and marketing strategies.

There are a variety of crops that are produced within the region; root crops (cassava, yams, arrow roots and sweet potatoes), horticulture crops (tomatoes, French beans, and kales), tuber crops (potatoes), Legumes (beans, cowpeas) Cereals (maize, millet) other food crops are bananas, and sugarcanes, fruits (mangoes, passion fruits, avocadoes), cash crops macadamia, coffee and miraa, with tea occurring in Runyenjes only. Maize, bean and potatoes are commonly planted each season, are the bulk of food security in the homesteads and formed the main crops observed in the study.

Maize

Maize is produced both as a food crop as well as a cash crop. It was mentioned by all respondents as the most important and frequently used food crop for domestic consumption. 77% of the farmers in Nembure district sell it for income, with 68% in Runyenjes division. Its high value as a cash crop is due to its increased nation wide demand, as well as low prices offered by other cash crop like coffee. Although it is both a cash crop and a food crop, its role for domestic food takes priority. Farmers sell the expected surplus or when certain that the next crop will give high yield. This means storing the harvest for a long time. This is as a risk management measure in case of low production in the following seasons due to reduced rainfall. It has other non-monetary values like contribution in the school feeding programs. These have been established to ensure every school going child gets a meal a day.

Lack of alternative sources of income also challenges their storage and forces farmers to sell immediately after harvest (73% Nembure & 63% Runyenjes). This is based on urgent domestic needs or if a farmer has harvested a lot and wants to sell on large scale at once. This scenario happens because the main market outlets are the brokers who visit the villages only during harvesting period. The prices then are low due to high supply. In other situations farmers sell small quantities locally to meet immediate needs. A proportion of farmers (36%

Nembure & 10% Runyenjes) in the villages have identified this opportunity and are individually buying maize and beans immediately after harvest and sells to the same villagers at later dates on a 40% profit margin.

Horticulture crops (tomatoes, French beans, and kales),

These crops are planted by 13% of the respondents whose farms have a river flowing through and have the capacity to irrigate. They main target is the local market, division and national market. They mostly target dry periods when demand is high, but this period also requires a lot of investment due to irrigation machinery otherwise it is very labor intensive.

Potato production

In Nembure division potato production is limited to domestic consumption, with 18% selling it for income. In Runyenjes division a higher percentage (53%) produces potatoes for domestic consumption as well as for income. This high percentage is attributed to the fact that many farmers in this region rent land in the lower zones, referred to as "*weru*" (desert). This area is preferred for potato production due to; low infestation of pests and diseases, higher yields enough for domestic use and for sale, land there is relatively cheaper, no spraying is done and a good yield is certain. Mulching is the only requirement to conserve moisture levels. The farmers doing this are able to fulfil domestic needs of potatoes and sell as ware and seeds.

The low use of potatoes as an economic crop in Nembure division is associated with lack of clean and high quality seeds and high incidences of bacterial wilt. The few that have clean seeds conserve them as seed and capture the planting period as the market niche. A 2kg bucket of potatoes which normally cost 25-40Ksh, during harvest time would increase by 3-4 folds. A 10kg bucket which cost 250-300Ksh, during harvesting time could double its cost during planting period.

Sweet potatoes

Sweet potato a crop used in the TOA model is produced by a limited number of farmers, (Nembure 14%, Runyenjes 37%). The low production is attributed to the increase in pest, the sweet potato weevil, locally referred to as *"gathua"*. This pest is associated with low moisture level in the soil. Pesticide control mechanism was always discussed as declared not available by the farmers. They have invented management practices of reducing the attacks by planting the sweet potatoes on raised beds on the wetlands or plots near the river banks where water moisture levels are higher. This is only possible to the farmers with access to these resources.

Arrow roots and Bananas

Arrow root are under intensive cultivation in the wetlands where they are grown to meet the market demand. They are planted by farmers with access to these natural resources. Bananas and especially tissue culture bananas are being grown in plenty and because they are easy to grow, are manageable and in case of reduced rainfall one can do irrigation.

Fodder and fodder crops

Maize stover and Napier grass are the main fodder crops for livestock. Maize stover is residues from maize production. Napier grass is mainly planted by livestock farmers. However upon sale or death of cows they become a source of income as are sold to other livestock farmers. The two fodder crops are however used as a source of income by a limited proportion of farmers (Nembure 32% & Runyenjes 16%). Okoba and Graaff (2005) equally in a study conducted in Runyenjes found out that use of plant residues as animal feed was a common practice and only a small percentage sold it for income. Unlike Napier grass where if a farmer has no livestock the only option he has is to sale, for maize stover farmers have yet another options other than sale and livestock, to make organic fertiliser. This is where it is used as mulching material for potato cultivation. This is done to keep temperatures low and conserve the moisture conditions in the soil as they are planted during the hot season. They later decay increasing the soil fertility and maize is planted the following season.

Tea, Coffee, Macadamia and Miraa

Coffee and tea the main cash crops with tea in Runyenjes only, however farmers are putting their hands on macadamia and miraa (*Catha edulis)*. Tea has an organised marketing system where all the villagers have one managing agent called Kenya Tea Development Authority (KTDA). They have established village buying centre where farmers take their tea and they can pick from a collective centre. The bushes the farmers own ranges from 400-3000 bushes. The reduction of rainfall amount has affected tea productivity, and hence the number of bushes required to earn a sustainable income. Tea harvesting is labour demanding due to everyday picking; it occupies a large space of land that can not be intercropped or abandoned as could cause more future challenges as they become unmanageable bushes. A few farmers with less than 1000 bushes have opted to uproot them and instead planted bananas.

Coffee production in both divisions suffers the collapse of the industry and currently rejuvenating. Their main marketing outlets are factories, societies, or brokers. The choice of the buyer depends on membership and the previous prices offered. The collapse of the industry although had faced many governance issues was also associated with low prices, reduced yields which resulted to farmers abandoning the maintenance. The industry seems to be reviving with the three agents offering different prices to attract farmers. The growing coffee market is however challenges by high temperatures and irregular onset of rainfall. This affects the flowering and yield of coffee as farmers are witnessing coffee berries of different ages in different times. Individual farmers take this revival of the industry differently. To some farmers coffee is still not a priority and therefore plant maize and beans in between the coffee rows. Intercropping maize and coffee is not allowed due to pollination and reduction of coffee quality. To those who take the opportunity they plant beans alone and apply fertiliser in the hope that both crops will benefit.

Macadamia trees and miraa bushes are both grown cash crop but do not have a well established and defined market. They are usually sold through the brokers. Miraa (*Catha edulis*) or *khat*, is a native flowering plant that contains an amphetamine-like stimulant (Roncoli et al 2010). Farmers have between 1-15 trees of macadamia and 200-1000 bushes of miraa. The price of miraa is dependent on season with the highest price ranging from 800-1200Ksh during the dry season. On rainy season the price goes down by four folds to a range of 200-500Ksh. To capture this fortune during the dry season, irrigation is done. Miraa production is a male crop and due to its financial rewards they put lot of effort and investment. Although the crop is associated with increasing household income, it faces social challenges where it is associated with reducing the economical and social productivity of young male adults. They form chewing groups and spend their productive time chewing the *khat* and not on other considered economic activities.

4.1.2 Individual adaptation: diversification in crops varieties planted

Adaptation through crop varieties was observed through planting decisions during short rains of October-November 2009. This is in relation to variety selection, reason for the selection and its purpose. Crop variety selection was done when 95% of the respondent had the information on forecasted El Niño. 52% of the respondent in Nembure and 33 % in Runyenjes division confirmed using the information. The selection of maize variety varied from one farmer to another. Although will see another type of adaptation on a large scale, a significant proportion of farmers (48% Nembure, 85% Runyenjes) opted to plant short seasoned crop varieties like Duma, Pana, Pioneer, DK 831 and local Kiembu seeds (*murafa, kishungu*). These are considered short seasoned crops requiring little amount of rain. These are considered risk mechanisms in an event of reduced rainfall from their previous experiences of consecutive drought seasons leaving them with food insecure. The high percentage in Runyenjes is associated with lack of government seeds aid as was in Nembure division. A smaller percentage (8% Nembure, 15% Runyenjes) planted small portions of hybrid maize variety 6 series *(kilo).* This variety is considered a long seasoned crop and requires lots of rain than the rest but has higher yield due to its big stem and long cobs with many lines of grains. Planting *kilo* depended on the land size of the farmer and his/her ability to take risks. This is the reason why it was planted by very few farmers who are considered to have large farm sizes. They too planted on small plots as they were equally not sure and did not want to take much risk. They decision was based on the predicted El Niño.

4.1.3 Government adaptation: diversification in crops varieties planted

The government aid on seeds and fertilisers allowed many farmers to plant maize variety DK 513, which was the seed variety given by the Ministry of Agriculture. Farmers described this variety as requiring a lot of rain and planted usually in areas with high rainfall.

4.1.4 Individual adaptation: apportionment of land to crops

In many homesteads maize occupies the largest proportion of land. In Nembure 65% of the respondent had maize occupy more than three quarter on their land, 63% in Runyenjes. These high percentages were associated with the high demand of maize for domestic need. With information on forecasted El Niño, and previous 1997 El Niño experience they planted more maize and less beans. This is because the previous El Niño spoilt a lot of beans. Some of the decisions they made included reducing the usual amount of beans the individual farmer plants and instead increased the amount of maize planted. The others due to land sizes intercropped both maize and beans and felt that they had occupied the same proportion. Others had planted more beans than maize as they are usually more expensive than maize, while other had reduced maize production due to reduced soil fertility and lack of artificial fertilizer. Other made the option of dry planting beans, (68% Nembure & 52% Runyenjes), giving a reason of early harvesting before the heavy El Niño, and replanted more maize.

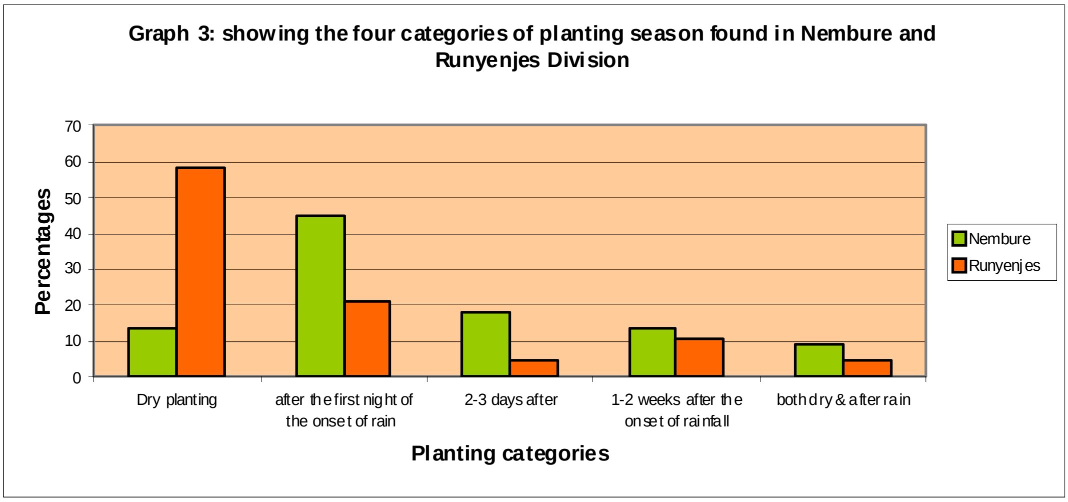
4.1.5 Individual adaptation: Planting time

Planting time as an adaptation strategy is dependent on crop selected by the individual farmer. This is observed through the decision made by the individual farmer to capture the unpredictable rainfall. It is based on the acquired experience, resources and cultural beliefs of the farmer.

Maize plating time

This was categorized into four periods, dry planting, after the first night of the onset of rain, 2-3 days after the onset of rainfall, and finally 1-2 weeks after the onset of rainfall. The percentage of farmers who chose different planting periods varied in the two regions as shown in graph 3.

Graph 3: The four maize planting time categories in percentage in the two divisions



The farmers explained that traditional maize was planted a week after the rains when the soil had attained sufficient moisture level. This period was described as planting when the soils are muddy *(matoro).* The current trend is to plant maize as close as possible to the onset of rain to capture the first rain. In Runyenjes division 58% of the respondent opts for dry planting which starts a week before the onset of rain. They are very keen with local knowledge indicators discussed in chapter 3 to predict the onset of rain. The main reason for this choice is due to the continued rainfall variability. They believe that the seed must capture every drop of rain and is only made possible if found in the soil at the onset of the rain.

