AGRO-ECOSYSTEMS' RESILIENCE TO DAMAGE: DETERMINATION OF INDEX OF SUSCEPTIBILITY TO CLIMATE CHANGE IN MOUNT KILIMANJARO, TANZANIA.

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AGRO-ECOSYSTEMS' RESILIENCE TO DAMAGE: DETERMINATION OF INDEX OF SUSCEPTIBILITY TO CLIMATE CHANGE IN MOUNT KILIMANJARO, TANZANIA.

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CERTIFICATION

The undersigned certifies that he has read and hereby recommends for acceptance by the University of Dar es Salaam a dissertation entitled: ***Agro-Ecosystems' Resilience to Damage: Determination of Index of Susceptibility to Climate Change in Mount Kilimanjaro, Tanzania***, in fulfilment of the requirements for the degree of Master of Science (Climate Change and Sustainable Development) of the Centre of Climate Change Studies, University of Dar es Salaam.

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DECLARATION AND COPYRIGHT

I, **Shirima Kelvine**, declare that out of quotes and other people's work of which I have consulted and acknowledged this thesis is the result of my original research work. This work has not been presented and will not be presented to any other University for a similar or any other degree award.

Signature…………………………………….

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ABSTRACT

This paper assesses maize-coffee-banana agro-ecosystems' resilience to damage as well as computing the social-ecological vulnerability index to climate change on the southern slope of Mount Kilimanjaro in Tanzania. The study focused on identifying agronomic practices and assessing their impacts on agro-ecosystems' resilience; examine the socio-economic status of the farmers in the region and its impacts on agro-ecosystems; and examine the agro-ecosystems' natural resilience and assess social-ecological vulnerability index to the impacts of climate change.

About 400 households was covered in this household survey with response rate of 97% where by farmers were asked on their farming practices and systems, key informants and transect walk was also employed in gathering necessary information. Study was carried out at a specific designed transect for a selected part of Kilimanjaro region between Kisangesangeni-Miwaleni (700 m.a.s.l) and Makunduchi/Kirua Vunjo (1600 m.a.s.l) of about 21.7 km long at the southern part of Mount Kilimanjaro in Moshi rural district. The study shows a significant variation in agronomic practices with altitude and lack of sufficient agro-ecosystem resilience framing like conservation agriculture including agro-forestry, conservation tillage, contouring and terracing, mulching, Mix-intercropping, and fallowing to mention a few; pest and disease control, soil conservation infrastructure, and off farm diversification were also key challenge to farmers. Social-ecological and economic Parameters was used in computation of vulnerability index. Because of variation in altitude which associates with different in microclimate and soils, the vulnerability also varied with altitude. Elements like household cooking energy (94.8%), agriculture as main source of household income (94.5%), off farm contribution to the household (34%) etc. has shown to have some implication on household on choosing alternatives options on adaptations.

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LIST OF ABBREVIATIONS

CBD	Coffee Berry Disease
CCA	Climate Change Adaptation
DRM	Disaster Risk Management
FAO	Food and Agricultural Organization
FR	Functional Relation
GDP	Gross Domestic Products
GNI	Gross National Income
GNP	Gross National Product
HDI	Human Development Index
IPCC	Intergovernmental Panel on Climate Change
KNCU	Kilimanjaro Native Cooperative Union
LPG	Liquefied Petroleum Gas
M.a.s.l	Metres above sea level
MSc.	Masters of Science
SACCOs	Saving and Credit Cooperatives
SPSS	Statistical Package for Social Scientists
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
URT	United Republic of Tanzania
VI	Vulnerability Index
WFB	World Fact Book

INTRODUCTION

1.1 Background

The Intergovernmental Panel for Climate change (IPCC) Fourth Assessment Report cleared the doubt against the existence of climate change by proclaiming that warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level (IPCC, 2007).

Climate change has gained momentum as a field of concern for the 21st Century whereby scientific community has reviled the persistence of change in hydrosphere and biosphere due to atmospheric alteration which is said to be exacerbated by the functions of anthroposphere. Anthropogenic activities have been said to increase the quantity of greenhouse gases, especially CO_2, which contribute to excessive global warming and threaten the living condition of both terrestrial and aquatic biodiversity.

"The current debate on climate change, its impacts on socio-ecological systems and the role of agriculture has shifted from an emphasis on how to mitigate the effects of increasing greenhouse gases emissions to how to prepare and adapt to the expected adverse impacts" (Thomas *et al*., 2007).

One suggestion for measuring vulnerability is to use poverty as a proxy for household welfare, and measure the degree to which households or individuals are susceptible to and unable to cope with adverse impacts of climate change as a change in poverty status or change in depth of poverty. Second suggestion, is the use econometric analysis to estimate either expected poverty measures or expected utility measures of vulnerability to a shock.

Agro-ecosystems in which humans manage and use communities of plants, animals, their biophysical environment, and their interactions (Gomiero *et al*., 2006) can be considered as social-ecological systems. In most modern agro-ecosystems, the native ecosystem has been replaced and has been dominated by humans over long periods of time (van Aperdoom *et al*., 2011). Although globally modern agro-ecosystems are seen as the epitome of non-resilience with their monocultures and energy-intensive farming practices (Holling and Meffe 1996), they are highly resilient at farm-field level. It is, therefore, important to consider the temporal and spatial parameters in determining the resilience of any particular agro-ecosystem taking into account the farming system, input and management employed over time.

Conventional farming differs from organic farming, as the latter responds to site-specific agro- cultural conditions by integrating biological and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity; rather than using synthetic fertilizers, pesticides, growth regulators and livestock feed additives, organic farming systems rely on crop rotation, animal and plant manures as fertilizers, some hand weeding and biological pest control (Williams, 2002).

The more diverse the agro-ecosystems and the longer this diversity remains undisturbed, the more internal links develop to promote greater insect stability. Therefore, any changes on the levels of plant diversity in such systems can lead to disruptions of natural pest control mechanisms, potentially making farmers more dependent on pesticides (Kakar, 2011).

Susceptibility is the concept which is used interchangeably with vulnerability. According to Adger (1999), vulnerability is the extent to which a natural or social system is susceptible to sustaining damage from climate change but vulnerability of a system can be determined by the nature of a system itself.

Resilience can be referred to as *"capacity of a system to experience disturbance and still maintain its ongoing functions and controls''* (Holling and Gunderson, 2002, P. 50). The resilience of a system can be determined by its exposure and vulnerability to internal or external shocks.

1.2 Statement of the research problem

During the course of this century the resilience of many ecosystems is likely to be exceeded by an unprecedented combination of change in climate and in other global change drivers (especially land use change and overexploitation), if greenhouse gases emissions and other changes continue at or above current rates (IPCC, 2007). By 2100 ecosystems will be exposed to atmospheric CO_2 levels substantially higher than in the past 650,000 years and global temperatures that will be the highest in 740,000 years. These two factors will alter the structure, reduce biodiversity and perturb functioning of most ecosystems, and compromise the services they currently provide (IPCC, 2007). On the other hand, these may also present some opportunities to some ecosystems by enhancing favourable conditions for survival.

Tanzania's economy depends on agriculture, which accounts for more than one-quarter of GDP, provides 85% of exports, and employs about 80% of the work force (WFB, 2013). Most interesting observation is that in Kilimanjaro, which is considered to be the main coffee producing region in Tanzania, cash income from coffee appears to be a very small share of total cash income among coffee producing households (a mere 8.7% of total cash income of coffee producers) (Sarris *et al*., 2006).

In addition to coffee the other cash crops grown there are sugar cane, sisal, pyrethrum and cotton. Kilimanjaro Region is also important in terms of food crops such as bananas, beans, rice and millet. Since the 1970s, generational fragmentation of peasant farms in Kilimanjaro has increased in the case of a positive demographic growth. In such situations, potential coffee farmers (i.e., the sons of older peasants) are likely to abandon coffee farming in lieu of other activities and to remain on their parents' tiny farms only as a last resort (Maghimbi, 2007).

Agro-ecosystems are different from natural systems in that there must be an intervention by humans for the system to meet our needs (Cabell and Myles, 2012). In this case, the interaction of human and natural environment would affect each other either negatively or positively. Therefore, how these interactions are going to cause either of them to compromise or lower the performance or its existence is the question to be addressed by this study. Studies have been done on agro-ecosystems' resilience, yet most of these have been done in dry land ecosystems outside the African context. This calls for urgent research on the African context where agro-ecosystems are said to be most vulnerable to climate change. This study will be undertaken in mountainous agro-ecosystems of Kilimanjaro Region in Tanzania whose resilience and susceptibility are yet to be well documented.

1.3 Objective of the study

The main objective of this study is to assess a maize-coffee-banana agro-ecosystems' resilience to climate change focusing on Kilimanjaro Region, Tanzania.

1.3.1 Specific objectives

i. To identify the farming practices of Kilimanjaro Region and assess their susceptibility to the impacts of climate change.

ii. To examine the socio-economic status of the farmers in Kilimanjaro Region and assess their capacity to adapt to the impacts of climate change.

iii. To examine the agro-ecosystems' natural resilience and assess their susceptibility to the impacts of climate change.

1.3.2 Research questions

i. What are the farming practices of Kilimanjaro Region and their susceptibility to the impacts of climate change?

ii. What are the socio-economic status of the farmers in Kilimanjaro Region and their capacity to adapt to the impacts of climate change?

iii. What is the agro-ecosystems' natural resilience and their susceptibility to the impacts of climate change.

1.4 Significance of the Study

This study significantly aims to disclose information on climate change impacts to ecosystem services and help policy and decision makers in formulating smart strategies to deal with them in site specific. Also it aims to enhance awareness to local communities and extension officers about their social-economic practices on the environment and their associated impacts on agro-ecosystem taking in to account the resilience of agro-ecosystem. Meanwhile, the study aims to come up with the information on the extent to which the agro-ecosystem is vulnerable and inform the local ecosystem managers on how to reduce vulnerability of that system.

LITERATURE REVIEW

2.1 Introduction

This section describes the secondary data about the situation of agriculture in Kilimanjaro and Tanzania in general with reference to its challenges especially climate change which is of no doubt unequivocal. Also it pinpoints the resilience issues and index of behavioural based to agro-ecosystems and its interaction to social ecological systems.

2.2 Agriculture and Climate Change in Tanzania

Agriculture is clearly one of the most important sectors of the Tanzanian economy. It comprised 45.1% of GDP in 2000 (World Bank, 2002). Upwards of 80% of the population of the country relies directly on agriculture of one sort or another for their livelihood. The three most important crops are: maize, coffee and cotton with maize being a major food staple, coffee a major cash crop grown in large plantations (and contributing significantly to the GNI), while cotton is another cash crop grown largely by smallholder farmers (Agrawala *et al*., 2003).

Widespread social and economic changes in the peasant society and regionally as a whole have led to a decline in coffee production in Kilimanjaro since the 1970s, despite the fact that coffee is its principal cash crop (Maghimbi, 2007). The argument is made that wider institutional changes, in addition to internal changes in peasant households, have contributed to the decline of coffee and the rise of maize and rice as the principal crops and Kilimanjaro peasants now produce only about 5,000 tons of coffee per year, which is less than half the yearly amount produced, on average, between the 1950s and the early 1990s (*ibid*).

A number of studies conducted recently in Tanzania have recognized that climate change and variability is happening and is coupled with significant impacts on these natural resources, including agriculture which is the main source of livelihood in rural areas (Agrawala *et al*., 2003; Majule, 2008). Recent research suggests that, along with other East African countries, climate change is having significant impacts on Tanzania (Mwingira *et al.,* 2011). "*Deteriorating water quality and quantity, loss of biodiversity and declining agricultural productivity due to climate change, are no longer potential threats but rather actual threats that have already materialized and caused Tanzanians repeated misery"* (Yanda, 2005).

So far the government of Tanzania has realized that dealing with climate change requires local, regional and international efforts as both the causes and effects of climate change recognize no geographical boundaries (IPCC, 2001). The country has taken some steps in addressing the issues of climate change in its widest sense and it has ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1996.

Policies on natural resources of the country are also not framed well, specifically to suit local areas rather they are too general to cater for designated local variability. Land ownership is also a factor affecting the agricultural sector in Tanzania. For example, the institution of land tenure for Tanzanian peasants has been weak since the days of colonialism. Because the male children must share their father's land, a peasant coffee farm in Kilimanjaro dwindles in size with each generation, especially when the father has no land other than the mixed coffee/banana farm where the family lives (Maghimbi, 2007). Farms have dwindled in size to the point that the returns for most peasants are likely to be very small, even if/when prices are fair or high (*ibid*).

2.3 Agro-Ecosystem and Social-Ecological Resilience

"Agro-ecosystem can be defined as an ecosystem managed with the intention of producing, distributing, and consuming food, fuel, and fibre. Its boundaries encompass the physical space dedicated to production, as well as the resources, infrastructure, markets, institutions, and people that are dedicated to bringing food to the table, fibre to the factory, and fuel to the hearth" (Cabell and Myles, 2012).

The primary purpose of assessing resilience is to identify vulnerabilities in social-ecological systems so that action can be taken to create a more sustainable future for people and the land (Berkes *et al.*, 2003). Essentially, building resilience gives agro-ecosystems the capacity to maintain the ability to feed and clothe people in the face of shocks while building the natural capital base upon which they depend and providing a livelihood for the people who make it function (Berkes *et al.*, 2003).

Complex agro-ecosystems are able to adapt and resist the effects of climate change. Many studies show that small-scale farmers who follow agro-ecological practices, cope with, and even prepare for, climate change, thus minimising crop failure (Altieri, 1999). Results from studies like Natarajan and Willey (1986) on polyculture, Linda and Abdulai (2012) on organic certification suggest that these practices provide a higher resistance to climate events reduce vulnerability and make farms more sustainable in the long term. Based on this evidence, various experts have suggested that reviving traditional management systems, combined with the use of agro-ecological principles, may represent the only viable and robust path to increasing the productivity, sustainability and resilience of agricultural production (Altieri and Clara, 2013).

"Data from nearly three decades of research trials indicate that wide-scale implementation of established, scientifically researched and proven practical farming methods will change agriculture from a global warming contributor to a global warming inhibitor, from a problem to a solution" (LaSalle, 2008:5). Similar, but more detailed studies, are required to develop plausible predictions of local impacts as the current models tend to operate at greater scales (regional and global) that are not particularly useful for any one locality. This remains a great challenge for developing countries that lack the appropriate know how and human capacity (Thomas *et al*., 2007) and appropriate social economic and natural capital to manipulate their surroundings for their better living standard.

2.4 Index of Behaviour-Based Indicators on Agro-Ecosystems Resilience

Darnhofer *et al*., (2010) affirm that developing sets of surrogates or indicators, as suggested by Bennett *et al*., (2005) and Carpenter *et al*., (2006), is a more useful approach to assessing resilience than trying to measure resilience itself. Cabell and Oelofse (2012) identified thirteen behaviour based indicators from resilience literature but only about five of them will be discussed hereunder. As is the case with other indicators, systems in which they are present are more likely to be resilient to shocks of vulnerabilities or indicate movement away from resilience. The following are some of those surrogates or indicators:

2.4.1 Socially self-organized

Carpenter *et al*., (2001:778) argue that the degree of self-organization in a given social-ecological system is assessed by the extent to which the system managers force a particular configuration as opposed to the components of that system arranging them. Less interference allows the system to settle into a configuration that is "diverse [and] persistent." The manipulation of the land in the form of tilling, planting, weeding, and harvesting is in a sense a repeated disturbance (Ohlander *et al*., 1999).

2.4.2 Ecologically self-regulated

A self-regulating agro-ecosystem, as with any ecosystem, relies on the work of regulating ecosystem services. It relies on the hydrological cycle, biodiversity, and soil resources upon which terrestrial communities depend (Carpenter *et al*., 2006). "*These regulating services provide the feedback mechanisms that make a system responsive and capable of adapting to both internal and external changes"* (Cabell and Oelofse, 2012).

2.4.3 Appropriately connected

This refers to the dynamic relationships between elements within a system and between systems across spatial and temporal scales (*ibid*). Number and strength of connections within a system and between systems can determine its capacity for adaptation, transformation, and overall responsiveness to changes, thus influencing the system's degree of resilience (Gunderson and Holling, 2002). Appropriate connectedness appears as: farmers collaborating with multiple suppliers and multiple outlets, including consumers, rather than just one; flexibility in laws that enable producers to adapt their practices to local and changing conditions; and access to a labour pool with a wide range of skills changes (Cabell and Oelofse, 2012).

2.4.4 High degree of functional and response diversity

Functional diversity refers to the variety of elements and the ecosystem services they provide within the social-ecological system (Moonen and Barberi, 2008). Each element has a different job in making the system work. Response diversity, as defined by Elmqvist *et al*., (2003:488), is *"the diversity of responses to environmental change among species that contribute to the same ecosystem function."* An agro-ecosystem that contains a high degree of response diversity will be more resilient against various types and degrees of natural and man-made shocks (*ibid*).

2.4.5 High degree of spatial and temporal heterogeneity

Heterogeneity in an unmanaged landscape results from the work of both biotic and abiotic actors. In agro-ecosystems the drivers of heterogeneity are more directly anthropogenic. Di Falco and Chavas (2008), argue that an agro-ecosystem with a heterogeneous pattern of land uses and crops, including crop varieties, is more resilient against future climatic changes. A temporal aspect of heterogeneity involves shifting cultivation which allows the long rest of the land and encourages biodiversity recovery over time which may facilitate the regeneration of natural enemy and in turn maintain the biological pest control.

MATERIAL AND METHODS

3.1 Introduction

The following chapter provide information on the characteristics and location of the area under study, methods and techniques used in conducting this study. The chapter is divided in to three sections; first section providing the description of the study area; the second section describes different data collection techniques used during field survey. The last section describes data analysis and presentation of findings.

3.2 Study area

This study was carried out at a specific designed transect for a selected part of Kilimanjaro region between Kisangesangeni-Miwaleni and Makunduchi/Kirua Vunjo of about 21.7 km long (3^0 28′ 0′′ S to 3^0 16′ 0′′ S) and about 2 km wide (37^0 30′ 0′′ E to 37^0 26′ 0′′ E) which is located in Moshi Rural District.

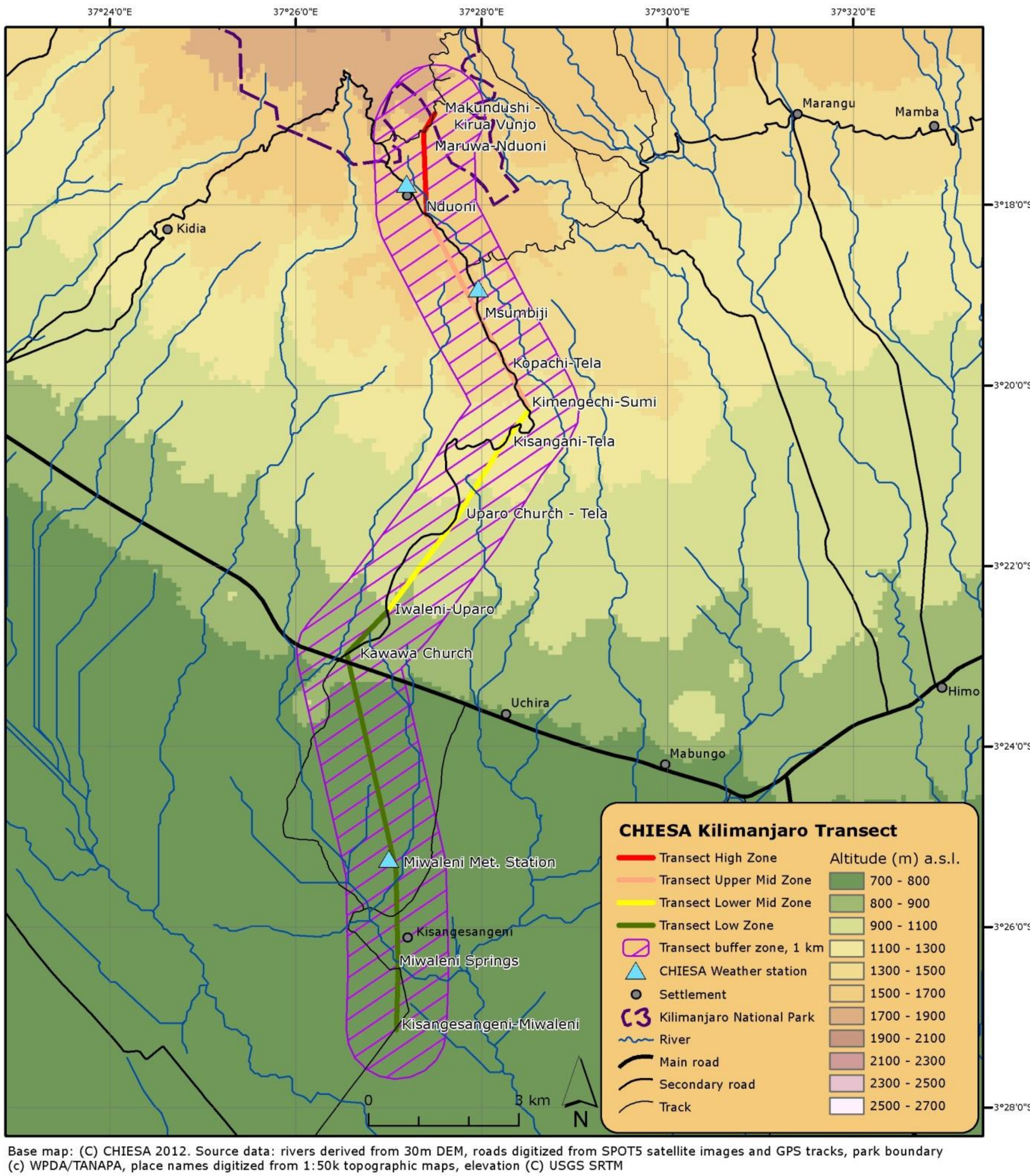
3.2.1 Geographical location

Kilimanjaro Region is one of Tanzania's thirty administrative regions situated in north-eastern Tanzania. The region is contiguous with the Republic of Kenya to the north, to Tanga Region in the south-east, to Arusha and Manyara Regions to the west and south-west, respectively. Kilimanjaro Region is administratively divided into seven districts, namely Hai District Council, Moshi District Council, Moshi Municipal Council, Mwanga District Council, Rombo District Council, Same District Council, and Siha

District Council. The regional capital is the Municipality of Moshi. According to the 2012 national census, the region had a population of 1,640,087 inhabitants (URT, 2013).

Map 1: ***The map of study site***

***Source*:** Chiesa geo-network site



Map 2: ***CHIESA, Kilimanjaro study area (Down from Kisangesangeni to Makunduchi Kirua Vunjo).***

Source**:** Chiesa geo-network site

3.2.2 Climate of the area

In Kilimanjaro region the year is divided into four seasons with respect to the amount of rainfall. Two rainy seasons of April to May as major and a minor one in September to November, and two dry seasons, a major one in December to January and a minor one in July to August mark seasonal variations due to largely influence of the Inter-tropical Convergence Zone (ITCZ). There is marked variation in the amount of rainfall according to altitude and the direction of the slope in the mountainous areas of Kilimanjaro Region. The mean annual rainfall varies from 500 mm in the lowlands to over 2000 mm in the mountainous areas of this region (over 1600 meters above sea level) (URT, 1998).

Temperatures are closely related with altitude. During the rains, more cloud cover and evaporative cooling tend to reduce maximum temperatures and cloud cover tends to raise minimum temperatures; hot seasons lasts from October to March with high humidity; temperatures going up to 40^0C the lowlands of the region (URT, 1998). In the mountainous areas temperature ranges from 15^0C to 30^0C while the soils of the region varies; there are alluvial soils which are good for crops cultivation through irrigation farming due to unreliability of rainfall of these areas (URT, 1998).

The Kilimanjaro region is divided in to four ecological zones based on altitude, soils, moisture and climate. The zones include the peak of Kilimanjaro Mountain, Highlands, Intermediate (middle) and Lowland/Savannah Plains (Tambarare) Zones (URT, 1998).

The peak zone lies between 1,800 and 5,895 meters above sea level and normally it receives annual rainfall of more than 2000 mm. The area between 1,800 and 2,400 meters is gazetted both as the Kilimanjaro National park and Forest reserve. Due to its altitude and weather conditions, it is uninhabited while the highlands zone lies between 1,000 and 1,800 meters above sea level with annual average rainfall falls between 1250 mm and 2000 mm and temperature range of between 15 ^{0}C and 20 ^{0}C (URT, 1998).

Intermediate zone lies between 900mm and 1100 meters above sea level and receives annual rainfall ranging between 800mm and 1250 mm. It has a moderate soil fertility which is good for coffee plantations, bananas, maize, and beans and also suitable for dairy cattle, goats, pigs, rabbits and poultry farming of which is the economic activities of the indigenous of this area. Lowland zone lies below 900 meters above sea level and has an average annual rainfall of between 700 and 900 mm, while temperatures are above 30 ^{0}C (URT, 1998). Common crops grown in this zone include maize, cotton, rice, sorghum, cassava and pigeon peas.

3.2.3 Land and land use in Kilimanjaro

The region has an area of square km 13,209 of which are divided by land use of five categories as indicated in table 1 below.

Table 1: ***Distribution of the area and land use for Kilimanjaro region***

APPLICATIONS	AREA (Km^2).	PERCENTAGE (%)
Arable land	6,433	48.7
Game reserve	3,051	23.1
Parks and Pastures	2,018	15.3
Forest	1,403	10.6
Water	304	2.3
TOTAL	**13,209**	**100**

Source: URT, 1998

3.2.3 Demographic characteristics of the region

The population in Moshi Rural District has been increasing over time since 1967 and so has been the population density of the district. While in 1967 the population was 241,490, it has reached 504,287 by the year 2002 (William, 2003), but 2012 Population and Housing Census for United Republic of Tanzania found the population of Moshi Rural District to be 466,737 which mark the decline since 1997. The decline may have been caused by natural decrease and out migration in search for livelihood elsewhere outside the region.

3.3 Study Design and Sampling Design

The study employed the cross-sectional study design. In this type of research study, either the entire population or a subset thereof is selected, and from these individuals, data are collected to help answer research questions of interest (Olsen and Daine, 2004). However, this cross-sectional design used household survey closed questionnaires to collect socio-economic characteristics of the respondents, and details regarding agriculture practices, opportunities and challenges.

In this study three sampling procedures was undertaken, namely purposive sampling, simple random and proportionate sampling. In purposive sampling farmers were selected across the transect. In selecting households (400 households) to be interviewed, a simple random sampling was employed to obtain representative households across the transect. Proportionate sampling was used to select villages across the transect, whereby the longevity and number of villagers within the zone determined the number of villages and respondents to be interviewed. A total of six villages were sampled along transect, these villages include Nduoni (in the upper zone), Iwa village (in the mid upper zone), Uparo village (in the mid lower zone), Yamu Makaa village, Uchira village and Kisangesangeni village (in the lower zone). A total of 400 households were proportionately chosen along the transect to provide an equal representation whereby the lower zone provided 150 household representation whereby three villages namely Kisangesangeni (530 households), Yamu Makaa (777 households), Uchira (600 households) was involved. The mid lower zone involved one village (Uparo) which had 747 households and provided 100 households as a sample. The mid upper provided 100 households as a sample from one village (Iwa) having a total of 528 households and the upper zone provided 50 households representation out of 625 households in Uparo village. Sampling intensity differed according to longevity of the zone and number of villages it contains. Meanwhile the response rate of the survey was 95.75% when 383 households participated fully, but addition of seven household was added to make up

400 households as a planned sample. One field assistant and one research assistant were involved in the data collection process which lasted for two months, i.e. March and April, 2014.

3.4 Methods Used in Data Collection

Basically there were two types of data collected, namely secondary and primary data. Secondary data were obtained from different resourceful literatures. Different documents related to the study were explored for in depth understanding of how far the problem had been studied. The sources included books, journals and unpublished literatures from the internet. Secondary data also gave an insight of what had not been covered about the research problem.

Primary data are findings from the field. The following were the methods that were used in collecting primary data from the field. These included household questionnaires; key informants' interviews and transect walk/field observation. About 400 questionnaires collaboratively designed with the manager and 6 M.Sc. scholars under the Work Package 7 of the CHIESA Project were administered to households to obtain their understanding of the problem under investigation. The open-ended questions from discussion was purposely designed to allow the respondents to freely provide their views and understanding about the problem being investigated on the ground (e.g. the status of agro-ecosystem, ecosystem service flow over time and the sustenance of these services to the local population). The focus group discussions were undertaken by selecting six to eight discussants per each village by summoning them for two to two and half an hour. Three key informants (Village agricultural officer, Ward extension officer and District crop pest and disease specialist) were involved under interview for in-depth clarification of agriculture status of the study area.

Field observation was undertaken by the researcher and indicators like crop pest and diseases, soil and water conservation strategies on the farm sowing systems, type of crops and their management at plot level and estimation of output was used to counter-check the responses given by the respondents and it was based on judgement on the relationship between the social economic activities carried out by the indigenous farmers on the environment and how the environment and agro-ecosystem would be capable to endure and become resilient against its damage. In each zone some farms were traversed during transect walks and field observation. In the lower zone about eight farm plots were visited for this exercise. In the mid upper zone about four farm plots were traversed while in the mid upper and upper zone three plots were visited.