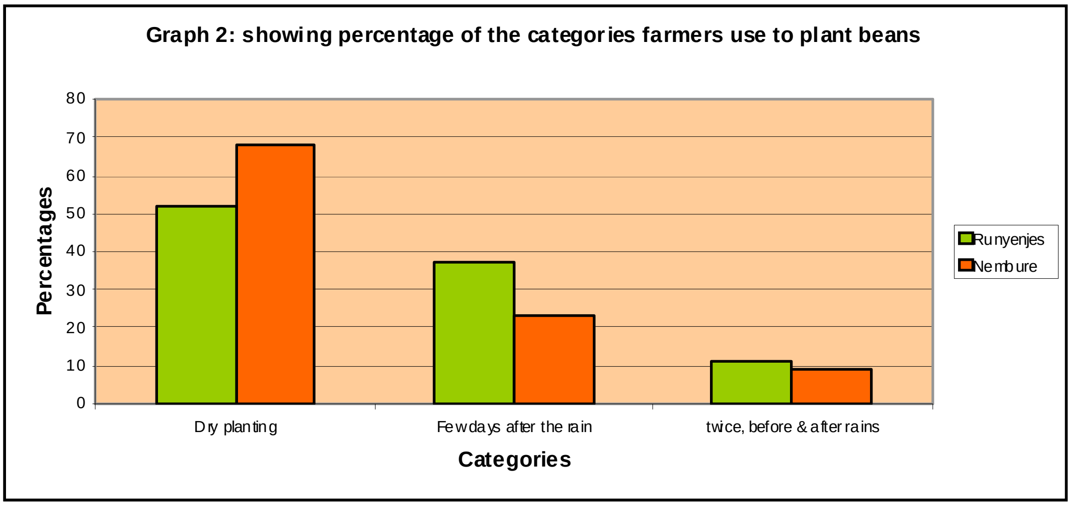
45% of farmers in Nembure division talk of their maize planting period as the current culture. They plant maize the following morning after the first night of the onset of rain. They opt for this strategy due to unpredictable rainfall pattern. They also use artificial fertiliser which in dry soils could damage the seeds. They explain that after 2-3 weeks of rain there is always 3-4 weeks of dry period and the crops need to be strong enough to endure this period.

A small percentage (9% Nembure, 5% Runyenjes) of farmers diversifies their risk by planting maize using two periods. They do dry planting as well as after the onset of the rains. The main reason for this strategy is to spread the risk from unreliable rainfall. In dry planting they plant the short seasoned maize varieties like D*uma,* while at the onset of rainfall with more certainty of the rains they plant the other long seasoned hybrid maize like 5 and 6 series.

Beans planting time

In both regions beans are planted within three categories; dry planting, few days after the onset of rain, and both dry planting and after the onset of rains. There are different reasons why farmers make these choices.

Graph 4: The three beans planting time categories in percentage in the two Divisions



A majority of farmers (68% Nembure, 52% Runyenjes) practise dry bean planting as their adaptation option. This is to capture every drop of rain but also to avoid labour pressure during maize planting. In dry planting potatoes are planted first followed by beans and then maize. They do this to capture the first rains required by both the maize and the beans. The beans are very sensitive to the 3-4 weeks of dry period within the rainy season and therefore dry planted to be strong enough to endure this period.

A significant percentage of farmers (23% Nembure, 37% Runyenjes) plant beans a few days (2-7 days) after the first rains. These farmers have small pieces of land ranging from less than an acre to an acre. They usually intercrop maize and beans to maximally utilise the available space. In this scenario therefore maize is planted first and after germination beans follow. This option is also becoming popular due to several experiences where beans withered and dried after germination due to poor start up and unreliable rainfall. Farmers explain that in a situation where it only rains for a few days and the already dry planted beans germinate then the rains stops, these young plants wither and dry up.

Farmers with big pieces of land 3-5 acres (9% Nembure, 11% Runyenjes) use “dry planting” and “after the onset of the rain” planting category. They start dry planting beans and as rainfall approaches they plant maize. When planting maize is finished, they plant the remaining portions of beans. This way they ensure they have enough labour during maize planting, but also diversify risk in case beans dry due to reduced and unpredictable rainfall.

Potato planting time

Potato planting in both divisions takes place long before the on set of the short rains. This is in the month of September when temperatures are high with low soil moisture levels. There are three main reasons why farmers do this; firstly to avoid muddy soils due to the rains as the soils are heavy and tiring to dig the furrows, cover and heap the potatoes which are basic requirements of potato planting. Secondly to avoid high labour demands when planting maize and beans near the onset of the rains. Finally farmers consider these period when the potato is in the soil during the dry period as a requirement for sprouting. This is facilitated by mulching of potatoes creating low temperatures at night. Environmental factors like long days and cool night temperatures have been documented to promote tuberization (V. Balamani et al 1985). Farmers have adapted to mulching their planted potatoes with maize stover, and *Grevillea robusta* leaves. Although it is usually very hot during the day the mulching reduces the temperatures and keeps the soil environment humid. This makes them germinate and shoots uniformly soon after the rains. With the reduced rainfall potatoes planted early capture the first rain and mulching is used to conserves the moisture level. Mulching of potatoes with maize stover in Nembure district is not a new practice. It has been used for years to weed control by farmers who did not want to weed and earth their crop. Currently it is done for additional reasons brought by climatic changes like reduced temperatures as well as conserving the moisture level. It is however a new practice in Runyenjes and picking up due to the same reason as in Nembure.

Sweet potato planting time

Rain fed sweet potato planting takes place after the three main crops have been planted. This is in the months of November-December. The respondents in Runyenjes planted 3 weeks after the onset of rain. This was attributed to the fact that they had the planting material given to them by the CIP/KARI project. The two main reason associated with late planting of sweet potatoes is to allow a sufficient moisture level in the soil which allows immediate germination. Secondly they depend on the old crops as the source of vines for the new planting material. This means waiting for the new shoots from the dried old crop after the rains. Over time farmers are losing their only source of vines as the new shoots with reduced rainfall wither and dry off. They are however adapting to the loss of planting vines by establishing small conservation gardens around the homestead where kitchen waste water is used for irrigation.

Summary on diversification of farming practises

Farmers' adaptation strategies involves diversification in livelihood strategies especially crop production as they are a farming community. Several strategies were observed like different types of crops grown for a particular reason, short seasoned crop varieties preferred, planting dates set aiming at the onset of rainfall, and large portions of land allocated to maize the crop that provides food security. Crane (2010) identified diversification of livelihood strategies to reduce vulnerability to climate shocks as a response to long-term environmental change.

4.1.6 *Individual adaptation: Land use management*

Land degradation in the face of climate change is reducing the agricultural productivity and increasing the vulnerability of the farming communities who depend on natural resources like rainfall. Soil and rainfall are the two main factors influencing land use management of the local farmers. Farmers having noted this challenge, they are individually taking measures in land management to reduce the fragile agricultural system. This involves the use of artificial fertilisers, crop rotation, and mulching. It is through this individual attempts that diversity in land management is observed (Foley Jonathan et al 2005). Adaptation is in the context of individual decision making process, land sizes, and crop production. Four strategies are identified, intercropping, mono-cropping, crop rotation and small and efficient land management.

Intercropping

Intercropping of maize and beans was used by 48% of the respondents. This is a practice often used by farmers with land sizes less than an acre. It is considered a risk measure against crop failure due to weather related risks, uncertainties in rainfall amount or due to pest and diseases. Beans are very sensitive to either very low or very high rainfall. Intercropping as an adaptation ensures maize is harvested within the same space if beans fail due the increased rainfall uncertainty. In the intercrop maize is planted first and beans follow 2-7day after the onset of rainfall to avoid competition.

Mono-cropping

Mono-cropping means planting maize and beans separately. 52% of the respondent planted using this practise. This is often used by farmers with pieces of land above two acres. Due to the unpredictable onset of rains farmers often plant beans and potatoes before the onset of rains. Once the rainfall signs become more reliable they plant maize on separate plots. These farmers choice this practise as they have observed that beans shoot faster than maize and results in competition for sunlight, soil nutrients, and moisture.

Crop rotation and mulching

Farmers divide their land into different plots and each season different crops are planted in an almost established regular sequence. The main crops used are potatoes, maize and beans in that order. Crop rotation is used for basically two reasons. To improve the soil fertility of the land as potatoes requires fertiliser application and mulching with crop residues which decays enriching the soil. In the second season maize is planted and farmers confirm of its high yields due to the inorganic fertiliser. Beans are planted after the maize crop, and the process continues. Crop rotation is also done to control pest and diseases.

Small-efficient field management; use of fertiliser,

Farmers are currently in favour of planting a small portion of their farm which they can afford to apply the required amount of fertiliser or manure. That is making a choice to plant on a portion of land than the entire farm with insufficient amount of farm inputs. The crops get sufficient nutrients and high yields are attained unlike planting a large area with below required amount and the consequences is low yields. The use of artificial fertilizer is an ongoing process and farmers argue that there is no need for planting without it. It is not about just fully embracing the use of artificial fertiliser but also the recommended amounts.

Summary

Local farming communities are dealing with the issue of fragile soils in the face of climate change in very different ways. These are individual decisions they make and are based on resources available. Intercropping, mono-cropping, crop rotation, and efficient field management actions were identified. Intercropping and mono-cropping focus on planting date, crop failure adapting mechanism and avoid crop competition for sunlight, moisture and nutrients. The rest two aim at enriching the soils fertility and improve productivity.

4.2 Adaptation as integrated in social economic activities.

This section identifies the adaptation actions based on other non climatic stimuli that either promote or hinder adaptation.

Skills and experiences of the farmers have grown as they interact with their changing environment. Majority of the farmer are in favour of the seed capturing the first drops of the rain. They mentioned that these kinds of seed, germinate uniformly matures faster and have high yields than those planted late and miss the first rain. They have also been trained on early planting by the MOA extensions officers and in radio programs.

High labour demands at the onset of rainfall makes dry planting of potatoes and bean very favourable. Potatoes are planted first followed by beans. The two are high labour dependant activity and made worse during raining season due to muddy soils. They are easy and faster to plant when the soils are dry and loose. As the onset of rain approaches or start planting of maize is a priority. To avoid the rush for all crops to capture the first rain, farmers plant those crops that can withstand high temperatures during the dry season. In Nembure division farmers culturally wait for the night it rains and the following day they plant maize. They trust that the rains will continue for the season. The planting culture and the norm of planting is to begins with potatoes in the dry spell followed by beans and later as it starts to rain maize is planted.

On farm job opportunities are highest during planting season. Many farmers who use this as an additional source of income prefer to plant in their seeds early creating time to capture this niche. This also provides an opportunity for some farmers to get income to buy seeds. This group of farmers usually plant after the rains.

Non-farming entrepreneurships especially in Runyenjes division where majority of farmers have other jobs promote adaptation. Farmers prefer to plant early before the onset of rains as the soils are light and loose making planting faster and creating time for the businesses.

Land sizes and labour is a consideration for the farmers with big pieces of land. They start dry planting and spills over to the onset of rain. This helps them maximize the use of family labour which is cheaper. This also ensures that they are not late with planting at the onset of the rainfall. For the farmers with small land sizes, less than an acre, they need a day to finish planting the entire farm and they start with maize then beans follow as it is an intercrop.

Irrigation and wetland farming is done by farmers with access to this resources. Irrigation is practised by those whose farm ends in a river bank. They practice horticulture by growing crops like kales, tomatoes, French beans, and green maize. The main target for this is the market. Wetlands are government properties and found in both divisions. They are used for sweet potatoes and arrowroots production among other crops.

Figure 11:- Irrigated kales near a stream and spinach on a new technique

Religion and spirituality may hinder adaptation as the strategy of the night it rains following day farmers plant is ineffective when the rains starts on a Friday or a Saturday. For example the rains in Nembure started on a Friday and many farmers are Christians. They prepare on Saturday for the Sunday activity and Sunday is a sacred day. A day when practical individual activities and pursuits are set aside for the sake of undertaking collective ritual actions which create abstract frameworks of meaning and identity by defining (or continually redefining) the community while still leaving space for individual (profane) behaviours (Richard P.).

Farm inputs availability determines when an individual farmer will plant. Some buy the seeds before the onset of rain and store waiting for any appropriate time to plant. They either practice dry planting or immediately after the first rains. Lack of seeds at the onset of rain means food insecurity due to delayed planting. Seed saving is practised by vulnerable farmers with limited access to hybrid seeds. The easy access to seeds comes in handy when rain fall unexpectedly. They are less painful if replanting is required due to minimum investment.

Bureaucratic seed systems especially in Nembure division where farmers were given farm inputs by the Ministry of Agriculture influenced adaptation. One of the qualifications was land size and National Identity card. This disqualified some farmers and had to wait to be given seeds by their neighbours. Some also received the seeds after the onset of rainfall. Those who had already bought their own and had planted stored them for another season.

Mixed farming with livestock conflicts was mentioned a lot in Runyenjes where maize that was planted during dry period was removed by chicken kept on free range system. This is solved by planting during rainy season. At this time it is informally known as the planting season and every farmer locks his chicken. The high moisture level in the soil also helps create a hard surface by stepping on the covered seed. This makes it difficult for the chicken to remove. Other plant treated seeds which are not eaten by chicken.