3.5 Data Analysis

Data from closed questions were analysed using IBM Statistical Packages for Social Sciences (SPSS) version 20 and Microsoft office Excel. The open ended questions were thematically analysed based the responses. Information collected through household surveys were summarized and put into descriptive statistics. Qualitative information collected through focus group discussions and key informant interviews was thematically analyzed and synchronized with household responses to add value to the information. Crop yield trend analysis from administrative offices was analyzed using

Microsoft Office Excel 2007 to present their patterns and trends in the form of graphs and tables. Findings from the analysis are presented in descriptive statistics, tables, charts, graphs, maps and photographs.

RESULTS AND DISCUSSION

4.1 Introduction

This particular chapter aims to analyse, describe, interpret and discuss the findings from the field data collected and its relationship with agro-ecosystem resilience to damage. Socio-economic parameters that lead to agro-ecosystems resilience to damage are also elaborated hereunder.

4.2 Socio-Economic Characteristics of Households

Among other things, the household survey was used to gather information such as age structure, gender status, education levels, primary and secondary occupation of households and how each of these factors determine the resilience of agro-ecosystem of the area under study and how they exacerbate the agro-ecosystem's vulnerability to climate change.

4.2.1 Gender characteristics

Very few cases of gender complications ware encountered in the field, and in this case the study was able to balance the gender representation between men and women of which 196 (49%) of male contributed to the survey and 204 (51%) of female were involved in it.

Gender may have influence on agriculture and other socio-economic parameters. In the study area, most of the households interviewed were headed by males, which is a usual tradition of most of African societies. Table 2 shows the gender distribution according to zone/altitude within the transect.

Table 2: ***Percent distribution of respondents by gender and zones***

Gender of respondents	Distribution by zones			
	(N=150) Lower zone	(N=100) Mid lower zone	(N=100) Mid upper zone	(N=50) Upper zone
Male	44%	54%	56%	40%
Female	56%	46%	44%	60%
Total	**100%**	**100%**	**100%**	**100%**

Source: Household Survey, May 2014.

2.4.2 Age structure of respondents

To ensure the validity and reliability of responses from the household survey, questionnaires were administered either to the heads of households or to adult children of a household. The minimum age was 23 years and maximum of 90 years with mean of 52.5 years and 14.6 standard deviation. Most of the respondents were aged between 25-54 years (57%). This was followed by middle aged of 55-64 years (22%). Only 20% was covered by elders aged 65 and above (Figure 1).

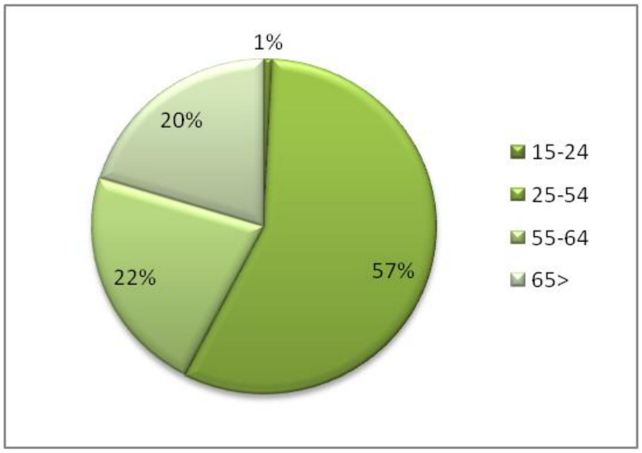


Figure 1: ***Age structure of the respondents***

Source: Field data, May 2014

4.2.3 Household size and dependence

The size of households in the surveyed villages varied across zones. Table 4 shows that 51% of the households along the transect had between 4-6 household members. More than 19% of households had 7-9 members, while 25.5% had 1-3 household members, only 0.8% of the households had between 10-12 members.

Table 3: ***Household size of respondents***

Household size	Percent (%) of households per zone			
	Lower zone	**Mid lower zone**	**Mid upper zone**	**Upper zone**
1-3	20	22	35	30
4-6	54	51	45	52
7-9	20	26	16	14
10-12	4	1	3	4
13-15	2	0	1	0
Total	**100**	**100**	**100**	**100**

Source: Field data, May 2014

Household size varied with zones, with households in upper zone and mid upper zone having fewer household members compared to mid lower and lower zones. The households having 1-3 members occupied 30% and 35% of the upper and mid upper zones, respectively. Households having 1-3 members occupied 20% and 22% of the lower and mid lower zones, respectively; with a relative difference of 23%. Households with 4-6 members covered 52% and 45% for upper and mid upper zones, respectively, while 54% and 51% of households having 4-6 members seen in lower and mid lower zone, respectively - a difference of 8%. Another remarkable variation can be seen in households having members between 7-9 which covered 14% and 16% in upper and mid upper zones, respectively, while in lower and mid lower zones had 20% and 26% respectively, showing a relative difference of 16%. Large household size creates high dependence on land which is limited and reduce its outputs over time.

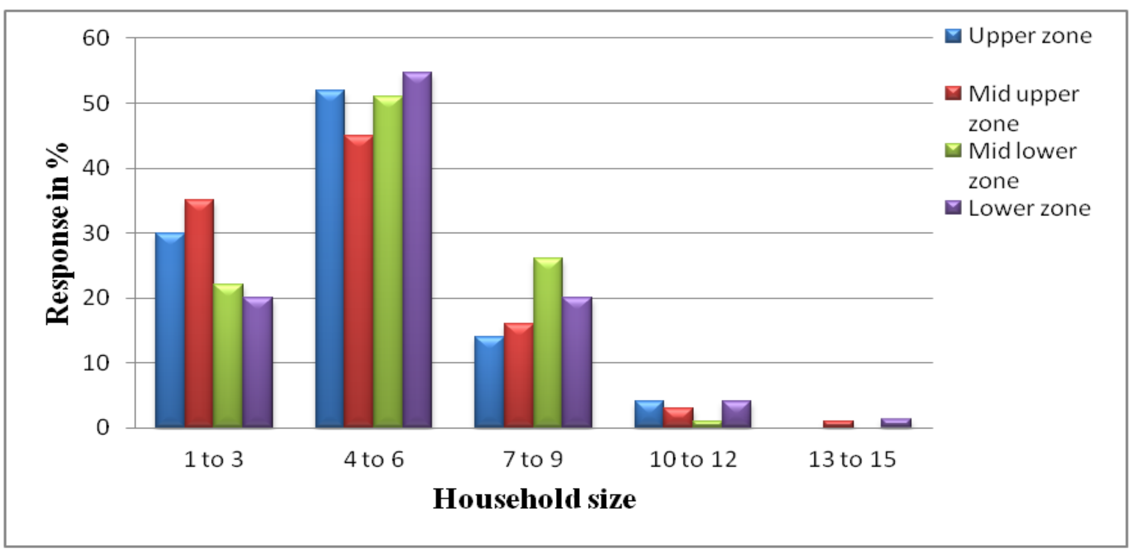


Figure 2: ***Comparative household size according to altitude***

Source: Field data, May 2014

Meanwhile, household dependence varies with altitude in some ways as households in the upper and mid upper zone had 22% and 23% of 4-6 household dependants respectively, while the households having similar size of dependants in lower and mid lower zone accounts for 34% and 38%, respectively, but there is no remarkable variation in households having no any dependants across the zones. High dependence in households may results in difficult in adaptation and household diversification taking in to account their limited resources and education which exacerbate the dependence on land and which in turn limit agro-ecosystems' goods and services provision.

4.2.4 Education level of respondents

Education is one of the factors that determine how people manipulate and master their surrounding environment. Education also influences the means of household income diversification and this reduces the dependence of agriculture per se for survival and can promote conservation or organic agriculture which is sustainable to agro-ecosystem. The study shows that 80% of the respondents had primary education. Only 17% of the interviewed respondents had secondary education. Very few (1%) had technical education, (1%) tertiary education, while 1% had no formal education (Fig. 3).

Education status has indirect or direct influence in agro-ecosystems' resilience. Most of adaptation and mitigation strategies on agro-ecosystem may require skills through formal education. Most of climate change challenges require sophisticated knowledge of which is learnt through formal education like model simulation, Disaster Risk Reduction (DRR) strategies like forecasting of climate related disasters and disaster responses. Therefore, the lack of education may aggravate vulnerability both socially and ecologically.

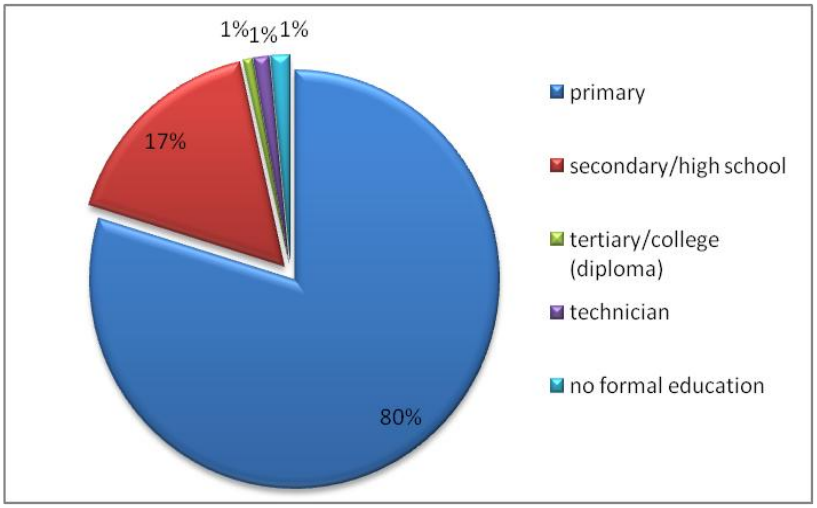


Figure 3: ***Education status of respondents***

Source: Field data, May 2014

4.2.5 Household cooking energy

Cooking energy is one of the basic energy which was discovered in ancient times whereby human kind was able to manipulate various types of food to make them easily edible. Hitherto, cooking energy has remained as one of the primary basic needs of the households for food preparation and to insure food security in the parameter of food processing and feeding habits. Fuelwood is one of traditional sources of energy which has remained the major source of fuel for over half of the world's population (FAO, 1981).

About 94.8% of households along the transect uses fuel wood as their main source of cooking energy. About 62.5% of households using woods obtain them from their own farmlands, 14.5% buy fuel wood from the market, 9.8% from neighbour farmland and 8% from gazetted forests. Only 5.2% use charcoal, Liquefied Petroleum Gas (LPG), Bio-gas, kerosene, animal dung, and farm residues. This may be interpreted that, there is heavy dependence on woods which may lead to negative implication on agro-ecosystem especially on the mid lower and lower zone where agro-forestry is not supported.

Figure 4: *A farmer showing biogas plant in Nduoni village-Upper zone*

***Source*:** Shirima Kelvine, May 2014

Due to limited economy of the households under study, it is difficult to manage biogas systems like the one shown in Fig. 4 as a source of household cooking energy because one biogas infrastructure costs not less than 1.5 million Tanzania shillings of which is difficult for an ordinary peasant to afford and this makes them rely only on fuel woods and few of them relied on charcoal.

4.2.6 Main source of household income

The study show that about 94% of respondents identified subsistence farming as their main source of household income. About 87.5% depended solely on rain-fed agriculture, 11.25% depended on irrigated agriculture, while 1.25% practised both irrigated and rain-fed agriculture in the lower zone. On the other hand, about 2.8% of households depended on remittances as the main source of household income, another 1.5% depended on non-agricultural salaried jobs as their main household income generation, and 0.8% was depending on coffee crop farming. The large percentage of households depending on subsistence agriculture are likely to increase the agro-ecosystems' vulnerability due to their entire dependence on farming because of constant soil disturbance and lack of fallowing and mono-cropping practice which led to constant fertility loss.

Table 4: ***Main household income by frequency and percentage***

Source of income	Number of households	Valid percentage (%)
Subsistence farming	378	94.5
Ranching (beef)	1	0.3
Cash crop farming	3	0.8
Non agricultural employment	6	1.5
Small business	1	0.3
Remittances	11	2.8
TOTAL	**400**	**100**

Source: Field data, May 2014

4.2.7 Off-farm contributions

Contributions from off-farm activities reduce overdependence on agriculture and lessens the agro-ecosystems' vulnerability and over-exploitation. However, the results show that very few people engaged in these activities. About 22% of households had petty businesses varying from sale of liquor, small retail shops and crop business which enabled them to make a little profit that allowed them to diversify household income (Fig. 4). Another 7% of households had an employed member to non-agriculture related employment in government and non government organizations where they earned salaries. About 66% of households had no off-farm income generation sources, therefore, entirely depended on agriculture for their livelihood.

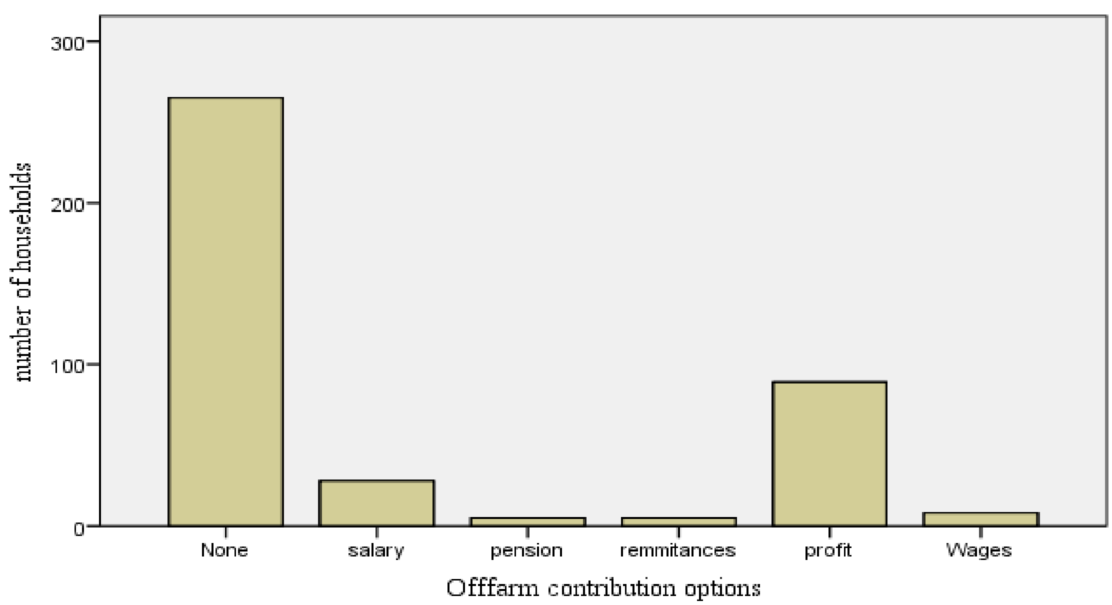


Figure 5: *Household off farm contributions*

Source: Field data, May 2014

4.2.8 Social safety nets of households

Social safety nets can help rural households respond to more severe and more frequent climate-related shocks and build synergies with disaster risk management (DRM) and climate change adaptation (CCA) interventions for a continuum of responses from relief to social safety nets and to resilient rural development (FAO, 2011). Rural finance and micro-credit can be enabling activities for adaptive response, which are also used by women for resilience-building activities, as documented in Sudan by Osman-Elasha *et al.* (2008) and IPCC (2014). Credit and storage systems are instrumental in supporting families during the lean period, to prevent the sale of assets to buy food when market prices are higher (González *et al.*, 2011).