4.3 Summary of the adaptation strategies of the farmers

The vulnerability of the local farmers in Embu district is increasing due to the effects of micro climatic changes on agricultural productivity discussed in chapter 3. The study revealed that farmers are reacting to past or current climatic events referred to as reactive adaptation (Adger et al 2005), and anticipatory figure 9 and 10 based on assessment of future conditions. A more interesting analysis reveals that their current actions are equally based on micro climate change phenomenon they are observing and experiencing. These strategies are private and visible within the household livelihoods. They were observed in crop diversification and land management as well as in social economic activities. Within an individual farmer several strategies are used. Two individual farmers could equally apply completely different strategy. For instance intercropping and mono-cropping with justified climatic reasons. The potato mulching and crop rotation were identified as common practices among many farmers. Potatoes were viewed as important crop in the farming practice as they can be planted early to avoid the labour pressure during planting. Secondly it is the starting crop in the crop rotation and soil fertility program. Sweet potato was regarded as a drought tolerant traditional crop and its importance as an adaptation crop is challenged by the increased infestation of pests.

CHAPTER 5:- TECHNOGRAPHY OF THE TRADEOFF ANALYSIS MODEL

The chapter addresses the second and the third question of the research which explores the processes, synergies and divergences in the process of making TOA model. Secondly how the adaptation options and strategies of the individual farmer identified in chapter four has been integrated in the development of the TOA model for effective development and deployment of anticipatory and public adaptation.

Technographic analysis as a methodology was used due to its ability to find causal powers in the context of the real world of the community. The four elements discussed in chapter 2 were used. Materiality is used to analyse material object as well as social element associated with it. Potatoes and sweet potatoes were the two main material objects under observation in this chapter. The concept is used to unveil the social, cultural, technical and economical dimensions within the production of the two crops. These are embodied within the experience, observation, analysis, training or practices (Richards & Vellema 2009) of the two actors, the farmers and the scientists. Modality as defined by Richards and Vellma (2009) refers to the structure and organization of the local philosophically referred to as "universal church". This was observed within the language and culture of the community. It was used to study the activities and events in the field of the common farmer. Sodality was identified as specific professional group of people following particular rules and routines (Richards & Vellema 2009). This was observed among the scientists and was used to identify scientific protocols, procedures, values and logics behind their interaction with the potato and sweet potato as data sets for TOA model development. The task group was identified as a group set to accomplish a particular task (Richards & Vellema 2009). Two groups are identified, the scientists group and the farmers' groups. The concept was used to describe the internal interactions, goals and purpose of the collectivity as they interact with the two material objects.

5.1 Introduction to the TOA Model development process

Tradeoff Analysis (TOA) is a software package used by a team of scientists to assess the economic, environmental and policies sustainability of technologies in potato and sweet potatoes (CIP 2007). It collects to a large extend quantitative site-specific data that can be aggregated for regional policy analysis. Different data collection methodologies are used to enhance this; stakeholders' workshops, a survey and field experiments. The last data collection methodology was the main focus of the study. The experiments are designed to take two years where four cropping seasons were tested. Participatory observation and informal discussion were conducted during the second cropping season of the project and observed potato production of short rains of 2009 and sweet potatoes were already planted.

The CIP/KARI project aims at anticipatory, planned and public adaptation strategies. The analysis of the model will inform policy maker for regional adaptation strategic decisions aimed at reducing the vulnerability of the communities to climate change. These decisions will address food insecurity, economic and environmental development as attributed by limited soil water availability, nutrients and soil organic matters (CIP 2007). The project is the second phase of the TOA project of the department of Agricultural Economic and Economic Montana State University. This University together with Wageningen University and the CIP form the main International Agricultural Research Centres (IARC) in the project. The aim is to meet the needs of the developing countries by generating farm and regional-level information needed for making adaptation strategies by the decision makers (TOA Project. 2008). The project analyzes the sustainability of existing potato and sweet potato technologies, their potential for adoption, the economic and environmental consequences of policy decisions for poverty, food security and sustainability of the agro-environment (TOA Project. 2008).

TOA methodology starting point is the recognition that the farming communities are near critical sustainability thresholds for soils and climate (CIP 2007). It consider solutions within the already developed agro-technologies of potato and sweet potatoes whose usefulness has been considered but not assessed under the rapid climate change (CIP 2007). This explains the main reason why the two crops were selected as the main material object under the technographic analysis. Analysing the interaction between the material objects and the different actors plays a role in adaptation technology development and facilitates deployment to address the vulnerability of the local community in Embu District, Kenya.

5.2 Modalities: farmers production realities

This subsection determines how institutional modalities of the farmers relate with the potatoes and sweet potatoes. Modality is considered a social unity of analysis as it gives the collectively of the shared values that define the social and the technical aspects of the two crops among the farming community. This is based on their positioning at the local social space and farmers decision making process. This helps identify social-technical and cultural issues that may have been filtered out by the quantitative requirement of the model. Focused group discussions and formal household interviews were used to collect data.

5.2.1 *Materiality: Potato production (post) among farming communities*

This explores the sequential flow of potato production and post production among the farmers. This identifies the social, cultural, technical and economical dimensions and lies the foundation for identifies synergies and points of divergence among the two actors.

Potato production constraints

In Nembure and Runyenjes division potato production is on small scale basis. A question posed during the household interview on how much potato one planted was answered by many respondents as "*just a small portion*". The exact amount of potatoes planted ranges from 1-2kg bucket to 6-10kg bucket. Several production constraints attributes to this.

Bacterial wilt

Bacterial wilt caused by *Ralstonia solanacearum* was regarded as the most important constraint of potato production. Farmers who did not plant in the season feared that the wilt had spread in the entire farm. Others had planted small portions as a trial after several crop failures due to the wilt and had kept off planting for several seasons. For others it was fear of high investment in terms of seeds, fertiliser and labour with high probabilities of risk. Local knowledge measures used to reduce risk includes; use of clean seeds although never certain, crop rotation, use of tobacco, *Tithonia diversifolia* and ash. Farmers spray against early blight and hardly mention of any damages it causes.

Marketing constraints

Local farmers explain that the potato produced from their farms does not meet the market standard. This is in comparison to what their neighbouring Meru district produces. They complain that the tubers are too small in size and only good for the village market. Majority therefore produced for domestic consumption. Since potatoes are the first to be harvested they are consumed in plenty before maize and beans are harvested. It acts as the transition bridge between dry period and the next harvest. This makes potato to be consumed in plenty leaving very little for the market. The storage capacity of the potato was highlighted as a challenge and hindered waiting period to capture good market prices especially for ware potatoes.

Unavailability of clean seeds

There is inadequate supply of certified potato seeds in the two regions. Farmers depend solely on informal seed sources (44% farm-saved, 18% local market & 35% neighbours). There are several ways they use to determine clean seeds. Firstly based on variety the neighbour had planted for example *meru*" variety is considered tolerant to the wilt, secondly on-farm observation where they look and see the farm with a good crop. They book seeds for the next season from this farm. Finally from village discussions where they talk about other farmers' produce the one said to have had good potato yield is considered to have disease free seeds. In the market they look at the variety and the shape of the "potato eye". If it is not clear or has a bad smell or oozing it is considered diseased and unfit for planting. One respondent bought from Kenya Farmers Association (KFA) Embu and was certain to be free from disease.

Potato cultivation Practises

Crop rotation

A successful potato crop depends on judicious cultural practices of the individual farmer. This involves good knowledge in selecting varieties that are tolerant to bacterial wilt and the choice of the plot to grow the potatoes. Potatoes are used as base crops in rotation programs where it is planted first and maize follows and beans in the third season. Rotation is a management practice to avoid accumulation of pests and diseases. It is also associated with spreading soil fertility to the entire farm. Bacterial wilt has forced a significant number of farmers to rent land else where in pursuit of disease free land. They have learnt that affected plots needs a resting period of 7 seasons or 3-4 years as the disease is active in the soil for a long period. Crop rotation as a soil fertility mechanism is associated with the use of manure, fertiliser and mulching with plant residues in potato production. The plant residues decay improving the soil fertility. In the next season that follows maize is planted in that plot many farmers do not use more manure and fertilizer, as the plot is considered fertile. These also apply to the farm plots that the farmer feels are infertile. Potatoes are planted to upgrade them.

Land preparation

Potato production requires well drained and aerated soil. The tool used to attain this is often a fork hoe where deep soils with ploughing is involved to remove hard pans or any roots of previous crops especially maize or perennial grass. It is also used to mix the soil with the manure if broadcasted. A hoe (*Jembe)* on the other hand is used for digging furrows as well as heaping the soil after planting. It is easy to use during the dry season as the soils are light and loose. Digging furrows involves removing the top soil which is kept on one the side in a row parallel to the furrow. The same soil is used to cover the planted tubers. Hoes are preferred due to the large surface area that carries a lot of soil.

Figure 12: Use of hoe in heaping after planting

Planting process

The common practice of planting potatoes is in the furrows. If manure is not broadcasted it is put inside the furrow 1-5 days before the actual planting. Well processed and dry manure is recommended to avoid spread of bacterial wilt. Some farmer uses *Tithonia diversifolia* leaves as organic fertilizer and are spread before the manure. This together with tobacco and ash are also used to control pests and diseases. Fertiliser application, Diammonium phosphate (DAP) is done the particular day of planting. Farmers ensure that during this process the fertiliser does not come in contact with the tubers. The fertiliser is broadcasted first on the furrows. It is covered with sprinkles of soil before planting the potatoes. There is no particular relation between rate of fertiliser application and quantity of potatoes planted. This purely depends on the capacity of the farmer.

Planting depth, spacing and placing

The main determinant of planting depth is the size of the tuber. Very small sized tubers are planted on shallow furrows while medium sized tubers on slightly deeper furrows. Farmers use different terms to explain the spacing used, a ruler distance, 1 foot apart or use of own foot. This gives a general agreement that the spacing of potatoes is 30cm or one foot apart. The eye of the potato is placed looking upward although this is not a common practice.

Mulching

Potato mulching with plant residues is done after planting. This is an old practise among the farming community in Nembure division. Maize stover was used as mulching material to avoid weeding. Currently farmers continue to do mulching to adapt to changing climatic conditions. Planting of potatoes is during the hot season of September when soil temperatures are high with low moisture level. The mulch is essential due to its cooling effect of reducing temperatures in the soil. Farmers consider this as an ideal condition for sprouting as temperatures are high during the day and cold during the night, allowing uniform germination after the rains. It also conserves moisture when the rainfall amount is low and used for soil fertility improvement upon decays.

Figure 13: A photo showing mulching residues after potato harvesting

The main mulching material used are Grevillea leaves (*mivariti)*, maize Stover (*masaki ma maveve*) and a mixture of many plant residues like grasses, mango leaves and banana leaves. Njeru Kimenji a male farmer from Nembure explained the differences. “Grevillea leaves keep the soil temperatures warm and in case of high rainfall the soils remain dry and warm”. Maize stover, “create a very cold environment in the soil which is helpful when rainfall is low”. Grasses although are used are not recommended because they decay fast and eaten by termites. Banana leaves encourage floating of water hindering penetration into the soil. The challenge with maize stover is that they are used as animal fodder and large amounts are needed for mulching in a small portion. In soil fertility improvement farmers prefer maize stover which they believe improves the fertility of the farm and the second season they plant maize even without artificial fertiliser. Leaves of grevillea trees are growing in importance as an alternative to maize stover, as they have no other use. They are easy to access when trees are pruned for firewood. The only challenge is that frequent pruning of trees is destructive and can cause firewood shortages. It use as soil fertility improvement material upon decay is not considered among the farming practise.

Figure 14: Transportation of maize stover for fodder use

In Runyenjes division mulching is a new practice with 60% of the respondent who planted potatoes within the region not applying it. It is not considered a norm in this particular region as it is considered cold. For others lack of mulching material was the reason for not mulching. Those who mulched within the region used a mixture of plant residues as discussed above. Maize stover is left to meet the high demand of animal fodder. Those who planted in the rented land in "*weru*" mulched with maize stover from the maize crop in the same plot.

Post production process

Triggers of harvesting

Several factors were identified as triggering potato harvesting. The main one is maturity indicated by the yellowing of the leaves. The green stem is slashed two days before the actual harvesting for stabilization and to avoid nematodes. To allow long time storage both the leaves and the stems are left to dry before harvesting. This allows the skin to harden. Cracking on the soil surface is also an indication of maturity of the potatoes.

In a scenario where the crop is attacked by bacterial wilt the farmer waits until all the parts of the plants dries up completely. The plot is dug out and any health tuber harvested is said to be disease free. Harvesting withering crops is discouraged as facilitates the spread of the wilt.

Unexpected raining when the crop is mature or nearing maturity can hasten harvesting as the wetness is destructive to the tubers encourages re-growth for instance the unexpected rainfall in December 2009.

Early piece meal harvesting of potatoes is common after the second month of planting. This is done to meet the urgent domestic food needs. The plants which show maturity first by yellowing are the first to be harvested. This continues till the entire crop is either finished or fully matured for full harvesting. Those who practice piece meal harvesting complain of lack of other source of food, or an alternative income. At the expected harvesting time very little is left or nothing. This makes it difficult for them to know the exact harvested quantities.

Harvesting process

Potatoes are harvested using a fork hoe or a blunt machete *(panga).*The use of the machete is often used by the aged people as it is considered user friendly. It is also used when doing piece meal harvesting to avoid disturbing the entire crop where only a few tubers from a plant are removed. A fork hoe is recommended when harvesting the entire plot as it causes minimum injuries on the tubers. Digging out the tubers is done one foot away from the centre of the ridge. The tubers are put in a plastic bucket as the digging continues and transferred to a stand by sack. This procedure avoids exposing the tubers to the sunlight and hence greening effect which is considered cancerous.

Grading and storage

Grading of potatoes at home where tubers are placed on the floor of the store or of the house. The unintentionally damaged tubers are consumed first. The ware tubers are stored depending on amount while the seeds are preserved. Farmers store potatoes for four major reasons; as seeds for their own subsequent crop, for sale as seeds during the next planting period; ware tubers for home consumption and finally storage of ware for sell at future date.

Potatoes are stored on the floor of the store or of the house in a location considered to be cool, dry and dark. For preservation purposes different treatments are given. Majority use the ash, while others use chemicals. Ash is said to prevent pests. Some spread banana leaves or tithonia leaves on the floor and spread the tubers and splash ash on top then cover with sacks. Others combine both ash and chemicals. There is no one way to preserve the potatoes.

Consumption

Potatoes are cooked as one of the ingredients in many dishes, *githeri* for example a common dish among the Embu community is a mixture of beans and corns and potatoes are used to add flavour. It is also cooked with beans to make stew for wheat and maize products (*chapati & ugali*). It is can be mixed with other starch food crops like bananas, cassava, yams, and arrow roots. It is considered the main ingredient of children's food.

Summary of potato production among the local farmers

In analysing the potato production among the farming communities low scale production is analysed. This is associated with lack of clean and high quality seeds and high infestation of bacterial wilt. Majority of the famers depend on informal seed sector which could be a source of the wilt. In the potato production process among the farming communities there are several techniques used to avoid pest and diseases like ash and tithonia. To improve soil fertility crop rotation and mulching is used. Potatoes are considered an important base crop in the rotation program. The rotation breaks the pest and disease cycle and improves the soil fertility due to mulching with plant residues. Mulching has attained a new paradigm shift where it was used for weed prevention and now to temperature regulation and soil moisture retention. Potato as a dish among the Embu community is not considered as a priority crop but an additional ingredient. This limits its production investment among the farming community.

5.2.2 Materiality: Sweet potato production (post) among Local communities

The second material object observed in the study is the sweet potato. This section equally identifies the constraints of producing sweet potato, the process of production and post-production processes. This opens the avenue to identify commonalities and discrepancies among the practice of science with the farming practice.

Sweet potato production constraints

The scale of production of sweet potato in Nembure division is low as 22% of the respondent planted them in the season observed. It was however high with 68% in Runyenjes divisions. This is associated with the 43% of the respondent who were given the vines as participated in the CIP/KARI project. This equally means a lower percentage or 25% of the farmers took their own initiative to plant sweet potatoes. The production aim is for domestic consumption as breakfast or as a "snack" (67% Nembure, 64% Runyenjes). A smaller percentage (Nembure 33%, Runyenjes 36%) target the market. This low production is associated with two main factors, the sweet potato weevil and the source of planting materials.

Sweet potato weevil* (*Cylas* spp), (*gathua)

The main challenge of producing sweet potato is the increased incidence of sweet potato weevil. This was mentioned by all the twelve focused groups. This incidence is associated with dehydrated soil caused by increased temperatures and reduced rainfall. The damage in yield can be up to 80% and 100% on specific tubers. The attacked tuber is described as full of spots and emitting a bad odour. This makes it difficult to discard the spoilt part and utilising the remaining as happens with other root crops.

The mention of sweet potato brings fold memories of a snack that could be eaten primarily for breakfast or lunch and children could never go hungry. Sweet potato weevil is slowly snatch away this opportunity from the farming communities. There is currently no pesticide known by the farmers to control it. Local knowledge being used are; use of ash, Tithonia or application of Calcium Ammonium Nitrate fertilizer during planting, the vines are also left to wither before planting and timely harvesting is recommended. Other options utilised are planting at the bottom of the valley or at the river banks and in the raised beds in the wetlands. This makes availability of these natural resources a determining factor in production.

Source of planting vines

Sweet potatoes are reproduced vegetative using vines or cutting. The main sources of these planting materials are the old crop as was mentioned by 56% of respondents in Nembure and 36% in Runyenjes or maintained through the dry season in the conservation garden. 33% in Nembure and 21% in Runyenjes get their material from social networks. This lack of reliable source of vines contributes to late planting as time is needed for the old crop to regenerate and produce new shoot which are then used. One farmer in Nembure mentioned of purchasing from the KARI stand during the Agricultural day in their division. 43% of respondent in Runyenjes got their vines from CIP/KARI project or from relatives in the project.

Sweet potato production practices

Crop rotation

In selecting the plots to plant sweet potato farmers prefer infertile plots as a mechanism to improve the fertility of that plot. They argue that sweet potato have inbuilt fertility due to the organic biomass they leave in the farm and provide the soil with a cover from direct sunlight. Many farmers prefer to plant legumes like beans or cowpeas after uprooting sweet potatoes.

Land preparation

Sweet potatoes are planted on loose and well aerated soil to allow root penetration and expansion. It involves removing any crop debris and digging a ridge or a furrow. In the wetlands a jembe is used to dig and remove the reeds and any perennial weeds.

Plating process

A machete (*panga*) is used to fix the vines to the soil either in the furrow and the vines lay on the ridge or fixed on the ridge or on a flat ground. These three planting strategies of sweet potatoes vary among farmers. In Nembure division 78% of the respondent planted on the ridges as opposed to in the furrows. The reason behind this is that on the ridges there is a lot of soil heaped there making it loose for easy expansion. In Runyenjes 57% planted on the ridges as opposed to 43% who planted on a flat ground. On the ridges farmers can also plant two rows of the vines. The few 22% who choose to plant on the furrows expected the vines to spread on the ridge and therefore produce from there. The flat land planting was chosen as the crop does not age quickly. No fertiliser or manure application is used. Only one respondent in Runyenjes used 23-23 fertiliser as she wanted to initiate fast root formation.

This analysis of the planting strategies of sweet potatoes reviews that majority of the farmers refer to plant on the ridge as opposed to in the furrow and on a flat ground.

Sweet potato post-production process

Triggers of harvesting

There are two main indicators of maturity of sweet potatoes where the soils start to crack and the roots try to protrude out or the aging of the plant and the leaves turn yellow.

Harvesting process

There are two ways of harvesting sweet potatoes depending on if everything is harvested at once or piecemeal. One time harvesting is done by farmers who plant on rented land and mainly for commercial purposes. They harvest and take to the market the same day. In this process the vines are first removed and the fork hoe is used to dig out the entire farm. In piece meal harvesting, a sharp stick "*moru*" or a blurt machete is used to avoid damaging the entire crop. It starts with the base of the vine depending on where it was planted. Hilling after harvesting is done for the small ones to continue expanding and to prevent the vines from drying. On the second round of selective harvesting is done where big roots are traced and removed. Based on the variety planted the farmer can harvest 2-3 round before the entire crop is harvested by digging up the entire plot using a hoe. Harvesting of modern varieties of sweet potatoes starts as early as 3 months while with the traditional varieties takes 9 to 12 months.

Grading and Storage

Grading is done to remove the diseased and damaged tubers. For market purpose different sizes are sought based target. Their storage is not a common practise due to the short life span. Harvesting is when needed either for consumption or taken to the market the same day.

Consumption

Sweet potatoes are primarily either boiled or roasted and consumed with tea for breakfast or lunch. One farmer talked of frying with other root tubers like cassava or with bananas while another talked of mixing it with wheat flour to make *chapati*. This two were real cases and did not come out as common practices among the farming communities. This means that sweet potato consumption is still based on the two traditional recipes of boiling & roasting.

Summary of sweet potato production among the farmers

This review indicates that farmers grow they consume and market sweet potatoes. They associate it with having inbuilt soil fertility traits and therefore planted in plots considered infertile. They production is however in very small scale and this is associated with three main constraining factors. The high incidence of sweet potato weevil, lack of reliable source of vines and lack of new techniques of utilisation of sweet potatoes hinder their maximum usage as an adaptation crop. The efforts taken by the farmers to overcome the first and the second challenges are planting on areas considered wetter than others and planting on ridges. The thesis recommends a need to tackle these production and post production challenges of sweet potato to increase its importance as an adaptation crop. There is need to reverse the place of sweet potatoes among the community by ensuring availability of varieties tolerant to pest or management practices that reduces the infestation.

5.3 Sodality: On farm research

In the technographic analysis the scientists were identified as the sodality due to their acquired professionalism. The concept was used to analyze the practices of science as performed by the scientists. The research sites were set in three divisions of Embu district, Manyatta, Runyenjes and Nembure and in farmers' fields. The overall aim is to investigate the " effects of farmers' resource endowment, anticipated temperature increase and rainfall variation, on soil Organic carbon and intern its effect on potato and sweet potato yields in Eastern Kenya" (Gacheru et al 2008). Three different research designs were observed and each had a different objective with a different variables being tested. In the first one potato experiments were laid in individual farmer's plots in the three divisions. The independent variable or the technique being tested was mulching potatoes with maize stover. The contribution of this technique to soil fertility, moisture level and yield were the key factors being analysed. The second experiment was based in Runyenjes division alone and involved the different planting strategies of sweet potato. These were the independent variable, in the furrow, on the ridge and on a flat ground. The elements observed were moisture content and nutrient level in the soil at different stages of growth and within the planting strategy and finally the contribution of their biomass on the soil fertility. The third experiment was discussed under the task groups where higher interaction of farmers and scientist was observed in potato production. These research experiments are part of an ongoing PhD project by a KARI scientist sponsored by the TOA project (CIP 2007).

5.3.1 Materiality: of on-farm potato trials

The concept of materiality was used to identify the practices of potato production and their usage as data sets for TOA development. The data collection methodology used was participatory observation and informal discussion during experimental lay out and implementations during land preparation, planting, data collection and harvesting and in the WUR/CIP PhD land dynamic workshop in Embu. The idea behind observing these processes was for purposes of comparing with farmers' production practices. The two being actors in the TOA model it facilitated identify the synergies and point of divergence with the process of making technology.

In this experiment mulching of potatoes using different quantities of maize stover is the technique under investigation and no mulching as the control. The aim was to determine the yield of a specific potato variety under varying soil organic matter content in small holder farms (Gacheru et al 2008).The replication in the three division of Embu district enabled comparison across the different agro ecological zone. The data set included collecting soil samples to analyse the nutrient build up and water holding capacity improvement over time and space. The discussion below filters out descriptions of scientific potato planting procedure as to a larger extent they are similar to the farmers. The observation although took place in all the sites the data is aggregated to represent one scientific practise.

Construction of land to fit scientific guidelines

The plot where the potato experiment laid was flat, with no perennial vegetation and away from shade or any other obstacles. It was selected from the main farm and was divided into twelve equally sub plots and semi permanent pegs used to identify the boundary. Two equal paths run parallel separating the treatments sub plots and three also equal paths run parallel separating the replicates sub-plots. This structure from the previous first experiment was not interfered with during harvesting as the same treatment was continuing through out the project process. The decaying maize stover which was used as mulching in the previous experimental was visible and although incorporated in the soil one could identify the sub plot which had the highest amount.

Potato cultivation under the scientific procedures

Potatoes were planted in a standardized way in all the plots and sites. This was in the furrows. Each plot and sub plots had equal number of furrows and each was planted equal number of tubers. The purpose of this was to ensure that difference in yield per sub-plot was not associated with number of tuber planted. DAP fertiliser was broadcasted in the furrow in each plot. However unlike the farmers the plots received equal amounts of fertiliser which had been pre-packed in polythene bags. No manure was applied. A little soil was sprinkled to cover the fertiliser and the seeds were arranged and covered forming a heap. These were followed by respective mulching treatment.

Mulching as an independent variable

In the scientific practise the manipulation of the independent variable was referred to as the treatment. These were; using little mulching, medium mulching and finally a lot of mulching and no mulching as control. The amount used during the second planting season was a repeat of the previous season where each plot received similar treatment as the previous season. The plots that had received the highest amount of maize stover in the second season received still the highest. Those that had not been mulched or the control remained like that for the second time. The amount used in each site was dependent on the dry content matter of the stover.

Source of seeds

The experiment used certified seeds from farmers associated with KARI-Tigoni station in Central Kenya. The distance from the seed source to the planting farm was approximately 200km and could take four hours drive. The seeds needed to be standardised by size as well as variety. This was a problem as was proved by the decision to return two sacks of the tubers to the seller for having not being graded.