However, the overall safety nets situation in the study area shows that about 59% of household did not belong to any social safety net group. The social safety nets that existed varied with altitude. In the upper zone, for example, 14% belonged to Saving and Credit Cooperatives (SACCOs) and 10% belonged to a farmers’ association, the Kilimanjaro Native Cooperative Union (KNCU) where they marketed their coffee. Other households’ social safety nets varied from political groups (6%), staff associations (4%) and women’s groups (4%). In the mid-upper zone about 46% had a membership in the farmers’ association KNCU, only 6% of respondents belong to various SACCOs, while the remaining belonged to other social assistance groups, such as women’s associations (2%).

The situation was different in the mid-lower and lower zones. About 26% of households in mid lower belonged to the farmers' association while 2% had membership in women's groups and another 2% belonged to the local SACCOs. About 22% of the respondents in the lower zone had membership in SACCOs and 8% were in women's groups. About 5.3% belonged to other social neighbourhood associations while 1.3% was in the farmers' association.

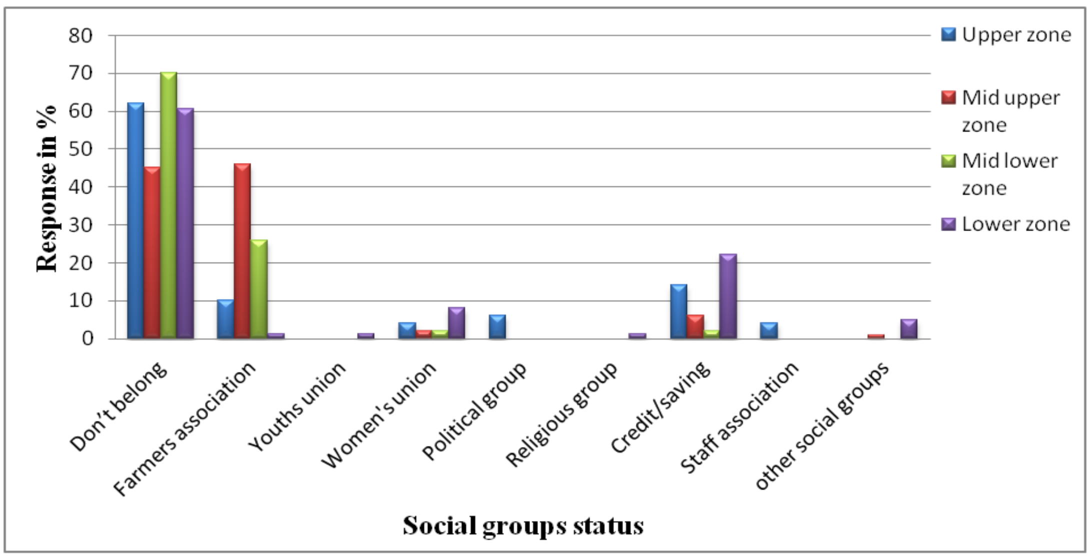


Figure 6*: Household social safety nets according to zone*

Source: Field data, May 2014

4.3. Climatic Challenges on agriculture

Farmers have experienced difference climatic disasters like droughts, floods, below average rainfalls and few cases of strong winds which have altered their agricultural productivity over time. Some of these challenges are going to be discussed hereunder.

4.3.1 Flood and drought status

Occurrence of different climatic disasters as mentioned above varies with zones due to differences in altitude of the study area with droughts and floods taking high frequency across the transect. In the upper zone with altitude between 1500-1900 metres above the sea level (m.a.s.l), about 42% reported drought as their primary climatic disaster while 10% of them reported they had not experienced any type of climatic disaster. This may be due to the fact that these households do not cultivate in the mid lower and lower zones of which are more vulnerable to droughts. About 44% of these households depend on bananas as their staple food, while 8% practiced mixed farming of banana and coffee. All these farming were associated with agro-forestry which is common in home gardens.

Meanwhile, 18% of these households claimed maize as their primary crop due to its ability to be stored for a long time. The maize is cultivated in the mid and lower zone from both leased plots and owned farmlands. About 22% of household sampled in Nduoni village in the upper zone reported below average rainfall as their primary climatic hazard. The remaining 22% of households reported a variety of other climatic events like floods (2%), erratic rainfall (2%), hail storms (6%), landslides (2%), strong winds (6%), and loss of top soils (4%).

In the mid upper zone with an altitude of between 1300-1500 m.a.s.l, about 90% reported drought as their primary detriment of climatic event that affect their agricultural quality and yields as shown in Fig.7 below. This may be because most of households (52%) cultivate maize as their primary crop in mid lower and lower zone farmlands where drought cases are mostly reported. About 39% of households sampled out in the mid upper zone depend on bananas as their primary and staple crop and only 9% reported coffee as their major cash crop. Meanwhile, about 5% households in mid upper zone reported below average rains as their primary climatic events while 4% mentioned floods because their farmlands were located in the mid lower and lower zones which are prone to floods.

The mid lower zone of altitude between 1000-1300 m.a.s.l reported almost similar situation as the mid upper zone as 89% reported drought as their primary climatic hazard with the remaining households reporting variously; from below average rains (3%), floods (3%), landslides (1%), strong winds (1%), and loss of top soils (2%) as their primary climatic issue Fig. 7. In this zone about 67% of the households depend on maize as their major crop and 33% depends on banana, there was no any household that depends on coffee as their major crop, because of price unpredictability and falling of market of this crop which led to its decline.

In the lower zone the situation seems somehow different since 58% reported drought as primary climatic issue while 30.6% reported floods of which seems to be true because of nature of terrain. This zone has an altitude of 700-100 metres above the sea level in which all the drainage from upper, mid upper and mid lower zone are directed. This lower zone is dominated by maize as the main crop since 100% of the household sampled identified maize as their main crop although crops like sunflower, ground nuts, sorghum, cowpeas and vegetables are cultivated by some few families either through irrigation or rain fed agriculture.

About 88% of respondents admitted that the incidents of floods and droughts are changing while 10.25% said these incidences are not changing. Meanwhile, about 61% identified the trend of increase to these disasters while 28% admitted the trend of decrease. The reasons for changing of these disasters was reported to be deforestation by 26% of the respondents while 13.75% reported climate change as the causative and 4.5% said it is a matter of infrastructures.

Unfortunately, about 41.7% of respondents did not know the reasons for changes in trend of climatic hazards over time. About 45.8% of farmers who have been impacted by drought responded to have altered their farming practices to adapt to these changes by either formulating or improving the existing soil and water conservation infrastructure or improve their seeds especially early maturity hybrid seeds. But unfortunately they claim these infrastructures like terraces and infiltration ditches to be inefficient due to increase in floods over time. About 51.3% of the farmers have not changed to any system after drought and the major reasons were economically driven and lack of enough extension services.

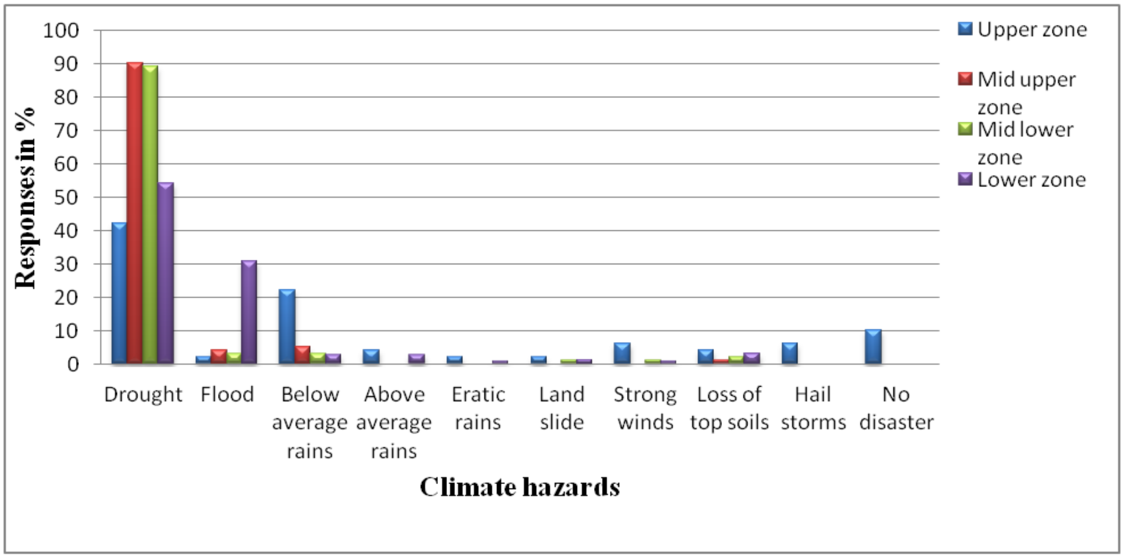


Figure 7: ***Climatic disaster responses according to altitude***

Source: Field data, May 2014

4.3.3 Crop yield trend analysis for Kilimanjaro region

The trend of two major crops of the region is analyzed from the data obtained from historical records from Moshi rural district archive. The trend of maize and banana crop from 1985 to 2013 will be taken in to consideration. Regionally maize crop shows different trend for between years (Figure 8). Between the year 1985 and 1991 there has been low yield of maize regardless the land size which has very small variation in size per year.

This might be caused by lack of enough inputs which may include improved hybrid seeds specific for a particular micro climate within the region. Also lack of fertilizers; pest and disease control inputs may have been among other the reasons. Meanwhile between the years 1986 to 1987 has shown a negative yield in relation to land size and this may have been caused largely by climatic disasters like drought or extreme below average rainfalls.

Between the years 1992 to 2005 the production seems to increase and probably it has been associated with availability and access of agricultural inputs and good climatic condition. Also there is a slight increase in land size under cultivation which may be as a result of availability and access of farm machinery like tractors which enable easy land tilling; also migration to arable land may have been a reason behind the increase in land under cultivation. Meanwhile there are four consecutive years thus between year 2005 to 2009 which shows the relative decrease in maize yield with almost similar size of land under cultivation. The reasons for these changes might be climatic problems and alteration of soil quality parameters due to farming system and inputs on the land. This trend has a closer relationship with household response as between 2003 to 2013 there has been a decline in maize yield due to two major reasons being lack of enough rains and land exhaustion.

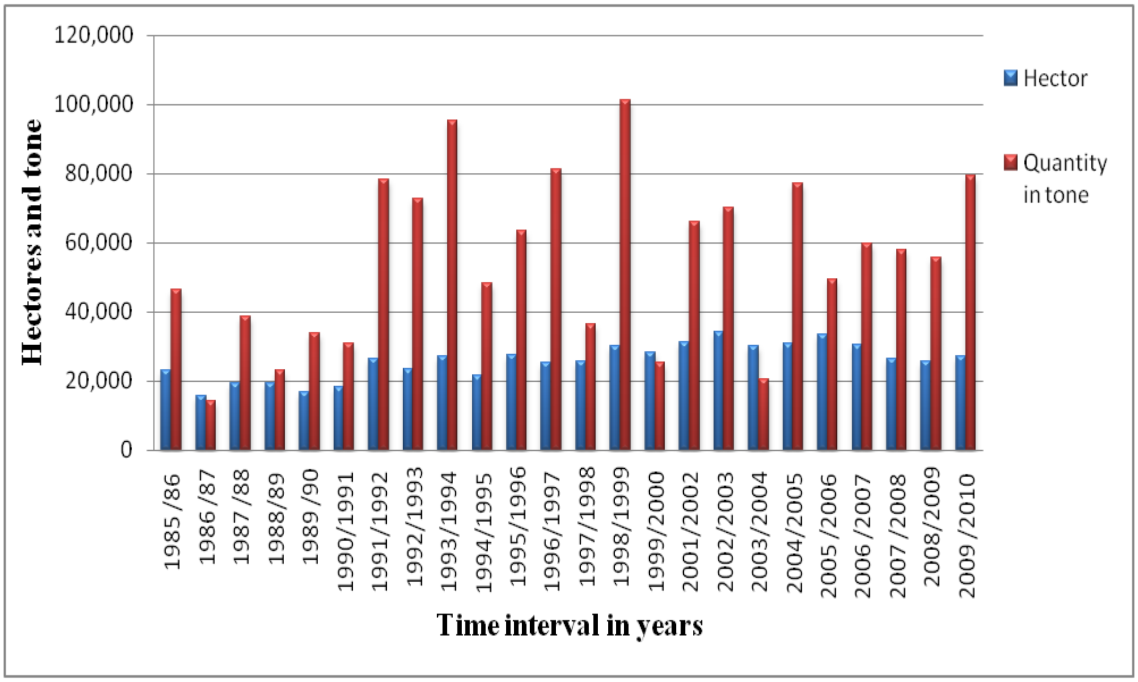


Figure 8: ***A graph showing maize yield trend analysis for Kilimanjaro region***

Source: Moshi Rural District archive data, May 2014

The case of banana crop trend analysis in Fig. 8 shows no significant changes from 1985 to 1991 and from 1991 to 2000 where there was a significant fluctuation in yield despite the same land size under cultivation. Meanwhile from 2001 to 2013 there was no significant fluctuation in yield and this is because banana crop is cultivated in home gardens where it is associated with many elements of conservation agriculture like agro-forestry, mulching and application of farm yard manure from zero grazed cattle. This situation seem to have maintained the agro-ecosystem stability that ensured the consistent yield in banana, contrary to maize which is cultivated in savannah plains of mid lower zone where conservation agriculture is not taken to consideration and this cause the variation in agro-ecosystem resilience according to altitude given the variation in agricultural practices.