On-farm potato experiments as embedded in the TOA model

This kind of scientific set up where the technique of mulching potatoes is continuously done in technology development determines the impact of technological changes in environmental conditions (Stoorvogel 2008). The data set required is soil nutrient and moisture level, crop yield, mulching management and rainfall and temperature data. All these contributes to environmental impact of agricultural production (Stoorvogel et al 2004). They are site specific meeting the data requirement of TOA model where the experimental set up captures three agro-ecological zones giving specific details which can be extrapolated to larger spatial variation needed for policy decisions (Stoorvogel et al 2004). The development of the TOA model observed in these experiments are based on “quantifiable indicators” (Stoorvogel et al 2004) of agricultural production. These are dependent on land qualities that influences water and nutrient availability and climatic characteristics like temperature and rainfall (Stoorvogel 2008). Replanting and mulching potatoes in the same plot over a period of time is an essential determiner of the impact of technology across space and time. It influences soil texture and depth the essential indicator of land qualities (Stoorvogel 2008).

Summary of the scientific practice of potato production

The procedure of planting potatoes within the scientific practice is to a large extent similar to the farmers' practice. They both plant during the dry period in the furrows, they use DAP fertiliser with the same spacing logic and finally covering and mulching with crop residues. The main point convergence is the use of potatoes as a starting crop for soil fertility improvement and use of mulching techniques as a current adaptation technique.

The comparison between farming and scientific practices of potato production identified a key point of divergence. This is particularly in relation to decisions and logics behind potato production, mulching and soil fertility improvement. The scientific community planted potatoes in the same plots for the second time and based on the data requirement of the TOA model this is planned to continue. The scientific logic behind this is that the impact of the mulching technique on the environment or soil systems needs to be analysed over time. This is due to organic matter build up from the decaying maize stover. This is meant to improve the soil nutrient level and water holding capacity. The farmers on the other hand do not believe in continuous production of potatoes in the same plot. They practise rotation where the plot which had potatoes is planted maize in the second season and beans in the third season. Their logic is to avoid build up of pest and diseases and to distribute soil fertility from the mulching technique evenly in the entire farm.

There is need to reduce Tradeoffs and increase synergies between the two practices. This is an important consideration behind developing an adaptation technology. It requires higher investment with local stakeholders using higher participatory and interactive approaches. They involvement should be from the initial designing of the site specific experiments to completion and analysis. For instance an important stage could have been to identify and assess the impact of climate change on already ongoing potato techniques which could have been an outcome of a participatory approach. This could be followed by assessing their viability as adaptation technologies that are sustainable with anticipatory climate change. In the TOA model development the basis crop data could be the potatoes, maize and beans. Relationships between the three crops could be determined based on their soil nutrient needs and contribution as well as crop characteristics like root systems and morphology. This could equally mean investing different research organisation with different mandates and a more interdisciplinary research. This in my opinion could have added value and avoided a remark from an individual farmer who asked "*Is this not an obvious experiment*". This was from an informal interview where the farmer felt that the result of the potato yield was expected. In her opinion the plots with the highest mulching material could yield the highest while the control plots with no mulching would yield the least. In the first season as was visible during the second planting the stover were not decayed meaning that soil nutrients were more less the same. There was therefore no much difference in yield realised in the potatoes with the treatments. The added nutrients were not used by the crop. The difference in yield was expected in the second season. The yield results of the experiments for the second season of the project was as expected. The highest yield realised was in the plot with the highest mulching material, followed by the medium treatment; the third was the plot with little mulching material and the last was the control plot. This was in relation to weighted Kilos. The scientists were more interested with the statistical analysis determining the significant difference. Unfortunately in one of the sites the potatoes were attacked by a disease that was not identified but was not declared as bacterial wilt. Pest and diseases were identified as one of the limitation of TOA (Stoorvogel 2008).

5.3.2 Materiality: On-farm sweet potato trials

This experiment was set in Runyenjes division only. It involved planting of sweet potatoes using three planting strategies as the independent variable. These are in the furrow, on the ridge and on a flat ground. The objective of this research design is to analyse the potential contribution of sweet potatoes planted in different strategies to soils ecosystems for anticipated climate change (Gacheru et al 2008). This section will identify the social-technical interactions and arrangement between the scientist and the individual farmers. It also describes the construction of land for and finally will identify synergies and elements that could have been filtered out in the process of making the technology

Social-technical interactions and arrangements

The experiment was set up by the scientist in two different plots belonging to two brothers and laid parallel to each other. Some were therefore in one farm while the others were in the other. It was based on cost sharing basis where the farmers volunteered the plots while the scientist was responsible for the experimental implementation, management, and administration. The farmer could benefit from the final produce, while the scientist used the set up to collect data for the TOA development. The methodology used to collect data was participatory observation and started two months after vines had been planted and had started flowering. Due to time limit research time elapsed before harvesting was done. The level of interaction observed was restricted to the land owners who followed the instructions given.

Research design and interactive learning

In the first farm which I will refer to as Emily's farm the plot was divided into three sub-plots and each had a specific planting strategy. Around these plots the farmer had planted guard rows of sweet potatoes on the ridge. She had also developed her own plot parallel to the scientists and planted double rows of the vine on the ridge and mulched with grevillea leaves. The research designs in Emily's farm were replication in the second farm referred to as Njeru's farm. The difference between the farming and scientific practice is quite visible in Emily's farm. There is land maximization within the logic of the farmer as shown in double rows and also water conservation and temperature reduction with mulching. Although the farmer had planted the local varieties while the scientist had the improved breeds, it could be interesting to compare yield per land size.

Two sides of coin, the farmers and the scientist view on performance

The experimental set up was in the middle of the farms. In the first and subsequent visits to the farm the vines were weak, retarded and drying up although a few had small fresh flowers. Emily the owner of the first farm could not hide the disappointment she had for the poor performance of the experiment. She associated these with late planting and dehydrated soil. The vines had not received any rain since planting. The scientist recognized the opportunity for good data as could determine the moisture content level that had sustained the crop that far. In the household interviews farmers are opting to plant sweet potatoes in plots with higher water table mainly because dehydrated soil are associated with sweet potato weevils but not because of poor performance.

Data requirement from sweet potato production for TOA development

The data requirement for the crop growth simulation within the TOA model was based on crop growth characteristics and soil qualities. The data determining the crop characterises included crop germination rate, crop cover and biomass. The three had different methodology and different equipments of determining them. This was done for comparisons across the planting strategies. The strategy with the highest of the three supposedly should correlate with soil nutrients and moisture levels. This was determined by collecting soil samples using soil auger.

Figure 15: Soil sample collection using soil auger

The soils were taken in each plot using specific oral communicated scientific procedures. The soil depth had to be uniform and soil was sampled from three different portions of the sub-plot, mixed in a container and a small portion of the mixture put in a plastic bag and labelled. The samples were taken for laboratory analyses on fertility and moisture content level. These data collection element were carried out several times.

Figure 16: Farmers vines next to the scientist, double rows & mulched

Summary of the sweet potato production as a data set for the TOA model

In analysing the sweet potato production practices between the two actors the study revealed that the three planting techniques being tested by the scientist are ongoing within the farming practice. However in relation to climate change adaptation planting on the ridge is more preferred than the others. 78% of farmers in Nembure choose the ridge than the furrow, while in Runyenjes 57% of the respondent plant on the ridge than on the flat ground. Sweet potatoes are identified by both as a source of soil fertility due to the amount of biomass it produces. Pest and diseases hinder production and this is technology development was recognised as one of the limitation of the TOA (Stoorvogel 2008). The research priority setting in fig 1 of Stoorvogel and Antle (2004 p. 45) suggests three key foundation stages of the TOA; identifying sustainability criteria, formulating hypotheses for potential tradeoffs and finally identifying disciplines for research project. This is an important for the TOA development and to identify local needs with their realities more preliminary work and details is needed.

This study reveals that the challenges of sweet potato weevil are perceived as caused by dehydrated soil. The adaptation by the farmers is to plant on the ridge in plots with higher water tables. Sweet potato biomass and its contribution to the environment regardless of the planting strategy cannot be ignored. However economic losses due to infestation can be up to 80% and opportunity cost of land if maize for example was planted needs more investigation.

5.4 Task group: Research groups

The concept of task groups was used to study the impact of higher level of integration of farmers and their farming practices in scientific research and how it shaped adaptation technology. Two task groups as units of analysis were identified, the scientists group and the farmers group. This methodology was used due to its ability to identify a task that joins the group, the purpose of the group and how it relates with the environment (Richards & Vellema 2009). It analysed the internal interactions of the groups and what glues them together as they interact with the material object the potatoes. Participatory observation and informal discussions with the farmers and the scientists was used to collect field data.

Composition of the task groups

The scientific task group was composed of the CIP project leader, scientists from IARC and NARS and the PhD student. Apart from the scientists being involved in the two experiments discussed above they invited five groups of farmers spread across three divisions of Embu district. Four of them were based in the two divisions under observation of this study, 2 in Runyenjes and 2 in Nembure division. This group of farmers formed the second task group which was the main focus of observation. These groups were already in existence before they were invited by the scientists to participate in the project.

The identified task of the groups

The harmonised interest of the two groups was to observe the productivity of potatoes if mulched with maize stover, with grevillea leaves, mulched with maize stover after germination and weeding and no mulching as control. The farmers' benefit was viewed in terms of experience they gained and obtained clean planting tubers from the produce. The scientists' interest was the data collection for the TOA model. The first stakeholder workshop was conducted before the observation of this study. The outcome was the planting strategies of potatoes with specific focus on mulching as well as action plans that described the groups' task and responsibility. This information was recapped during the second workshop which I participated and observed. Each farmer group provided land, labour, manure and mulching material. In some groups the scientist had to assist in getting maize stover from other regions. The researcher on the other hand provided the planting seeds, fertiliser and pesticides.

Group purpose

The group population ranged from 15-30 farmers, both men and women. In this experiment there was a higher level of interaction between the scientist and the farmers than the other two. The farmers' groups remained focused and edger to make a conclusion of the best adaptation strategy. They were in charge of the experiments even when the scientist was not there. No new member joined in during the process but there was evidence of sharing material gain with non members. The officer from the MOA was present in every village level meeting where joint activities were conducted. Her presence was seen as a means to facilitate the continuation of the project once CIP/KARI pulled out.

Production constraint

Choice of land

Three of the plots the farmers had availed for experimental purposes had not met the condition of the scientist. There was need for almost standardized plots to avoid inconsistence and interference with the yield results. Some groups had burnt trash inside the experiment plot, others had chosen a plot where there was traces of cow shed on one side while the other had trees creating shade. All these elements were discouraged and some plots disqualified requiring more search for better plots by the farmers.

Bacterial wilt

Bacterial wilt being a common challenge in potato production the two groups agreed on reliable disease free seed which was the responsibility of the scientist. She purchased from certified farmers associated with KARI-Tigoni. These were hybrid seeds and of high quality. Disease free land was left at the prerogative of the farmer groups. To do this, farmers had to consider the history and previous usage of the farm. For example farm that had not been planted potatoes for a long time was preferred.

Social- technical interaction in the group

The group members in this experiment unlike the first experiment where the individual farmer owned the entire produce, these members had to share the produce among themselves. Prior agreement with the owner of the plot was therefore necessary to avoid conflict after harvesting. This was the responsibility of the group. Some opted to rent land. Others were given for a season but with clear terms on sharing the produce equally. In one of the groups the farmers gave the plot owner, also a member an additional portion as appreciation.

Planting process

Needless to repeat, the potato planting followed similar steps as described in the first experimental set put. The plot sizes were smaller with few and shorter furrows allowing few tubers to be planted. The cause of this was on plots selected by the farmers and need to standardise in all the groups. The paths left between replicates and treatments were seen as waste of land by the farming community. They wondered if it was a practise that they needed to also do in their farms. The paths were explained as creating standing points while learning.

Mulching

In this set up, mulching was the technique under analysis as an adaptation technology. It was referred to as the "treatment" and therefore the independent variable. All the groups worked on the harmonised treatments; mulching with maize stover and mulching with grevillea leaves immediately after planting, weeding and mulching potatoes after germination with maize stover, and finally the control where potatoes were not mulched but weeding after germination. This was replicated. To break down the scientific jargon into farmer friendly terms, the replication was referred to as three classes and the treatments as four subjects. The classes were doing to study four subjects. The subject with the total highest score from all the classes could be regarded as the best adaptation strategy. To determine which treatment was to be done on each plot voting method was used. Four balloting papers were written the treatments and folded and four farmers numbered 1- 4 were asked to pick. The first farmer picked the treatment that was done to plot number 1 and so on. This was repeated until all the plots had specific treatments.