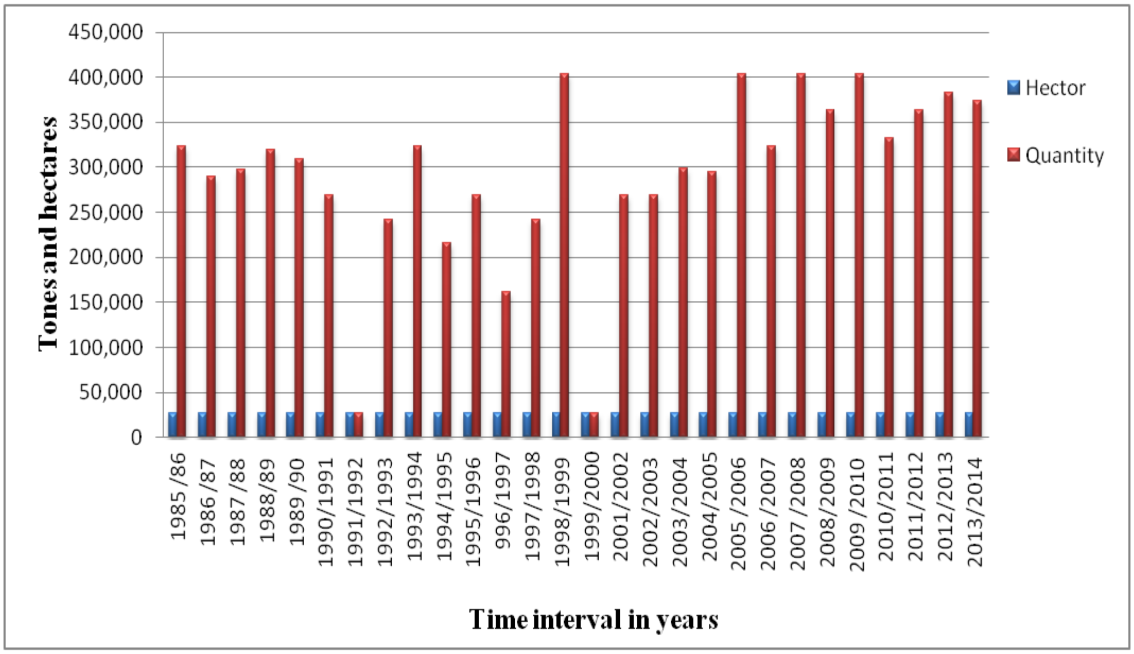


Figure 9: ***A graph showing banana yield trend analysis for Kilimanjaro region***

Source: Moshi Rural District archive data, May, 2014

4.4 Farming practices

Farming practices and cropping systems are directly proportional to agro-ecosystems' resilience and this is determined largely by the conservation agriculture on farm lands. Conservation agriculture has good potential to both bolster food production and enable better management of climate risks (Verchot *et al.*, 2007). Such practices, which include conservation/zero tillage, soil incorporation of crop residues and green manures, building of stone bunds, agro-forestry, and afforestation/reforestation of croplands, reduce runoff and protect soils from erosion, increase rainwater capture and soil water-holding capacity, replenish soil fertility, and increase carbon storage in agricultural landscapes. Conservation agriculture systems have potential to lower the costs of tillage and weed control with subsequent increase in net returns, as found in Malawi by Ngwira *et al.* (2012).

4.4.1 Cropping systems

This study explored existing cropping systems in the area namely mono cropping, mixed cropping, crop rotation, fallowing, mulching, cover crops and inter cropping. These cropping systems varied with altitude from lower zone to upper zone due to variation in soil types, temperature, moisture and perhaps land size per family along the transect. These cropping systems have different implication on the soils and hence determine yield and quality. For example, when a farmer practice mono cropping, it is difficult to maintain cover on the soil, encourages pests, diseases and weeds; and it can reduce the soil fertility and damage the soil structure (FAO, 2007).

Due to variation of microclimates and ecological niches across transect, the farming systems also varies with altitude. The upper zone which is predominated by home gardens, mixed intercropping (the growing two or more crops simultaneously with no distinct row arrangement (Gliessman, 1992) system is common. About 63% of households practice mix intercrop, 34% intercrop banana, coffee, yam, trees and cover crops. About 4% of households in the upper zone practice mono cropping because their major farmlands were located in the mid lower and lower zones which support maize cultivars.

Figure 10: ***Mixed cropping at Iwa village in mid upper zone (Kilimanjaro)***
Source: The author, March 2014.

In the mid upper zone about 42% practice mixed farming and 19% intercrop in their home gardens as their major farmland and the mixed inter cropping involve the same crops as in the upper zone while 39 % of households in the mid upper zone have their major farmland in the lower and mid lower zone where they practice mono cropping of maize as their primary and major crop. The mid lower zone where the conditions is different from mid upper zone, mixed cropping and inter cropping is highly practiced. According to the study about 51% of households sampled practice mixed cropping and 29% practice inter cropping while 20% practice mono cropping system. This large difference is because this zone has a combination of favouring condition for maize, beans and little banana growth. This zone is said to be deprived with banana due to series of droughts of 1974, 1984, 1994 and below average rainfalls experienced in recent years as reported from focus group discussions. This condition has altered this zone and therefore possessing most conditions of lower zone. Mono cropping households in this zone which occupy 20% have their major farmlands either in this zone or lower zone of which they cultivate maize as their major crop.

Figure 11: ***Mixed cropping of maize and beans with stunted banana at the right background in mid lower zone (Uparo village).***

Source**:** The author, March 2014.

The lower zone is dominated by mono cropping system where by 79.3% of households practice mono cropping of maize while some few households cultivate sunflower, sorghum and ground nuts. About 5% of households practice mixed cropping and 15%

intercrop. The reasons for predominant mono-cropping has been reported that when they intercrop they get very little yield from legumes of which is intercropped with maize. In this zone it is possible to mix or intercrop between maize, cowpeas and common beans, but focus group discussion revealed that, the maize pollen has very negative effects on common bean and highly reduce the yield. Generally, the practice of planting two or more crops on the same field is more common in tropical regions where more rainfall, higher temperatures, and longer growing seasons are more favourable for continual crop production (Gliessman, 1992).

Figure 12: ***A farmer showing irrigated mono-cropping system of beans (centre) and maize (right and back grounds) in the lower zone (Kisangesangeni village)***

Source**:** The author, March 2014.

Crop rotation is one of the key principles of conservation agriculture and it has many advantages varying from improvement of soil structure; some crops have strong, deep roots which can break up hardpans and tap moisture and nutrients from deep in the soils, others have many fine shallow roots and tap nutrients near the surface and bind the soils, increasing soil fertility; legumes (such as groundnuts and beans) fix nitrogen in the soil. When their green parts and roots rot, this nitrogen can be used by other crops such as maize (FAO, 2007).

Out of six traditional crop-pest control practice at farm level investigated in the study area which include crop rotation, sanitation, using of ash, trap cropping, early planting, and mixed cropping, only 2.5% of all households sampled along the transect practice crop rotation. Rotating crops also control weeds, pests and diseases; it also produces different types of output and reduces risks in case of failure of one or two crops due to climatic disaster like droughts (FAO, 2007).

The farming systems which seem similar to rotation but not the case is the sequential cropping which has been caused by different rainy seasons of short and long period due to bimodal rainfall characteristic of these area. Sequential cropping is where two or more crops are grown on the same piece of land, but one following the other (Gliessman, 1992). In this case most of farmers plant maize during long rains and common beans during short rains given time maturity of these two crops.

Depending on the length of growing seasons, numerous sequential plantings can take place during a single year. Such systems require special management, with timely harvest, use of proper varieties, alteration of the standard planting distance, special selection of herbicides so as to not create antagonisms or residual effects, and also the possibility of using no-tillage planting with certain of the row crops (Gliessman, 1992) of which most of these farmers seems to lack these skills.

According to Gliessman 1992, in all of the aspects of multiple cropping systems, his review considered yield, resource use, pest and disease control, weeds, use of space and time, types of planting systems much of the evidence indicates that generally there are more advantages than disadvantages of a biological, physical, or agronomic nature.

4.4.2 Fallowing, mulching and cover crops

Most of farmers in the area of study do not practice fallowing and their reason is that the land is very limited. About 89% of households sampled along the transect do not practice fallowing while 11% practice this system and these are households with enough land to do so. The Trenbath model suggests that 'improved fallows' with a reduced 'half recovery time' can indeed lead to increased cumulative crop yield per unit land area because fallow periods can be shortened (Noordwijk, 1999). The improved fallows can also be used to obtain higher yields in cropping years, if the fallow period is not reduced. The options for benefiting by both higher yields per unit land (cumulative yield) as well as per unit labour (yield in cropping years) are, however, limited (Noordwijk, 1999).

Mulching is another farming practice of concern in agro-ecosystem sustainability. Mulch is a layer of vegetation, dead, decaying or living, that acts as a protective cover over the soil; nevertheless this little appreciated biological process could be of great importance for future agricultural production and the politics of climate change (Scale *et al.,* 2002). Some households across the transect have tried to practice mulching especially in home gardens but still most of them does not since about 68% claim not to practice while 31% practice it and this is mostly in home gardens of upper, mid upper, and mid lower zone, while few (9%) of interviewed households in lower zone practice mulching.

Mulching is associated with a multitude of advantages in agro-ecosystems, varying from preventing germination of weeds and smothers existing weeds, moisture conservation and drought resistance; mulches can also reduce soil evaporation, and increase the amount of water absorbed by a bed by holding water on the surface until the soil is able to absorb it (Scale *et al.,* 2002). Mulches usually regulate soil temperature keeping it cooler than bare soil. This can help cool seasonal crops in summer; mulches can also add nutrients and organic matter to soils and by "composting in place" sheet mulches add organic matter and humus to the soil as well. Also it encourages and protects soil microbial activities, Soil P^H, encourages and protects soil microbial populations, keeping dirt from splashing on plants, and controls erosion" (Scale *et al.*, 2002).

4.4.3 Farm preparation implements

Farm preparation and farming implements have different implications on soils sustainability and quality. Given the study area has been divided according to altitude, the farm implements varies accordingly. In the upper zone where home gardens concentrate, manual implements is the sole option to prepare the farm and therefore about 74% of households uses manual implements to prepare their farmlands which are located in this zone, while 24% of households which have their main farmland either in lower or mid lower zone uses tractor to prepare their farmlands.

In mid upper zone 69% have confirmed using manual implements in their farmlands and 31% uses tractors to their plots located in lower and mid lower zone. It has to be noted that the 69% of these farmers have most of their farmlands in the mid upper zone of which are home gardens. In mid lower zone where the condition fairly support maize crops in some portions and lacking enough condition for using tractor, about 74% uses manual implements while 26% uses tractor in their farmlands either located in this zone or lower zone.

The lower zone which is characterized with flat terrain and savannah type climate is the only zone which highly supports the use of tractors and mouldboard plough in preparing the farms and therefore about 92% of households uses tractor to prepare their farms and 0.7% uses mouldboard plough while 7.3% uses manual and this is because these households cannot afford hiring a tractor.

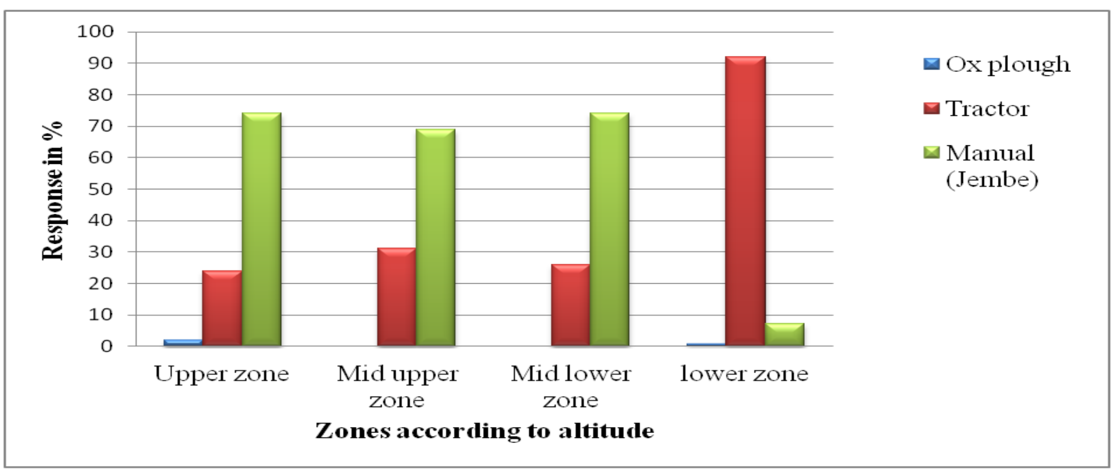


Figure 13: ***Land preparation tools according to zone***

Source**:** Field data, March 2014

Ploughing has been relatively efficient in weed control. For example the modern steel mouldboard plough helped avoid famine and death at the end of the 18th century, since it was the only tool that could effectively control couch grass, a weed that could not be controlled with conventional tools of the time (Scale *et al.* 2002). So the plough and tillage have become the most frequently used symbols of agriculture worldwide and it has taken many decades to discover that the same tool that brought food and wealth would bring soil erosion and degradation to more fragile environments (Scale *et al.* 2002). Therefore the implement that has brought temporary control of weeds has come at a cost, and there is little evidence on the advantages of ploughing on the soils, yield and quality of crop outputs.

Figure 14: ***A panoramic view of farm prepared by tractor in lower zone***

Source**:** The author, March 2014

4.4.4 Crop pests and diseases

Apart from floods and droughts which were noted as major cause of loss on crop yield, there were other minor causes of loss which were also investigated and in this case about 59% of respondents admitted insect pests attacks on crops before harvest. Meanwhile 15% reported large decline in crop prices especially for coffee while banana and maize had no remarkable price decline. About 9% reported plant diseases on maize, coffee and banana as minor losses.

The disease causing loss in banana is reported to be panama disease and currently infiltration ditches in home gardens with steep slope is said to be the solution. Before the application of infiltration ditches against panama disease the solution was to up root the whole of banana and its roots and fill the pit with farm yard manure and replant another bud, but for the flat home hardens the solution towards panama disease is said to be effective use of farm yard manure. According to focus group discussion, mole rats have been reported to be most destructive pest to banana and these pests are exacerbated by increase in soil temperature because the farmers said these pests grows in high temperature farms, so if farms have no enough farm yard manure these pests grew in number and increase the loss. Pests and diseases are reported to increase over time and one of discussant (*mzee* Juma) at Nduoni village at 9:20 AM in 3rd April, 2014 said they have formulated a saying that "*our fore farther have gone with their farms"* following the decline in yield per farm plot.

Coffee is said to be subject to diseases like Coffee Berry Disease (CBD) only in the upper zone because the mid upper and mid lower zone did not report this disease but admit that this is common in upper zone. Leaf miner, stem borer and coffee berry borer has been reported as an insects causing main loss in coffee which prevails in upper, mid upper and mid lower zone to those who grow coffee. Nduoni farmers reported to have been prohibited using industrial pesticides by the local government for environmental reasons. In other two zones farmers applies different insecticides to deal with these pests and diseases.

Figure 15: ***A coffee affected by stem borer at Iwa Village-Mid upper zone***

Source**:** The author, March 2014

Maize is not much subjected to diseases; some of the diseases reported by key informants include leaf rusty, bacteria leaf/blight and maize stric virus. Meanwhile there are different pests mentioned by farmers which include African army worm, maize stock borer, and elegant grasshopper. About 97.8% of them do not practice Integrated Pest Management (IPM).

Figure 16: ***A Maize field affected by African army worms at Kisangesangeni***

Source**:** The author, March 2014

4.5 Land ownership and status of land parcel

In the study area the land of the household is owned by the household head, and about 98.5% of respondents claim the land to be owned by the household heads. About 84% of households have their own land as major farmlands while 12% rent in the land for cultivation and most of them rent in between 1-2 hectares of land. Most of household acquire their land parcel through inheritance from their fathers as 74.5% admitted to have inherited their land. Land title also seem to be a problem in the study area because about 76.5% of households have no any kind of land title where by 10.3% said to have communal land titles and only 1.8% said to have formal title deeds.

Land size per household has shown a variation with altitude/zone by which 20% and 3% of households in upper and mid upper zone respectively, possess less than 1 hectare as a household farmland while less than 1% of households in lower and mid lower zone had less than 1 hectares per household. About 22% and 18% of households in upper and mid upper zone respectively had farm size of 1-2 hectares while 38% and 33% of households in mid lower and lower zone respectively had farm size of 1-2 hectares making a relative difference of 31%. Meanwhile there is a difference of 3% of households possessing 2-3 hectares as farm size. Another remarkable difference from the study is the presence of households possessing farm size between 12-21 hectares in the lower zone of which there is no any household having such amount of farm size in other zones.

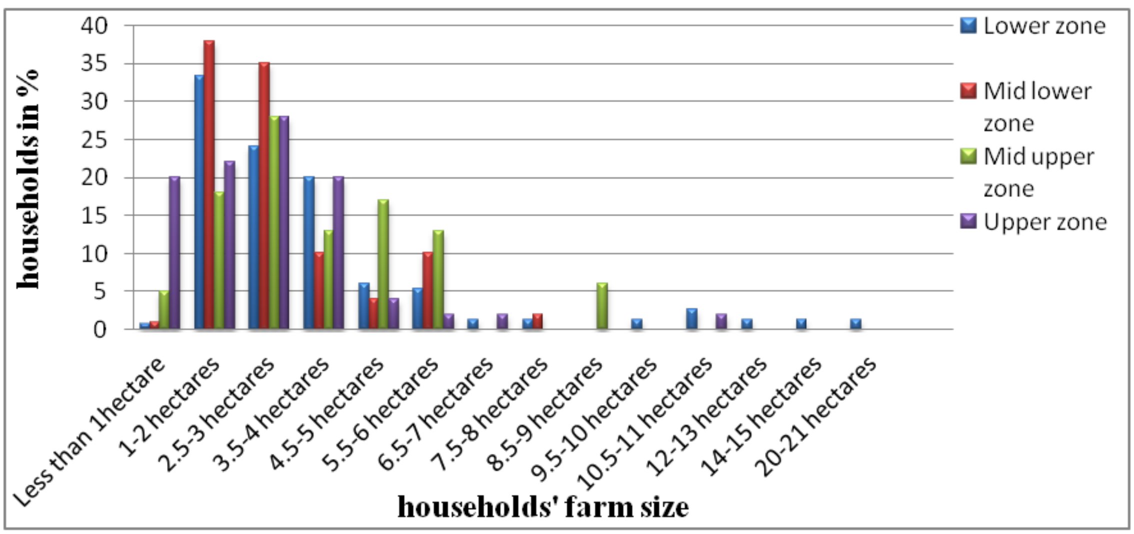


Figure 17: ***Comparative household land parcel ownership per zone***

Source: Field data, 2014

Soil fertility is one of the most determinant of crop yield per farm and this determinant has been considered in this study whereby farmers were asked to rate the changes in fertility of their parcel overtime. Different farmers replied differently with 8.8% claimed the fertility to increase overtime in their land parcel due to application of organic manure. 48.3% said the fertility remained the same while 43% admit the soil fertility to decline overtime. Most of those responded to change in fertility (25%) claim to be the use of inputs and about 16% claimed the changes to be caused by floods, 4% as lack of fallowing, 5.5% as drought, 3.3% due to surface runoff.

The nature and orientation of farmlands also may influence yields and quality of produce. The farmlands were rated from flat, slight inclination and steep whereby respondents stands at 50.8% to have flat farmlands, 48.5% having slight inclined farmlands and 0.8% to have steep slopped land parcels. Erosion per land parcel also was to be investigated and 42% of households admit to have parcels with no erosion while 52.5% had farms with mild erosion and 4.8% of them had parcels with severe erosion. Therefore the nature of land parcel may increase the vulnerability of agro-ecosystems' functioning, since the slope of parcel may exacerbate erosion when the conservation agriculture is not well taken in to account.

4.5.1 Soil and water conservation infrastructures

Farmers are actually responding towards agro-ecosystem challenges and in so doing they have employed different means to maintain soils and water quality and quantity. The application of infiltration ditches and trenches has been commonly seem to be adopted of which about 33.3% of respondents along transect have been adopted this practice recently. Infiltration ditches are commonly used in home gardens which are located on a steep slopes for different purposes, first being to reduce surface runoffs which may destruct the soil humus, to provide ventilation and reduce heating in to the soils so as to get rid of panama disease to bananas, infiltrate water slowly to the soils and maintain soil water retention capacity. A ditch of about a metre deep and two metres wide is dug across the farm as seen in Fig 19. In savannah plains of the lower zone, the tractor ridges are common (Fig. 18). Terraces also account for 20.5% as the main conservation practice but farm yard manure which is highly practiced in home gardens is the tradition which started from time immemorial and it has occupied 19% as the main soil management practice. About 28% of households used different practices varying from using bags filled with sand for flood protection on their farms to inter crop, cover crops, fertilizers, composting, fallowing, ridges and furrows, conventional tillage, grass strips, tractor ridges and stone bunds.

Figure 18: ***A farmer showing tractor ridges at Kisangesangeni village-Lower zone***

Source**:** The author, March 2014.

Figure 19: ***A picture showing infiltration ditch at Uparo village-Mid lower zone***

Source**:** The author, March 2014.

4.6 Animal husbandry

Animal domestication in the study area was also investigated because it has very close relation with crop farming and as a livelihood on farm diversification. Cattle and goats are the predominant livestock which are kept in this area and the domestication systems differ with zones. The lower zone and mid lower zone famers use cattle routing due to the availability of grazing land in savannah plains (Fig. 20). In upper and mid upper zones where home gardens and agro-forestry dominate, zero grazing is the only option where farmers have opted in time immemorial. Meanwhile about 55.5% of households have reported decreasing trend of pastures over time, this has caused about 70.3% of farmers to slash and store plant residues after harvest while 3.8% who does not keep, slash and sale to keepers and only 12% slash and leave on the farm as mulches.

Figure 20: ***Cattle routing at Kisangesangeni Village-Lower zone***

***Source*:** The author, March 2014.

4.7 Agro-ecosystem adaptation and household diversification

Households have shown different livelihood diversification in agriculture by employing some high value crops varying from fruits to vegetables. These crops also has shown a variation in altitude on its predominance along the transect. In upper, mid upper and some parts of mid lower zone is predominated by avocado trees as agro-forestry which are cultivated in home gardens and these fruits adds an extra income to farmers. Another crop of interest which was rarely grown in these zones was vanilla which has high economic value and has proved to be easily manageable by farmer in upper and mid upper zones. Another advantage of this crop is that it does not consumer larger space and it can be synchronized with other crops like banana.

Figure 21: A-***Individual vanilla crop with a tree,*** B-***Individual vanillas with banana at Iwa Village***

Source**:** The author, March 2014

In lower zone irrigation gardening was common, where vegetable like tomato, sweet pepper, and onions are cultivated. This gardening is usually cultivated during dry seasons by irrigation using water from their personal boreholes.

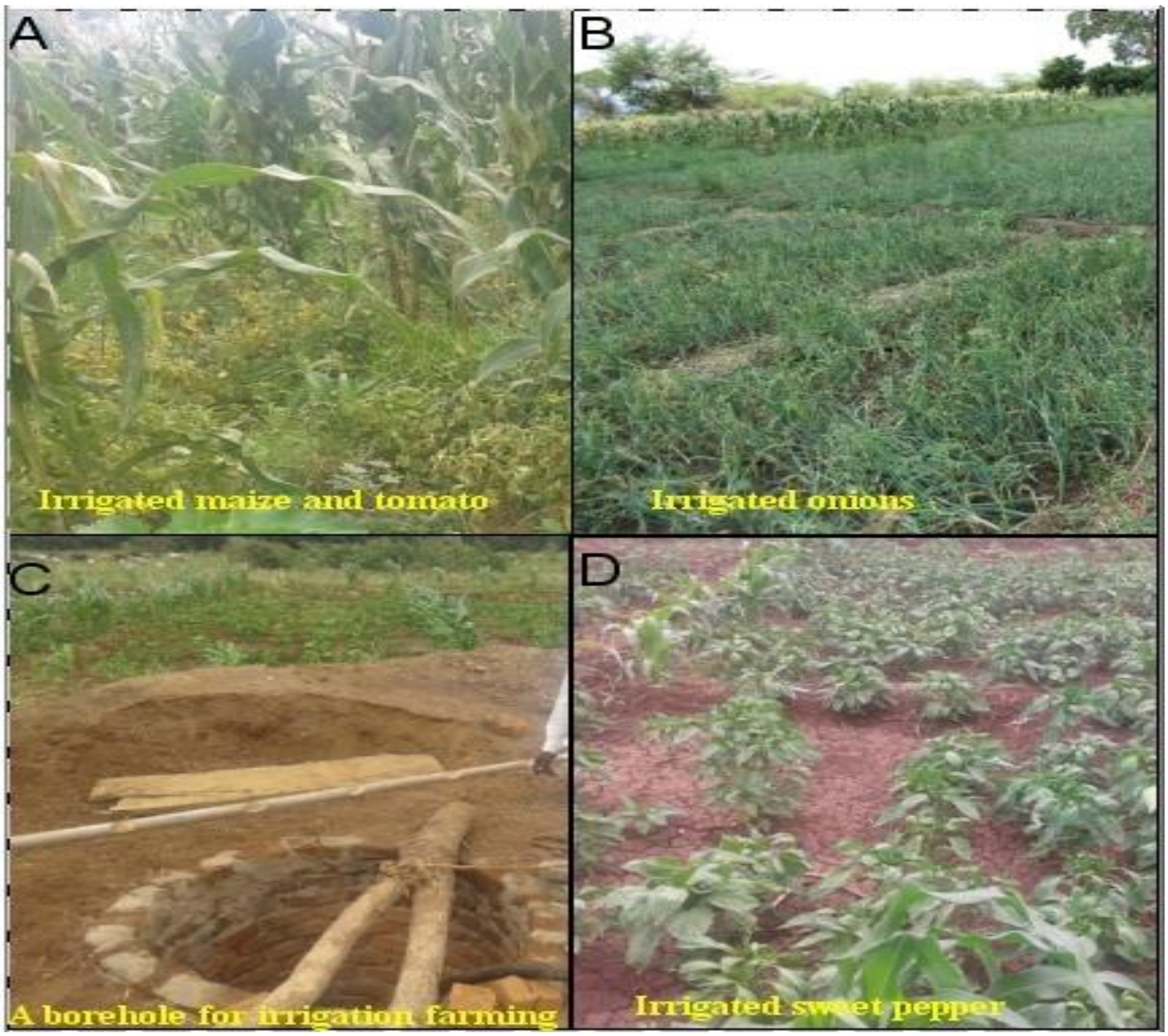


Figure 22: ***Irrigated gardening at Kisangesangeni village-Lower zone***

Source: The author, March 2014

Despite limited amount of land, some farmers of the mid lower and lower zones has divided their land in to parcels so that they can grow another crops particularly drought resistant crops like sorghum, sun flower and cow peas and short term leguminous crops like ground nuts and beans. Farmers hardly mix or intercrop these crops with maize because of lack of knowledge of handling these crops. These leguminous crops have a very good potential to soil nitrogen improvement but unfortunately most of the farmers grow them in a specific portion of land and most of times sequentially.

Figure 23: ***Drought resistant crops in lower zone***

Source: The author, March 2014

4.8 Vulnerability and Vulnerability Index

Chamber (1983) defined that vulnerability has two sides. One is an external side of risks, shocks to which an individual or household is subject to climate change and an internal side which is defencelessness, meaning a lack of means to cope without damaging loss. Blaikie *et al.*, (1994) defined vulnerability as the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impacts of natural hazards and states that vulnerability can be viewed along a continuum from resilience to susceptibility. According to Adger (1999) vulnerability is the extent to which a natural or social system is susceptible to sustaining damage from climate change.

4.8.1 Vulnerability index

Quantitative assessment of vulnerability is usually done by constructing a 'vulnerability index', this index is based on several set of indicators that result in vulnerability of a region and it produces a single number, which can be used to compare different regions (www.icrisat.org). Literature on index number construction specifies that there should be good internal correlation between these indicators and the relevance of this criterion depends on the relationship between the indicators and the construct they are supposed to measure (www.icrisat.org). For this we must know whether the index is based on a 'reflexive' or a 'formative' measurement model. In the reflexive measurement model, the construct is thought to influence the indicators, for example, a poverty index is a reflexive measurement because poverty influences the indicators such as literacy; expenditure and so on and all these indicators are correlated (www.icrisat.org).

On the other hand in the formative model the indicators are assumed contribute to the construct. In the case of vulnerability index, all the indicators chosen by the researcher have an impact on vulnerability of the region to climate change. For example, frequency of extreme events such as flood, drought and earth-quakes, contribute to vulnerability of the region to climate change, hence vulnerability index is a formative measurement and the indicators chosen need not to have internal correlation.

Construction of vulnerability index consists of several steps. First is the selection of study area which consists of several regions. In each region a set of indicators are selected for each of the three component of vulnerability. Since vulnerability is dynamic over time, it is important that all the indicators relate to the particular year chosen and if vulnerability has to be assessed over years then the data for each year for all the indicators in each region must be collected. For each component of vulnerability, the collected data are then arranged in the form of a rectangular matrix with rows representing regions and columns representing indicators. As shown in Figure 11, let there be M regions/districts and K indicators. Let X_{ij} be the value of the indicator j corresponding to region i. Then the table will have M rows and K columns.

Table 5: ***A sample of variable and region on vulnerability index computation***

Region/district	**Indicator**					
	1	2	.	J	.	K
1	X_{11}	X_{12}	.	X_{1j}	.	X_{1K}
2	.	.	.	.	.	.
.	.	.	.	.	.	.
I	X_{i1}	X_{i2}	.	X_{ij}	.	Z_{iK}
.	.	.	.	.	.	.
M	X_{M1}	X_{M2}	.	X_{Mj}	.	X_{MK}

Source: www.icrisat.org

4.8.2 Normalization of indicators using functional relationship

It is obvious that indicators will be in different units and scales therefore the methodology used in UNDP's Human Development Index (HDI) (UNDP, 2006) is followed to normalize them in order to obtain figures which are free from the units and also to standardize their values, first they are normalized so that they all lie between 0 and 1. The concept of functional relationship between indicators and vulnerability has to be underscored before the normalization of these indicators.