The farmers were responsible of bringing the mulching material. The material came from different farms resulting to a lot of inconsistence that is not accepted in the scientific practice. Grevillea leaves brought for instance had a mixture of fresh and dried leaves. Others had many sticks and had to be pruned away. This resulted in different quantities being used in the different groups. Three sets of weighed maize stover were placed aside for mulching after weeding.

Division of labour among the members of the groups was easier than in others. For instance some group leader divided the task upon realising that the mulching material was not enough. Some went to get more while others were left pruning off the sticks and others were involved in weighing and taking the mulching material near the plots. At planting time, all the group members were involved. There was excitement, discussion and comparisons with their farming practices. The selection of treatments through voting made the participating farmers own those particular plots. This was observed as they called their friends not involved in the voting to help in applying the treatment and wanted to see how they "class" could perform.

Summary of the task group in experimental set up

The replication of the experiment for purposes of farmer learning according to the scientist was not necessary; however it was done for purposes of collecting scientific data where replication is mandatory. The learning process with farmers used only one set with the four treatments. Only the yield after harvest was combined to determine which had the highest.

This kind of research design prioritized the farmers' needs. The higher level of integration of the farmers' practices and ideas shaped the research design in different way than the rest. The purpose of using both mulching material is to integrate the farmers' actions which involves using either of the crop residues as adaptation strategies in potato production. Use of Grevillea leaves is up coming as an alternative to the increased scarcity of maize stover which faces reduced production as well as animal fodder challenges. They are both considered slow in decomposition and therefore can sustain their role during the growing season of the potato.

Post production process

Triggers and processes of harvesting

The harvesting time of this experiment was late January after most farmers had harvested their own crop. These delay was associated with planning logistic of the scientist, however the potatoes had dried both the leaves and the stems. Several data sets were taken before harvesting, germination count for all dried stems and soil samples to determine the moisture level and the nutrient content at the time of harvest were taken. The rest was on yield and was taken after harvesting. A fork hoe was used to harvest. This choice fell under normal practices of the farmers. The harvesting process as explained by the scientist to the farmers was each plot harvested individually and all the tubers kept separately.

Grading and results

Grading was done per plot where three grades were determined. The marketable size referred to as ware, medium size or seed/egg size and finally the rejects. The rejects as defined by the scientist were the very small, unintentionally damaged or had pest damages. According to the farmer only the diseased and the damaged by pests could be considered as rejects. Within the farming practise the damaged could be consumed first followed by the very small or as well kept as seeds. The total yield was determined by mixing tubers of similar grade in their respective treatment. Care was taken to avoid confusion. A particular pattern was followed in weighing. The yield from the maize stover treatment was first where the ware, then the seeds and finally the rejects were weighed. This was followed by grevillea treatment with the same pattern; the third was the yield with the treatment where weeding and mulching was done after germination and finally yields from the control.

Summary of the potato production with integration of farmers' views

In this particular research design both economic and environmental consideration of mulching materials is considered in the TOA model. Maize stover is considered by the farmers for its economic benefit as animal fodder and this takes priority. Grevillea leaves do not attract any economic value and makes a cheaper alternative for mulching. This design provides an opportunity to test both materials subject to be used by the farmers. Using the model to determine the best option with highest results will influence adoption rates (Stoorvogel et al 2004), for instance the knowledge on facts and figures of benefits of using one and not the other. The farmers can therefore choice a mulching material from a point of knowledge.

Summary: The process of making TOA model, Technographic analysis

Chapter 3 discussed climate change as a reality within the micro spatial scale of the local farmers. Chapter 4 analysed several adaptation strategies which involves crop and land management. The two were combined in a crop diversification and soil fertility program. This is where three crops were identified; potatoes, maize and beans and operated under crop rotation and mulching as a production technique and a strategy for adaptation to climate change. This has a positive impact on crop performance and in soil fertility improvement. Chapter 5 narrowed down to analyse how farmers and the scientists are interacting with potatoes and sweet potatoes as material objects within the development of adaptation technologies. This is because they are the main crops identified as starting crops in soil fertility programs and they are as well the main data set for the TOA model.

In comparison of the practices of the farmer and the scientist, important points of synergy were identified. The practices view the two crops as essential in soil improvement programs. Potatoes are considered due to their mulching requirement as a production practice. For sweet potatoes, it is due to their high biomass that they produce. Several potato mulching materials were identified, from maize stover, grevillea to a combination of grasses, bananas and any green vegetation. The use of maize stover is challenged by its multiple uses especially as animal fodder. This requires a detailed data collection for Tradeoff Analysis model to give specific recommendation. Its availability is also challenged by crop failure due to reduced rainfall. Sweet potato production within the regions is very low and this challenges its usage as adaptation crop. These is associated with high rates of infestation by sweet potato weevil, lack of planting material and lack of modern techniques of its consumption and preservation.

The diverging points and logics were also identified in the comparison process. The farming practice supported crop diversification and rotation to break the disease and pest cycle and to spread soil fertility in the entire farm. The scientific practice embedded in the TOA data requirement encouraged continuous potato production with mulching in the same space over time. This practice did not fit in the farming practise and could be the first challenge of implementing decisions made using TOA model. This is however not to undermine the important of determining the impact of technological changes in environmental conditions (Stoorvogel 2008) where data on soil fertility build-up over space and time is needed.

Figure 17: A photo showing farming practice of sweet potato planted on the ridge

Figure 18: A photo showing scientific practice of planting sweet potatoes on the ridge

CHAPTER 6: DISCUSSION, CONCLUSION & RECOMMENDATION

This study aimed at contributing to adaptation science by exploring the adaptation activities on the ground. The study analysed the modes of integrating current farmers' adaptation initiatives to future scientific adaptation modelling. This was viewed as an essential component for the current and future adaptation technology development and deployment of the same. The first step used the lens of climate change to analyse the farmers' perceptions to climate change and variability. This was followed by discussion on adaptation strategies or actions that farmers are undertaking to overcome the challenge of local climate change. Results of step one and step two addressed research question one that looked at the perceptions of local farming communities to climate variability and change, and how this has influenced their adaptation strategies. Potatoes and sweet potatoes being the main data set crops in the TOA development had special attention in the thesis. The way the farmers and the scientists interact with them through their defined practices was identify. These aspects answered question two of the research which analysed the processes, synergies and divergences in the process of making TOA model. The third question focused on how the individual farmer's adaptation options and strategies could be integrated in the TOA model for effective development and deployment of anticipatory and public adaptation. The research question three actually linked the other two research questions and provided the basis for the discussion chapter. It identified and suggested the point of linkage or the meeting space of the farmers and the scientists. It explored the connection between the exogenous and endogenous decision variables in adaptation science and technology development. Synergies and tradeoffs between the types of adaptation were analysed as a mechanism of shaping technology.

Technography as a methodology in climate change adaptation research

Technographic analysis was used to analyse how the practise of science and the practise of farming is socially shaping adaptation technology. The TOA model in adaptation science is a decision tool to guide policy makers in assessing economic and environmental sustainability of technologies and policies (CIP 2007). Different stakeholders are involved in the assessment including farmers who are indirect and final beneficiaries (CIP 2007). Involvements of farmers in the assessment justified their selection in investigating their perception and contribution to the process. The technographic methodology analysed the materiality of the potato and sweet potato in the farming practice as well as in the scientific practice. It enabled the organisation and description of data is sequential ways that allowed easy comparisons of social, cultural and technical processes. This systematic process gave a break through into the complexity of climate change and adaptation among the farming communities. It identified new techniques among the farming community within a given time and space. The meeting space of the two actors allowed comparisons and were discussed as synergy and points of divergence between the different practices. The methodology considered different social scales starting with the lowest level of a farmer, individual farmer working with the scientists and group of farmers or village level social scale. The write up of this technography analysis was useful in describing human systems and material object interactive processes. These processes were described together with the logics of the actors in a detailed way. Technography was however limited in capturing the ethnographer insight and inferences. Its use to describe techniques of similar material object among many actors involves a lot of repetition before attaining a point of linkage and a conclusion.

The role of local, narrow spatial scale climate projection

The fourth assessment report of the IPCC (2007b p.4) asserts that the “world wide climate is changing” and will increase the vulnerability of African agricultural production. This is due to reduced growing seasons due to uncertain future rainfall scenarios and higher temperatures (IPCC 2007a; Ngigi 2009). Climate change projections are based on global scenarios which are subject to great uncertain (Klein et al 2005). This was also acknowledged in Stockholm Environment Institute report submitted in advance to COP 15 (SEI 2009).

Climate change based on narrow spatial and social scales is an area that has not received a lot of attention among the scholars. Correlating global circulation models of climate projections with the experiences and observations of the local community can tackle the uncertainty and challenge of climate variability and climate change. Climate change based on analysis of the perception of farmers living at the slopes of Mount Kenya and as a micro phenomenon is a reality. This view is based on narrow spatial, temporal and social scale dependent on experiences, observations and interpretation of specific landscapes surrounding the local communities (Roncoli et al 2002). The climate anomalies they have observed are average reduction in rainfall, changes of the wet foggy winter season to dry cold clear season and increased temperatures. While global climate change is associated with global scenarios reflected in economic development, population growth, and consumption (Klein et al 2005), local climate change is associated with negative impact to the environment by local human induced activities. These to a larger extent are influenced by national and global agendas like modernity and religion. They were identified as destruction of natural forests or shrines, increased population pressure on agricultural land, the over exploitation of the wetlands, irrigation along the river banks and industrialization.

In 1992 the UNFCCC in Rio de Janeiro established two actions; mitigation and adaptation to deal with climate change (Schipper 2006). The concept of adaptation as it continues to develop within the UNFCCC emphasises adaptation to future climate change based on global circulation models. Adaptations by local farmers and communities have been refereed to as adapting to climate variability (Klein et al 2005). Orlove (2005) noted the difficult involved in distinguish the two especially at regional specific climatic conditions due to earlier societies negatively affecting their environment.

Analysis in chapter 3 and chapter 4 suggests a paradigm shift that considers African farmers are experienced challenges of micro climate change phenomenon. This is however coupled with other multiple stressors which have negative consequences on food security (Boyd et al 2008). This is confirmed by the general decrease in agricultural productivity with a specific mention of bananas, coffee and tea in Runyenjes and Nembure division. They importance as cash crops is going down resulting to overdependence on maize and beans both as food and cash crops. Production of potatoes and sweet potatoes are considered important food crops that can ensure food sovereignty, improve environment soil conditions and uplift the economic states of the homesteads but their production is hindered by pest and diseases.

The farmers' adaptation occurs in the midst of other non-climatic stimuli that either influence or hinder adaptation. Acquired skills and experiences of the farmers, their culture, peak period of farm labor, non farm entrepreneurs are all biased toward early planting and therefore adaptation to capture the first rain. Other factors hinder adaptation; mixed farming increases competition for plant residue as livestock fodder and mulching material, lack of seeds at planting time causes delayed planting, spirituality does not allow planting at specific days, small pieces of land demand maize to be planted first followed by beans as an intercrop.

Farmers' experiences on seasonal climate forecasting

This review was used to discuss how climate and climate information is viewed among the farming communities. The analysis of farmers' perception on use of scientific and local knowledge forecast identified challenges experienced when forecasts are used as aid in decision making process and in adapting to climate change. The farming community in the study area has access to both types of forecast. The practical challenges experienced in utilizing the scientific climate-related forecast opened a framework to theoretically explain the consequences of viewing climate change on a wider scale than on narrow local scale as a micro climate change phenomenon. The discrepancy between how farmers perceive seasonal climate forecast generated by scientist was noted by Roncoli (2006). Kenneth and Praff (2002) discussed their limitations as hindrance to their potential benefits due to lack of appropriate spatial resolution for regions of interest. The FGDs in the study area identified onset of rainfall seasons and duration as the main aspect of weather that is most important and discussed local means of predicting it. The scientific forecast information although highly accessible through media receives low reliability and confidence from the farmers. This could be associated with its inability to predict reliably the duration and distribution of seasonal rainfall (Roncoli et al 2002). Integration of scientific forecasting with farmers local knowledge has been advocated to allow inferences (Roncoli 2006) and as a way of reducing misinterpretation (Kenneth et al 2002).

Analysis of farmers' experience of the 1997-98 El Niño and followed by the 2009 El Niño projections revealed that there are other key factors that hinder the maximum benefit of scientific forecast other than misinterpretation. The latter is ruled out as the main hindrance as weather information is translated and transmitted in the local language. The challenge proposed for further evaluation could be due to generalization and large spatial scale at which scientific weather forecast are based. Secondly lack of repackaging and delivering the information in appropriate form to the target audience (Kenneth et al 2002). This is evidenced by the reported reality of the 2009 projected El Niño which varied in various regions. At the Kenyan coastal and southeastern region a bumper maize crop was expected due to the enhanced rains (IRIN 2010). In the study area farmers reported that the rains prolonged till January, however magnitude wise it was not the expected El Niño. They equally confirmed high maize yields. Other parts of the country experienced flooding where people were killed and damage caused (IRIN 2010).

In September before the onset of rainy season farmers using local knowledge observed the moon which was "U" shaped and interpreted the observation as an indicator of high rainfall in their region and the entire country and therefore expected good yield. This observation to a larger extent was right as the region experienced high duration of rainfall, enough for maize and banana production which requires a lot of rain to grow. This interpretation of local experiences and observable natural phenomenon along side the scientific weather forecasts can improve local farming decision making and utilisation of climate opportunity and avoiding the risks. In reference to adaptation science, local experiences and observation needs to inform the wider debates and analysis of future climate preparedness and adaptation. The increased climate uncertainty and vulnerability of the farming community demands reduction of risk through appropriate and well delivered information and technologies.

Adaptation strategies on the ground

Chapter 4 and 5 described and analysed how the farming community in Embu district and CIP/KARI scientific community are responding to climate change and variability. The goal was to identify and compare adaptation strategies within the institutional modality of the farming communities as well as within the sodality of the scientists. The strategies of the farming communities are treated as adaptation when climate change is centred within the local micro observations and farmers' cognitive experience on climate phenomenon. This includes decisions and actions they within the complex and dynamic process embedded in livelihood practices. These actions by the local farmers have been referred by scholars as reactive, autonomous and private adaptation (Adger et al 2005; FAO 2007; Orlove 2005). The scientists' adaptation strategies are based on long term future climate assessments with conscious and deliberate policy actions. This have been referred to as anticipatory, planned & public adaptation strategies (Adger et al 2005; FAO 2007; Orlove 2005). This thesis agrees and contributes to the work of Adger and Arnell (2005) on "successful adaptation to climate change across scales", which views farmers' strategies and actions as both reactive triggered by past or current events, as well as anticipatory based on assessment of future conditions. Further more, the analysis reveals that their current actions are equally based on micro climate change phenomenon they are observing and experiencing. A consideration of this fact within the adaptation policy can yield substantial benefits in supporting and developing anticipatory, planned and public adaptation technologies in Kenya.

Despite the micro climate change experienced agriculture remains the main source of livelihood among the farmers in Embu district. They are developing techniques to adapt to the unpredictable rainfall patterns and the increased temperatures. These techniques were identified during the FGDs and formal household interviews. They were categorized into two based on purpose and mode of implementation (Adger et al 2005; Smit et al 2000) and were observed in crop diversification and land management. The most important adaptation strategy identified in this study among the farmers community involves diversification of three crops; potatoes, maize and beans, and their crop rotation in response to the fragile soil conditions. Potatoes in the rotation program are the preferred starting crop as they are mulched with plant residues which act as organic fertilizer for the maize and beans. Sweet potatoes are also considered as a soil improvement crop due to their generated biomass. They are planted in plots delayed infertile and after harvest, beans are planted with no artificial fertilizer added.

The TOA model field experiments were initiated in 2009 and forms the part of the field work that collects data to feed into the development of the TOA model. The data source is from potato and sweet potato on farm experiments. The important observation identified is the methodology used to build soil fertility and moisture level for purposes of analyzing the impact to the environment with changes in technology (Stoorvogel 2008). This is the continuous replanting of potatoes and mulching with maize stover within a defined space and time. In the third experiment where higher levels of farmers integration was observed, a different set up was realized where maize stover as well as grevillea leaves were used as mulching materials. In the sweet potato experiments the effects of different planting strategies to soil nutrient and moisture levels were tested.

Synergy in the process of making Tradeoff Analysis (TOA) Model

The farmers approach adaptation to climate change in a holistic dimension. They consider crop diversification and land management as one unit for a sustainable adaptation. They mulch potatoes with plant residues like maize stover and grevillea leaves then they do a crop rotation with maize and beans. This in their opinion improves the soil fertility and breaks the disease and pest cycle. Sweet potatoes are often planted on plots considered infertile as the biomass generated is perceived to be inbuilt fertility. Majority of the farmers use "on the ridge" planting strategy. The potato mulching and sweet potato biomass are techniques existing within the farming community and have been integrated within the materiality of the scientific research program. These formed the synergy point between the practise of farming and the practise of science. Potatoes and sweet potatoes are both considered as base or foundation crops for soil fertility improvement and soil moisture conservation.

The importance of specific crop models can not be undermined (Ngigi 2009). The quantitative data collected and validated in the models can give specific outcome to lay solid foundations for policy formulation and strategic planning (Crane 2010; Ngigi 2009). Crane (2010 P. 15) questions the process of incorporating society into models, or "when and how to incorporate models into society". In Adger and Arnella (2005) successful adaptation is categorized based on spatial, temporal and social scales where sustainability is evaluated against different criteria. The adaptation modelling can only be useful if societies controversies are articulated and adjusted (Meinke et al 2009). Meinke and Howden (2009) advocated for adaptation science to stand at the boundary space between society and science. High levels of integrations is needed if adaptation science (Meinke et al 2009) is to be relevant in the rain-fed agricultural systems in Kenya. In the analysis of the different field actors involved in TOA development the integration of farmers' within the task group expressed the highest partnership, participation, involvement and commitment of the farmers. This scientific experimental approach opened doors to more actions that met the local reality and needs of the farmers. The use of two plant residues as mulching materials acknowledged the diversification within the farming practises where maize stover has multiple functions. The integration creates new insights and wider data collection for adaption modelling that meets local reality.

Tradeoffs within the process of making Technology

Adaptation is local specific and should aim at meeting local needs and realities. The adaptation science should aim at creating synergies (Meinke et al 2009) of competing goals and activities of the locals. This should reduce tradeoffs among the diversity of the farming communities.

In the process of developing adaptation technology by the scientists an important point of divergence between the practice of farming and practice of science in potato production was identified. The scientific community adding value to the mulching technique by investigating its impact to the environment requires potato to be planted on the same plot over time and space. The farming practice furthermore advocate for crop diversification and rotation to spread the fertility and break the disease and pest cycle. The scientists look at specific technical details of the environment that can be extrapolated into the future; the farmers are holistic and practical to their daily livelihood practicalities. This creates a technological gap between the practises of the two actors. It is not clear if these three crop diversification (potatoes, maize and beans) and rotation technique among the practice of farming is local knowledge but it is already embedded within the livelihood of the farmers. It is one area that farming practices can advance scientific practices in the TOA model. At the farm level the total number of different crops is the simplest criteria for measuring crop diversity and acts to reduce vulnerability to climate change and variability that can result in crop failure (Ngigi 2009). A narrow focus of particular elements in adaptation technologies for example a crop or the environment can result to specific details that are importance in modelling adaptation. It can however undermine the opportunities availed by holistic approaches, diversification and local practicalities of adaptation and local climate change phenomenon.

Analysing the materiality of the sweet potato production and especially the planting strategies "in the furrows, on the ridge and on a flat ground" these are not conflicting issues. The mode at which the different actors interact with the sweet potato creates a diverging point between the practise of farming and scientific practice. The adaptation modelling collects data based on planting strategies and the impact on soil fertility, moisture level and yield. The production of sweet potato among the farming community is going down due to increased challenge of sweet potato weevil. This is associated with dehydrated soils and farmers opt to plant in areas with higher water table. The production is increasing been limited to farmers with access of these natural resources. Identifying the best planting strategy alone will not yield the expected usage of sweet potato as an adaptation crop. An essential focus in adaptation technologies need to reflect on soil fertility, moisture level and pest and diseases. There is need to first tackle existing challenges before venturing into future challenges of agricultural production.

CONCLUSION

This thesis is set to contribute to adaptation science by technographically exploring the adaptation activities on the ground and analysing the modes of integrating current farmers' responses to scientific long term projections. Hypothetically this will facilitate adequate development and deployment of adaptation technologies which are designed to address the impacts of climate change. In chapter 3, I argued the reality of micro climate change based on local experiences and observation of specific landscapes by the farmers. This observation contributes to the current scientific debate regarding whether climate change is occurring or not. It confirms that it is already happening based on the perception of the farming community. This community is adapting to climatic chances by developing new techniques and ways of doing farming as discussed in chapter 4. This is often at individual homestead level to ensure agriculture remains a source of livelihood. Contributing to the work of Adger and Arnell (2005), the actions taken by the farmers are viewed as both reactive triggered by past or current events as well as anticipatory based on assessment of future conditions. Additionally the actions are based on micro climate change phenomenon they are observing and experiencing. The development of adaptation modelling and technologies discussed in chapter 5 represents initial steps towards anticipatory, public and planned adaptation.

The finding of this research and its contribution to adaptation science is to emphasise the value and the need of getting specific localised knowledge, practicalities and realities of farming diversification especially in the context of small holder farmers when responding to climate change. These are under the custody of the local communities and their integration into scientific long term projections is essential. For instance farming communities perceive climate changes and associate it with local human activities or human induced climate change. This although coupled with other multi-stressors it goes beyond climate variability as it is increasing their vulnerabilities and reducing their adaptive capacity. Identifying synergies and tradeoffs within the practices of both actors indicates that integration and participatory research has the capacity to socially shape adaptation technology that neither of them can achieve individual.

The relation between crop and soil models being tested by the scientific community is a critical step in developing anticipatory, planned and public adaptation. While this is so the reality of crop diversification and land management among the farming community has been filtered out in the development process. Crop diversification is not only an adaptation strategy but an important aspect of the farmers' livelihood. Adaptation modelling other than de-contextualising the farmers' reality should be open to holistic view of systems upon which anticipatory, planned and public adaptation should be based on. Farmers already exist and operate within particular defined contextual frameworks. This exclusion observed within TOA development process could be attributed to the low level of involvement and participation of the farming community. Kamau (2007) reason for this could also be due to lack of “a deliberate effort to find out what data and criteria the farmers look for in a technical innovation”. Crane (2010) recommends incorporating the farmers into adaptation modelling to expand the scope of data required to develop an appropriate anticipatory adaptation.

Adaptation science and modeling should not only be based on future climate projections but be built on experiences and challenges observed yesterday, today and tomorrow. Farmers are experiencing crop failures, increased pest and diseases and weather anomalies that increase their vulnerability and reduce their adaptive capacity. They are taking actions and trying to adapt to these changes experienced. Adaptation strategies within rain fed agricultural systems are expected to increase in a future uncertain rainfall scenario (Figure 9 & 10). A strong link is needed between ongoing actions to climate variability and development of future technologies for adaptation climate change. This should be clear within the adaptation policy of UNFCCC. This combination will meet the current vulnerability, open new opportunities for future adaptation and will be a prerequisite for successfully reduction of vulnerability of small holder and semi-subsistence agriculture in Kenya.

RECOMMENDATION

Research is needed to identify current adaptation strategies, assess their viability and build on them for future adaptation. The adaptive local capacity becomes the foundation for designing future technologies. A multi-disciplinary research for instance, investigating crop diversification where a cereal crop, legume and a root or tuber crop are integrated. Secondly how rotation mechanism crops could sustainability meet the current and future climatic challenges and considering the ecological, economical and social political dimensions.

Potatoes and sweet potatoes are acknowledged as an important crop both as food security and within the soil fertility improvement program. However, a detailed study investigating the social cultural aspects and marketing of these crops that hinder their production could be important step towards improving their value in the region.

An approach toward higher levels of integration and involvement of farming communities and scientific communities needs to be encouraged in adaptation science. This is essential in unveiling the complexity of the agricultural systems within the smallholder and semi-subsistence farmers. This is from dialogues, field implementation and research, policy formulation and implementation.

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APPENDICES

Appendix 1: Discussion guide during Focused Group Discussion

Focus group discussion, observation, informal and formal discussions)

TOOL 1: History and Current CC information

a. How does the current middle level farmer understand climate change?
b. What are the specific things that guide the farmers in making agronomic decisions? I.e. local knowledge, rainmaker, culture beliefs etc?
c. Do farmer use weather forecast information?
d. With the knowledge on climate variability what does the farmer do to ensure agriculture remains a source of livelihood?

TOOL 2: Adaptation Practices and decision making process

e. What is the farmer doing to fight the climate variability and expect harvesting?
f. What has changed in the farming systems

TOOL 3: Technology application

g. Does the farmer have any other relation with agro technology seed developed by research organisations? E.g. hybrid maize or sorghum
h. What is the role of potatoes and sweet potato in his adaptation process?

TOOL 4: Potato and sweet potato technologies

i. What kind of knowledge and information does the farmer know about new sweet potato variety developed by research organisation?
j. How does the farmer use new potatoes and sweet potato varieties in the efforts of reducing his vulnerability to climate change?

Appendix 2: FORMAL HOUSEHOLD INTERVIEW: SHEET NO. …..

Coordinates …………………………Altitude……………………………

Introductory statement

This research survey is conducted as a requirement of the MSc requirement from Wageningen University. It is in collaboration with the International Potato Centre which is currently conducting climate change adaptation research in the area. The aim of the interview is to do an in-depth study of the role of technology in facilitating farmers adapt to challenges of climate change

Name: ……………………………Sex………. age ………………date………..……

Village……………………sub-location……………….….Division………………

Education level (a) primary, (b) secondary, (c) collage (d), University

A. GENERAL INFORMATION

What are the main sources of livelihood in the family?