There are two functional relationships: vulnerability increases with increase or decrease in the value of the indicator. Assume that higher the value of the indicator more is the vulnerability. For example, change in maximum temperature or change in annual rainfall or diurnal variation in temperature. The higher the values of these indicators more will be the vulnerability of the region to climate change as variation in climate variables increase the vulnerability. In this case the variables have ↑ functional relationship with vulnerability, and the normalization is done using the formula below.

NB: this formula is for normalization of variables with functional relation (FR) ↑

$$x_{ij} = \frac{x_{ij} - min\{x_{ij}\}}{max\{x_{ij}\} - min\{x_{ij}\}}$$

Where:

x_{ij}= Normalized scores for the variables having ↑ FR

$max\{x_{ij}\}$ = Maximum value of Normalized scores for the variables having ↑ FR

$min\{x_{ij}\}$ = Minimum value of Normalized scores for the variables having ↑ FR

For example, consider the table below with score variables in percentage whereby the maximum Value for drought frequency response is 78% for mid upper zone and minimum in upper zone with 34%, therefore the normalization can be calculated as:-

$$x_{ij} = \frac{x_{ij-34}}{78-34} = \frac{x_{ij-34}}{44}$$

So the normalization of drought frequency for the lower zone in this case will be:-

$$x_{ij} = \frac{67-34}{44} = 0.750$$

It is clear that all these scores will lie between 0 and 1. The value 1 will correspond to that region with maximum value and 0 will correspond to the region with minimum value.

For the normalization of variables with functional relation (FR) ↓ like literacy rate of the community is computed by the following formula.

$$y_{ij} = \frac{max\{x_{ij}\} - x_{ij}}{max\{x_{ij}\} - min\, x_{ij}}$$

Where:

y_{ij} = variables with functional relation ↓ FR

$max\ x_{ij}$= Maximum value of Normalized scores for the variables having ↓ FR

$min\ x_{ij}$= Minimum value of Normalized scores for the variables having ↓ FR

In this case normalization will be calculated as follows: for example in social safety nets

$$y_{ij} = \frac{55 - x_{ij}}{55 - 30} = \frac{55 - x_{ij}}{25}$$

Therefore example normalization of social safety nets variables for the upper zone can be calculated as:

$$y_{ij} = \frac{55-38}{25} = 0.680$$

Table 6: ***Score variables of the indicators selected***

		Zones score variables (%)			
Variable	**FR**	**Upper**	**Mid upper**	**Mid lower**	**Lower**
Drought frequency	↑	34	78	49	67
Household dependence	↑	22	39	55	47
Social safety nets	↓	38	55	30	39
Off farm contribution	↓	38	33	30	38
Possession of land title	↓	6	2	3	6
Wood as cooking energy	↑	94	97	99	91
Access to extension	↓	40	54	59	55
Fallowing practice	↓	2	16	11	11
Farm acreage	↓	30	36	16	22
Response to drought	↓	20	56	52	43

Source: Field data, 2014

Apart from the formulas above, the normalized scores for each variable can also be calculated by using MS-Excel's Maximum and Minimum functions.

Table 7: ***Normalized scores of the variables***

		Zones' normalized score variables			
Variables	**FR**	**Upper**	**Mid upper**	**Mid lower**	**Lower**
Drought frequency	↑	0	1	0.341	0.750
Household dependence	↑	0	0.515	1	0.758
Social safety nets	↓	0.680	0	1	0.640
Off farm contribution	↓	0	0.625	1	0
Possession of land title	↓	0	1	0.750	0
Wood as cooking energy	↑	0.375	0.750	1	0
Access to extension	↓	1	0.263	0	0.211
Fallowing practice	↓	1	0	0.357	0.357
Farm acreage	↓	0.300	0	1	0.700
Response to drought	↓	1	0	0.111	0.361

Source: Field data, 2014

After computing the normalized scores the index is constructed by giving either equal weights to all indicators/components or unequal weights. In this case the indicators were given equal weight and the vulnerability index is calculated using the following formula.

$$VI = \frac{\sum_j x_{ij+} \sum_j y_{ij}}{K}$$

VI= Vulnerability index

$\sum$= Summation

x_{ij}= Normalized scores for the variables having ↑functional relation

y_{ij}= Normalized scores for the variables having ↓ functional relation

K= Number of indicators involved

For example the vulnerability index for the lower zone can be calculated as:

$$VI = \frac{0.375 + 3.980}{10} = 0.377$$

Table 8: ***Normalized scores with vulnerability indices for each zone and overall index***

		Zones' normalized score variables			
Variables	**FR**	**Upper**	**Mid upper**	**Mid lower**	**Lower**
Drought frequency	↑	0	1	0.341	0.750
Household dependence	↑	0	0.515	1	0.758
Social safety nets	↓	0.680	0	1	0.640
Off farm contribution	↓	0	0.625	1	0
Possession of land title	↓	0	1	0.750	0
Wood as cooking energy	↑	0.375	0.750	1	0
Access to extension	↓	1	0.263	0	0.211
Fallowing practice	↓	1	0	0.357	0.357
Farm acreage	↓	0.300	0	1	0.700
Response to droughts	↓	1	0	0.111	0.361
Vulnerability indices		0.436	0.415	0.656	0.377
OVERALL VULNERABILITY INDEX = 0.471					

Source: Field data, 2014

Based on the selected indicators in this study for vulnerability index computation, the vulnerability differs with zone for this particular year. The mid lower zone seem to be more vulnerable of all by having 0.656, the upper and mid upper zone vulnerability indices are more or less the same by having 0.436 and 0.414. The lower zone indicates to be the least vulnerable of all the four zones with 0.377. The index will differ with other indicators apart from those which have been chosen in this study. Therefore there is a need to take note that the vulnerability index may have a relative difference with zones. This output suggests that the mid lower zone has to be put in much attention to formulate comprehensive adaptation options to restore its natural existence since it is the one which shows high vulnerability status of all.

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This particular chapter is intended to summarize the results under subject and indicate different crop farming adaptations techniques employed by farmers on the study area. Also it will recommend improvement areas of agricultural practices and policy issues and later conclude the findings.

5.2 Summary by Objectives of the Study

5.2.1 Socio-economic status of the households and agro-ecosystems' susceptibility

To some extent the issue of socio-economic status of households along transect have negative implications on agro-ecosystems' susceptibility. The issue of household size and dependence shows that large family size and presence of high dependence on household heads create a high dependence on agriculture as a means of income generation as the study indicated 94% of households got their main income from subsistence farming. Meanwhile, a very big concern is on the small size of household land parcels compared with household size especially in the upper and mid upper zone where land is very limited and force for land borrowing by which the borrowers does not take any care of the land parcel because of the notion that if he/she does so the land rent will increase and the highest bidder will take over.

Education is also having an implication on farming system and adaptation to new farming technology because most of respondents had primary education and rarely get extension services. Lack of skills may lead to mal adaptation in farming practices. Fuel wood dependence as a cooking energy has the implication on the ecosystem in general and this may exacerbate agro-ecosystems' natural resilience. Another area of concern in socio-economic parameters that may influence the agro-ecosystems' susceptibility is the social safety nets whereby most of households found to have not belong to any social safety net group and this led to total dependence on agriculture as the main household income generation activity.

5.2.2 Farming practices and their implication on agro-ecosystem susceptibility

Conservation agriculture provides a viable means for strengthening resilience in agro-ecosystems and livelihoods that also advance adaptation goals *(high confidence*); wide array of conservation agriculture practices; including agro-forestry and farmer-managed natural tree regeneration, conservation tillage, contouring and terracing, and mulching are being increasingly adopted in Africa (IPCC, 2014). These practices strengthen resilience of the land base to extreme events and broaden sources of livelihoods, both of which have strongly positive implications for climate risk management and adaptation. Moreover, conservation agriculture has direct adaptation-mitigation co-benefits (IPCC, 2014).

The farmlands in upper zone and mid upper zone are characterized with mixed farming and agro-forestry which may sustain the agro-ecosystem resilience but unfortunately it is threatened by the series of below average rains which has been reported to start since 2004. These zones are not suitable for maize cultivation and this may be due to excessive shading from banana, coffee and trees which are common vegetative cover of these zones, this situation compel the households in these zones to have at least one to two hectares in mid lower or lower zone for maize cultivation either by lease or buying as about 40% of households in these zones depends on maize as main crop even though they have banana at their home gardens.

The situation is different in mid lower and lower zone where mono cropping is predominant. This system of cropping has negative implications on the soil as one crop grown most often may reduce the soil quality. It has been also found that most often than not farmers in lower and mid lower zone practice sequential cropping of which is not as efficient as crop rotation and this may lead detrimental impacts in the soils and farmers also admit that the yield of beans grown during short rains are not pleasing as in past ten years. Fallowing which is the best method for soils to regain fertility is no longer practiced in this area since it has been confirmed that 89% households does not practice the system due to limited land and farmers has reported the decrease in yield due to this factor. During group discussion with farmers, they strongly admit that the yield is no longer corresponding with inputs in their farms and this has led to hand to mouth cultivation and sometimes very little for sale compared to more than ten years.

5.3 Conclusion

Generally, this study has found a relative relationship between farmers' socio-economic status and ecosystem exploitation given the lack of enough means of household diversification which force them highly depend on nature for their survival which cause constant soil disturbance that lessen the efficiency and performance of agro-ecosystem. Furthermore their initiative to maintain production like soil and water conservations are said to be under performance overtime due to increase in severity of climatic hazards like floods and droughts. Meanwhile, farming practices relevant to sustainable agro-ecosystem's resilience seems to lack among farmers and hence exacerbate their vulnerability over time. Natural hazards like droughts, floods, below average rains and pests and diseases also has proven to lessen goods and services from agro-ecosystem as it has decreased yield over time

5.5 Recommendations and policy consideration

5.5.1 Supporting new and existing soil and water conservation infrastructure

The farmers have shown their own traditional systems of improving and maintaining soil and water on their farmlands like infiltration ditches, mulching, water boreholes (in lower zone), grass strips, stone bunds to name some. These infrastructures need urgent support for improvement through extension services. In the lower zone there has been reported by ward extension officer that the *subsoilers* are the best for water retention in soils but for all interviewed farmers no one reported the use of these *subsoilers* because it is very expensive to hire and this calls for subsidies on these equipments from the government. The lower zone is a victim of floods from upper zones and these calls for enough water retention soils which can be fulfilled by employing *subsoilers*.

5.5.2 Social safety nets for household diversification

Social safety nets especially credit and cooperative association can be the best attempt to reduce household vulnerability by diversifying household economy. The prevalence of less concern over social groups especially SACCOs may imply that there is no motivation of small scale farmers to join these cooperatives and calls for motivation engineers so these farmers may join and diversify household income and get rid of entire dependence on land per se.

5.5.3 Alternative household cooking energy

Most of farmers depends on fuel wood for their household food preparation and thus pose a threat to ecosystem given the scarcity of trees especially in mid lower and lower zone where agro-forestry is not common. The upper zone highly depends on fuel wood from the agro-forestry and this may be a threat to environment. Nevertheless it has been found that other alternative energy for household can be introduced in these areas because from the study, two farmers were on the process to establish the bio gas cooking infrastructure which they claimed to be expensive for the common small scale farmers but the raw material like cow dung is readily available from zero grazed cattle in upper zones. In the lower and mid lower zone the availability of enough sunshine for solar cooker calls for the implementation of these infrastructures so as to serve the existing vegetative covers and government may act as subsidies provider and creating room for importation of solar cooker equipments.

5.5.4 Promotion of dairy cattle as on farm diversification and adaptation option

The conditions in lower zone is conducive for dairy cattle raring, meanwhile the farmers in this zone practice cattle rooting due to the number of cattle and the availability of pastures but these raring system has implication on soil quality since cattle reduces the soil water retention capacity by hardening the top soil and increase surface runoff which in turn worsen the soil moisture over time. In this case it is better to introduce and promote few and highly productive dairy cattle to diversify the household income and improve the soil water retention capacity.

5.5.5 Promotion of traditional and nontraditional high value crops

The promotion of production and consumption of alternative cereal and non cereal crops which are traditional or nontraditional high value crops which include drought resistant crop and early maturing seed breeds has to be a priority in this era of climate change to ensure food security and household diversification in mountainous vicinities. These crops includes Vegetables, fruits, flowers, houseplants and foliage, condiments and spices, green gram, cassava, sorghum, beans to name some. Because of nature of the study area being vary with altitude and other climate and soil parameters it may accommodate many traditional and nontraditional high value crops crop variety as it has been the case of vanilla and mushroom in the upper and mid upper zone whereby gardening and drought resistance crops in mid lower and lower zones. Meanwhile, new evidence is also emerging that high-value perennial crops could also be adversely affected by temperature rise (*medium confidence*) (IPCC, 2014).

5.6 Suggestion for future research

The research was taken in the southern part of Mount Kilimanjaro with different micro climate depending on altitude at where the community surrounding the mountain dwell, this calls for more research in other sides of the mountain to deepen our understanding of the farming systems, soils and crops suitable for these areas, including potato cultivation in west Kilimanjaro. Also this research covers a representative sample for that region in which there might be remarkable difference in land use around this mountainous part and needs more research.

Meanwhile, the case of crop and climate trend analysis is general over these areas while this area has different specific microclimates which calls for climate downscaling and identify specifically which crops can grow well over these micro climatic areas especially this era of climate change in which adaptation and mitigation is of priority concern. Also more research are needed to identify potential drought resistant crops which are either cash or food crops because it has been found to be difficult to adapt some drought resistant crops which is not preferred in diets of community in Kilimanjaro, e.g. sorghum; this can be adapted as long as a reliable market is available for the farmers.

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APPENDICES

Household Questionnaire

CLIMATE CHANGE IMPACTS ON ECOSYSTEM SERVICES AND FOOD SECURITY IN EASTERN AFRICA (CHIESA) HOUSEHOLD QUESTIONNAIRE FOR ASSESSMENT OF HOUSEHOLD VULNERABILITY AND RISK

We are researchers from the CHIESA Project which deals with research on the impacts of climate change on smallholder farmers and the formulation of suitable climate change adaptation strategies to help in reducing the impact of climate change on agriculture. The information you provide will be used solely for research purposes and will be treated with utmost confidentiality.