1. How big is your farm?

a. ………<1acre, b………<3acres, c……………<5acres, d…………>5acres

2. Agriculture
    a. Sale of agricultural products from own farm, 1. Maize 2. Beans, 3. Potatoes, 4. Sweet potatoes or others specify…………………..
    b. Sale of livestock products:
       1. Manure,
       2. Milk,
       3. Raise bulls for Slaughter,
       4. Others ………………
    c. Sale of crop residues…………………………………….which one?
    d. Sale of fodder crops like Napier grass
3. Enterprises related to agriculture not produced from own farm, buys and sells
   What and from where? ………………………………………….
4. Enterprises from sale of forest and forest products: trees which one (Exotic or indigenous) name……………………… and as what? Logs, timber, firewood or charcoal
5. Other sources of income: - causal labourer, salary, shop, small entrepreneurship. Give details ……………………………………………….

B. PLANTING DATA FOR THE SHORT RAIN PERIOD (OCT- DEC)

1. During this season what crops did the farmer plant? 1. Maize 2. Beans 3. Sweet potatoes 4. Potatoes others specify……………..

2. What period (in the planting season) was each crop planted? 1. 1 week before the rains, 2. 1 week after the rain 3. Over 3 weeks after the rains. Give reasons to the farmers decisions regarding the decision on the planting time. Dates if possible.
   a. Maize ………………………………………………………………
   b. Beans………………………………………………………………..
   c. Potatoes…………………………………………………………………
   d. Sweet potatoes……………………………………………………..
   e. Others……………………………………………………………….

3. What long term cash crops are in the farm, what proportion of the farm do they occupy? 1. Less than ¼, 2. Less than ½, 3. Up to ¾ 4. none
   a. Coffee ………..
   b. Tea…………….
   c. Miraa………….
   d. Macadamia……….

4. What proportion of land is under food crop cultivation or acres.....................?

   1. Less than ¼, 2. < ½, 3. Up to ¾ 4. None

5. What percentage or proportion of the specific crops in relation to the farm size? What is the reason behind the decision?

Crop	Proportion	Reason
a. Maize	……………………	……………………………………
b. Beans	……………………	…………………………………….
c. Potatoes	………………….	……………………………………..
d. Sweet potatoes	……………	………………………………………..
e. Others	…………….	………………………………………..

6. How was labour organised? How many people were used in planting each crop and what was the wage paid per day and in total?

Crop	How many people	Wage/person	Total
a. Maize	……………………	…………	……….……..…
b. Beans	……..……………	..………….	….………..….
c. Potatoes	….………………….	..………….	………………..
d. Sweet potatoes	……………………	…………..	……….……..
e. Others	………..….…………	….…………	….……………..

7. Who decided what to plant and where to plant in relation to the four crops?
    a. Maize
    b. Beans
    c. Potatoes
    d. Sweet potatoes

8. Is there a particular ownership of these crop planted to any individual person in the homestead? Give details in terms of

Activity	maize	beans	potatoes	S. Potatoes
Who planted				
Crop Mgment.				
Sales determination				

9. Did you use any local weather prediction to determine exactly when to plant,
    1. Yes 2. No
10. Which one and give reason and details of how it was with dates if possible.
    a. Dragon flies………………………………………………………
    b. Moon…………………………………………………………..
    c. Wind…………………………………………………………
    d. Muvuti tree…………………………………………………….
    e. Others………………………………………………………….

11. How reliable was it? Did it work as predicted? Give details
12. Did you hear on radio weather focus any information on probability that this year will be El-Niño season? 1. Yes 2. No
13. How where you prepared during planting in relation to weather prediction of El-Niño, emphases on the four crops in terms of
    a. Date of planting

    b. Seeds variety used,

    c. Fertiliser application and

d. Time of purchase of farm inputs, before the rain or at the onset and

e. Where purchased.

14. How was it (potatoes and sweet potatoes) planted: describe the process and the reason to each process?

Potato:- land preparation

a. Location of land, reason for choice

b. Tools used

c. Method of ploughing

d. Time of land preparation

Potato Planting:

a. Seed source

b. Planting processes,

c. Planting rates;

d. Type of fertiliser or manure used, rates used,

e. Mulching or not, material used and reasons for choice of the material

Potato:- Disease & pest management while the crop is in the field

Sweet Potato:- Land preparation;

a. Location of land where SP was planted, Reason,

b. Tools used,

c. Method of ploughing,

d. Time of land preparation

Sweet potato: - Planting

a. Source of planting material

b. Planting processes; ridges, furrows or flat area,

c. Type of fertiliser or manure used, rates applied,

d. Mulching or not, material used & reason for the choice of the material

Sweet Potato:- Disease & pest management while the crop is in the field

C. HARVESTING SEASON DATA FOR THE SAME PERIOD (OCT- DEC)

15. What trigged harvesting of the two crops? Maturity, economic or social reason.
    a. Potato

    b. Sweet potato

16. How where they harvested: describe the process & reasons behind the process?
    a. Potato

    b. Sweet potato
17. Are there any special or unique events in relation to harvesting of sweet potatoes and potatoes? E.g. Rituals, gifts, security, economic & social need.

18. How do farmers in general compare the crop yield in this season with yield during the March 2009 long rain season? This is based on farmers' ways of measuring?

19. How do farmers relate the yield in this season with experienced rainfall?

20. What do farmers plan to do with the harvested, potatoes and sweet potatoes? For subsistence, Sale as seeds, to who? Sale to the market how?
    a. Potatoes

b. Sweet potatoes

21. Where do farmers store their potato and sweet potato? Is there any treatment involved?
    a. Potatoes

    b. Sweet potatoes

22. How is it consumed or cooked? And how often, through out, or harvesting season or months after harvest.
    a. Potatoes

    b. Sweet potatoes

D. SWEET POTATO & POTATO AS ADAPTATION TECHNOLOGIES

23. What kind of good agronomic practices known to the farmer goes along with sweet potato and potato production? e.g. soil type, rotation, planting time, mulching etc

24. How does the farmer relate maize production to potato and sweet potato production, social economic, cultural, land & farming plans and other issues
    a. Potatoes

    b. Sweet potatoes

25. How is Sweet potato & potato ranked in relation to other crops grown in the area? Rank the crops based on importance criteria of the farmer.

26. What external input must be available for the production of both potatoes and sweet potatoes? A must have for production to go on.
    a. Potatoes

    b. Sweet potatoes

27. What was the yield performance of the 4 crops for a period of 5 seasons?

year	Long rains				Short rains			
crops	**Maize**	**beans**	**potatoes**	**S. potatoes**	**maize**	**beans**	**potatoes**	**S. potatoes**
2009								
2008								
2007								
2006								
2005								

28. Is there any particular yield trend noticed by the farmers? details
29. What could be a general possible reason of yield variability across the seasons and years? If increase or decrease.
30. What is the likelihood of success if improved sweet potato & potato varieties are used as an adaptation strategy to climatic change such as reduced rainfall to reduce the vulnerability of communities in Embu?
    a. Potato 1. Very successful 2. So so/half half 3. No success
    b. Sweet Potato 1. Very successful 2. So so/half half 3. No success
31. At household levels, what do farmers think about
    a. Climate change,
    b. Climate variability,
    c. its causality and
    d. Predictability?

How do farmers in Embu access their own vulnerability to climate change? Use of decision tree, if rainfall goes on decreasing and we expect lower than average rainfall scenario. What kind of adaptation decision will farmer have to make?

Appendix 3: Contacts

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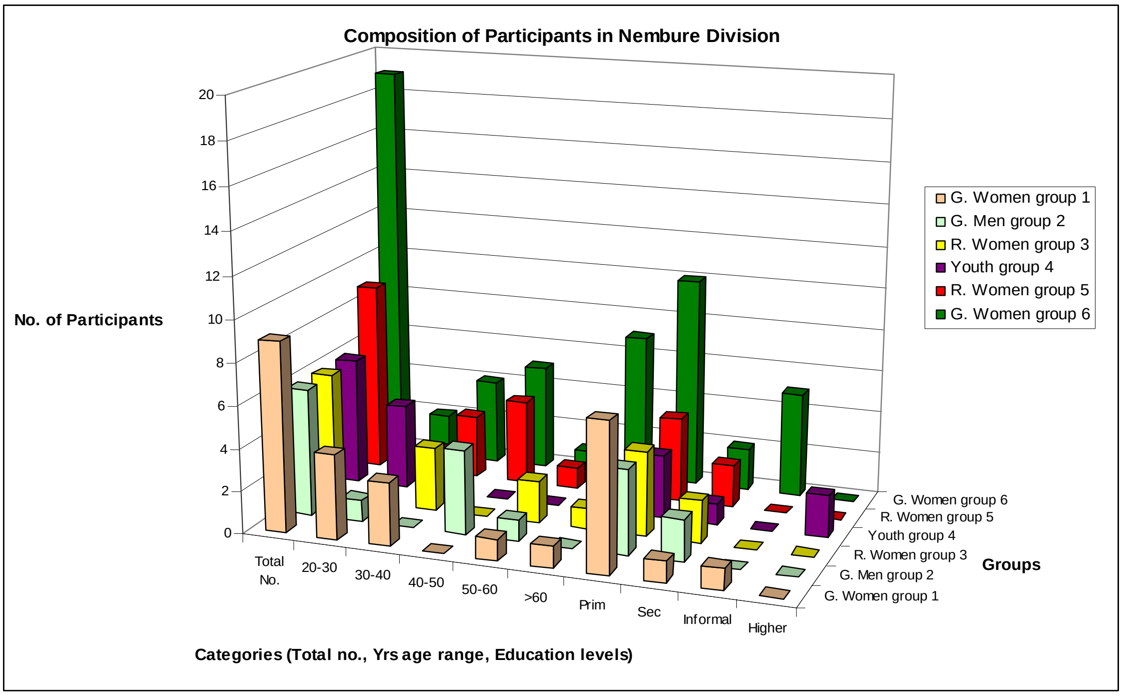
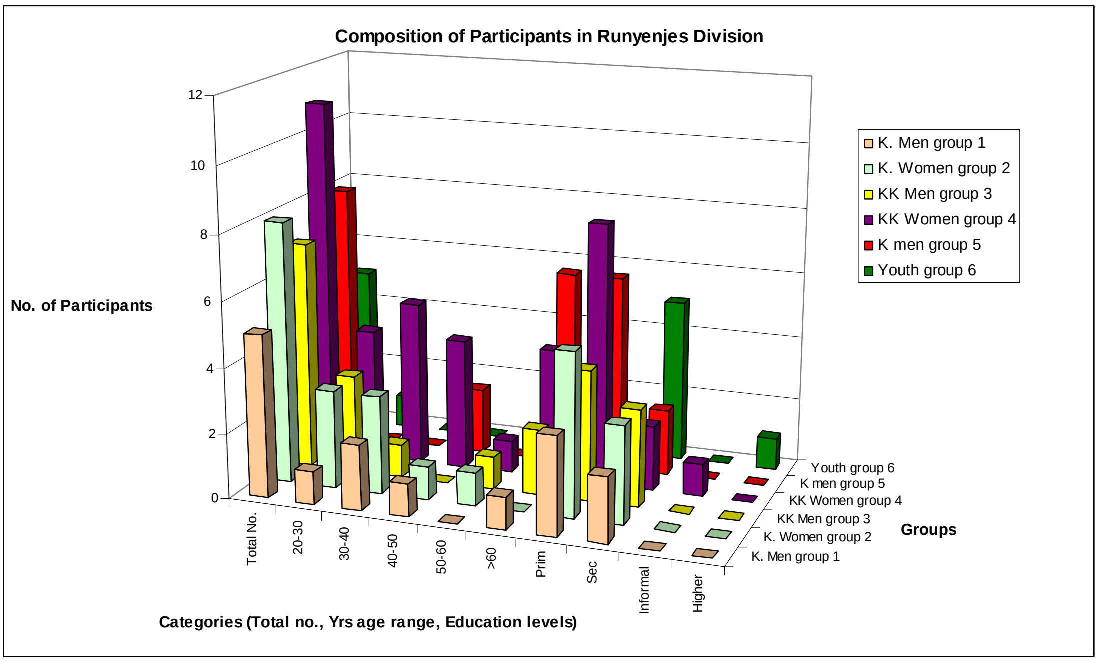
Appendix 4: Participants profile

Composition of participants in Nembure division, based on aged & education level



Composition of participants in Runyenjes division, based on aged & education level



Age: The age of the participants during the FGD ranged from 22 to 90 years, with the highest representation being age group 30-40 (27%) and the lowest age group 50-60 with 7%.

Education: 50% of the participants had basic primary education, 100% of the participants with informal education were aged over 60 years, only 3 participants had higher education.

Gender: Women dominated the FGD (68%), household interviews 56% female & 44% male