Name of the Interviewer ______________________________ Date: (DD/MM/YYYY) _________________

Region ____

District ____

Village ____

Location of Household in GPS Coordinates

Latitude (N/S) ____

Longitude (E/W) _______________________________________

Elevation (m.a.s.l) ______________________________________

Indicate time in 24 hour system

Start of Interview (HRS/MIN)____

End of Interview (HRS/MIN) ____

A. DEMOGRAPHIC PROFILE

	CODE	RESPONSE
A1. Name of the Respondent (Optional)	*(Mark N/D if the information is not available)*	
A2. Address		
A3. Mobile Phone Number		
A4. Age		
A5. Gender	1. Male 2. Female	
A6. Marital Status	1. Never Married	

	2. Married and living together 3. Married but not living together 4. Married to more than one spouse 5. Widowed 6. Divorced	
A7. Ethnicity (Optional)	(*Mark N/R if there is no response)*	
A8. Religion (Optional)		
A9. Occupation		
A10. Respondent's Relationship with household head	1. Household head 2. Mother 3. Father 4. Husband 5. Wife 6. Child 7. Grandchild 8. Other Relative (Specify)	
A11. Head of Household (indicate male/female/child headed)	1. Adult Male Headed 2. Adult Female Headed 3. Boy Child Headed (< 18 years) 4. Girl Child Headed (< 18 years)	
A12. Respondent's Highest level of education	1. Primary 2. Secondary/High School 3. Tertiary / College(Diploma) 4. University (Specify; Undergraduate, Graduate, PhD) 5. Technical (e.g. Tailoring, Carpentry etc) 6. Other (Specialties) 7. No formal Education	
A13. Duration of residence in Jimma Highlands/Mt. Kilimanjaro/Taita Hills *(Indicate area clearly)*	1. Not a resident (Indicate where from) 2. <1 year 3. 1 year – 5 years 4. 5.1 years – 10 years 5. 10.1 years – 15 years 6. 15.1 years – 20 years 7. 20.1 years – 25 years 8. 25.1 years – 30 years 9. >30 years	
A14. Main Source of Household Income (Indicate only one) *(*From Code 3-6 indicates income earned outside of the respondent's own farm)*	1. Subsistence Farming 2. Dairy farming 3. Ranching (Beef farming) 4. Goat/sheep rearing 5. Cash Crop Farming 6. Short Term Agricultural Wage Labour (<3 Months) 7. Short Term Non-Agricultural Wage Labour (<3 Months) 8. Permanent/ Salaried Agricultural Related Employment 9. Permanent/Salaried Non-Agricultural Related Employment	

	10. Business (Specify) 11. Remittances (Indicate Source) 12. Pension 13. Government Welfare 14. Other(Specify)	
A15. Other Sources of Household Income (Specify)		
A16. Household size (members currently living in the household)		
A17. Number of dependants (*Count only those dependants currently living in the household but not contributing to the household income in cash or in kind)*	1. 1-3 2. 4-6 3. 7 and above 4. None	

B. DEPENDANTS IN THE HOUSEHOLD

B1. Member	B2. Age	B3. Marital Status	B4. Level of Education

Inform the respondent that the succeeding questions address only the other household members who contribute to the household income

C. MEMBERS CONTRIBUTING TO HOUSEHOLD INCOME

C1. Member	C2. Age	C3. Occupation	C4. Contribution to the household (In terms of Days per Week)	
1. Head of Household 2. Spouse(s) 3. Son 4. Daughter 5. Granddaughter 6. Grandson 7. Grandmother 8. Grandfather 9. Other (Specify) (*if more than one member is contributing, indicate them ALL)*		1. Smallholder Farmer 2. Casual Farm Labourer 3. Self employed 4. Business and Retail/Trader 5. Artisan/Mechanic/Factory Worker/Mason 6. Health Worker (Private/Public) 7. Teacher(Private/Public) 8. Government Employee 9. Parastatal Employee 10. Transport Sector 11. Other (Specify)	C4.1 On Farm Contribution	C4.2 Off Farm Contributi on

D. SOCIAL SAFETY NETS

<table>
<tr><td>D1. Group</td><td rowspan="2">D2. Member (Use codes in C1 of preceding table)</td><td rowspan="2">D3. Duration of Membership (In case of multiple membership indicate the earliest year joined)</td><td rowspan="2">D4. Type of help received from group
1. Loan
2. Credit
3. Livestock/Poultry
4. Transportation Support
5. Marketing of Produce
6. Technical/Equipment Support
7. Seeds
8. Tree Saplings (Agro-forestry)
9. Food aid
10. Land preparation
11. Harvesting
12. Weeding
13. Buying inputs
14. Building and maintenance of terraces
15. Other (Specify)</td></tr>
<tr><td>1. Farmers' Association
2. Youth union
3. Women's union
4. Political group
5. Religious group
6. Credit /Saving group
7. Community Based Organization
8. Water Resource Users Association
9. Staff Association
10. Other (Specify)</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>

E. HOUSEHOLD ASSETS

E1. Type of Asset (Owned by the Household)	E2. 1:Yes; 2: No	E3. How many?	E4. Who owns these assets? From C1 (member id)
1. Primary residence a. Permanent b. Semi-permanent c. Temporary			
2. Business building			
3. Solar panel			
4. Toilet (pit)			
5. Toilet (modern flush)			
6. Car			
7. Motorcycle			
8. Refrigerator			
9. Television			
10. Radio			
11. Cell phone			
12. Bicycle			
13. Computer			
14. Hand Cart			
15. Tractor			
16. Other (Specify)			

F. HOUSEHOLD CHARACTERISTICS

F1. Do you own the main dwelling See Codes	F2. Roof material for the main dwelling unit See Codes	F3. Main source of cooking fuel See codes	F4. Main source of lighting See Codes

F1	F2	F3	F4
1. Owned 2. Rented 3. Other (Specify)	1. Thatch 2. Sticks 3. Tin 4. Iron roof sheets 5. Asbestos 6. Tiles 7. Other (Specify)	1. Firewood from own woodlot 2. Firewood from neighbours' woodlot 3. Firewood bought from the market 4. Firewood from the gazetted forest 5. Gas (LPG) 6. Electricity 7. Animal Dung 8. Biogas 9. Farm residue 10. Other (Specify)	1. Electricity 2. Candle 3. Lanterns 4. Firewood 5. Solar Panel 6. Generator 7. Biogas 8. Other (Specify)

G. DOMESTIC WATER USE

G1. Sources of domestic water **key**	G2. Distance to source ***km***	G3. Time to Source	G4. Seasonal Use ***key***	G5. How do you consider quality ***key***	G6. Used for ***key***	G7. Payment for use? ***1=Yes, 2=No***	G8. If yes, how much? (*in local currency)*	
							Amt/month	***Amt/liter***

G1. Source of Rain Water

1. Rooftop rainwater
2. Borehole
3. Spring
4. River
5. Dam
6. Water Pan
7. Lake
8. Stream
9. Piped water at source
10. Piped water into dwelling
11. Irrigation canal
12. Water vendor
13. Other (Specify)

G3. Key for Time to source
1. <30 min
2. 30-60 min
3. > 2 hrs

G4- Key for seasonal use:
1. Rainy season
2. Dry season
3. All year

G5 – Key for water quality:
1. very good
2. good
3. fair
4. poor
5. very poor

Key for G6- used for:
1. Drinking
2. Livestock watering
3. Washing
4. Cleaning
5. All household needs
6. Other (specify ________)

H. ACCESS TO BASIC FACILITIES

H1. Type of Facility	H2. Do you currently have access? (1: Yes; 2: No)	H3. If no, why? ***(key)***	H4. If yes, distance from the household (km)	H5. Did you have access 10 years ago? (1: Yes; 2: No)
Electricity (*ask if electricity is available in the h/hold)*				
Telephone (land line)				
Mobile Phone				
Primary School				
Secondary School				
Medical center				
Market				
Grocery/Hardware Store/Agrovet				
Transport (Bus, Motorcycle, Taxi, Tuk Tuk (Bajaj, Animal Powered Transport)				
Water Point				
Extension Services				

<u>**Key for H3 If no access, why?**</u>
1. Government did not provide
2. Financial constraints
3. Not available
4. Political instability
5. Insecurity
6. Cultural belief
7. Religious belief
8. No need
9. Time Distance
10. Terrain
11. Physical Constraint
12. Other, specify___________________

I. AVAILABILITY OF AND ACCESS TO WEATHER FORECAST

<table>
<tr><td colspan="4">I1. Are weather forecasts available for your local area (1. Yes 2.No)</td></tr>
<tr><td colspan="4">I2. Does your household have access to weather forecasts (1. Yes 2. No 3. Other (Specify)</td></tr>
<tr><td colspan="4">I3. If no, give reasons</td></tr>
<tr><td colspan="3">I4. If yes, what type of weather forecast do you have access to
1. Conventional Weather Forecast (Provided by National Meteorological Agent)
2. Traditional Weather Forecast (Provided through local observations)
3. Both</td><td></td></tr>
<tr><td>I5. What is the temporal scale of the weather forecast provided?
1. Daily Forecast
2. Weekly Forecast
3. Monthly Forecast
4. Seasonal Forecast
5. Annual Forecast</td><td>I6. Source</td><td>I7. Level of Reliability</td><td>I8. How information is utilized</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Source of Forecast(I6)
1. Radio
2. Newspaper
3. TV
4. Chiefs’ barazas
5. Government extension agents
6. Traditional forecasters
7. Local elders/religious leaders
8. Friends or neighbours
9. Other (Specify)</td><td colspan="3">For level of reliability of the forecast (I7): 1. Very Reliable, 2. Reliable, 3. Unreliable, 4. Very Unreliable 5. No Answer</td></tr>
<tr><td colspan="3">For utilization of information (I8):
1. For land preparation
2. For seed selection and preparation
3. For fodder collection and storage
4. For planting
5. For pesticide/herbicide application
6. For harvesting
7. For post harvest activities
8. Other (Specify)</td></tr>
</table>

J. CLIMATE IMPACTS TO THE HOUSEHOLD MODULE

J1. Has your household been impacted/affected by climatic events in the last 10 years? (1. Yes 2. No)						
J2. If yes, which climatic events (climate events that significantly affected household income) have affected your household during the last 10 years?						
J3. Type of event *(key)*	***J4. When was the event (year in last 10 years)***	***J5. What was the outcome of the event?*** *(key)*	***J6. What did you do? - Action?*** *(key)*	***J7. Who took the action?*** *(member id C1)*	***J8. How widespread was the event?*** *(key)*	***J9. Estimate of the amount of loss/gain to the household*** **(local currency)**

Key-Type of climate event (J3):
1. Drought
2. Above average rainfall
3. Below average rainfall
4. Floods
5. Erratic rainfall patterns
6. Hailstorms
7. Lightning
8. Fire Outbreaks
9. Landslides
10. Strong Winds
11. Loss of top soil (Soil Erosion)
12. Frost
13. Above average daily temperatures
14. Below average daily temperatures
15. Heat waves
16. Others (specify)

Action (J6)
1. Did nothing
2. Assistance from friends/relatives
3. Relied on savings
4. Government food aid
5. Sold land
6. Sold house
7. Sold crops
8. Sold livestock
9. Changed farming practice
10. Bought food
11. Reduction in household food consumption
12. Sought off-farm employment
13. Ate different types of food
14. Ate wild plants/fruit/animals
15. Exchange animals for cereals

How widespread was the impact (J8)?
1. My household only
2. A few households in the village
3. Most households in the village
4. All households in the village
5. A few households in the region
6. Most households in the region
7. All households in the region

Outcome of climate event (J5)

1. Decline in crop yield
2. Increase in crop yield
3. Loss of income
4. Gain of new income sources (Specify)
5. Loss of assets
6. Acquisition of new assets
7. Loss of entire crop
8. Death of livestock
9. Decline in livestock production
10. Increase in livestock production
11. Increase in food prices
12. Decrease in food prices
13. Food Shortage
14. Food Surplus
15. Damage to infrastructure (e.g. roads, canals, sewerage)
16. Increase in area under production
17. Increase in the length of growing season
18. Increase in the number of growing seasons
19. Occurrence of conditions suitable for growth of new crops and fruit
20. Change in the onset and cessation of the growing season
21. Others (specify)

16. Borrowed from bank
17. Borrowed from private money lenders
18. Borrowed from relatives and friends
19. Household member migrated to other rural area
20. Household member migrated to urban area
21. Participated in Food for Work initiative
22. Kept children out of school
23. Others (specify)

K. EARLY WARNING SYSTEM FOR CLIMATE EXTREMES

K1. Have the incidents of 1. drought/ 2. floods changed in your area? 1. Yes 2. No __________
K1.1 If yes, have they 1. Increased 2. Decreased
K1.2 Give reasons for change ________________________________
K1.3. Did you have access to early warning before the last drought/flood? 1. Yes 2. No ____________________

K1.4. If no to the above question, why? 1. Not available, 2. Non access to media devices 3. Delay in the reception of information 4. Other (Specify)

K1.5. If yes, how did you utilize the information in coping with the drought/flood? ___________________

1. Stocking up on food items
2. Digging trenches
3. Planting drought resistant crops
4. Selection of drought resistant seed/crop varieties
5. Purchase of irrigation equipment
6. Purchase of rooftop rainwater harvesting equipment
7. Moving livestock/poultry to higher ground
8. Stocking up on fodder
9. Preparing the furrows
10. Other (Specify)

K2. When was the last drought the household experienced? ______________ (year)	***K3. When was the last year the household experienced too much rain/flooding? ____________ (year)***
K4. Do you have food reserves for use during the dry season/periods of drought? 1. Yes 2. No	***K4.1. Do you have food reserves for use during periods of drought/floods?*** 1. Yes **2.** No
K5. If yes to the above question, how long do the reserves last you in times of need? 1. 0-2 month 2. 2.1 -4 months 3. 4.1-6 months 4. > 6 months	***K5.1 If yes to the above question, how long do the reserves last you in times of need?*** 1. 0-2 month 2. 2.1 -4 months 3. 4.1-6 months ***4. > 6 months***
K6. During the last large drought, did you change your farming practice (crop and livestock)? _______ (1. Yes 2. No)	K7. During the last year with too much rain, did you change your farming practice (crop and livestock)? ________ (1. Yes 2. No)
K8. If no, why did you not change your farming practice (use key) (*For both drought and too much rain section*)	

1. No access to money 2. No access to credit 3. No access to land 4. No access to equipment 5. No access to extension services 6. No inputs (e.g. fertilizer/seeds) 7. Shortage of labor 8. No information on climate change and appropriate adaptations **9.** Other (Specify)							
K9. If you changed the farming practices please answer the following questions							
Drought				**Flooding/Too much rain**			
K10. If yes, what did you do? (key)	K11. If yes, how?	K12. If yes, who? (C1-member id)	K13. Indicate from whom you got information on how to implement the change Key**:** 1. Relative 2. Neighbor 3. Project/NGO 4. Government extension 5. Other (specify)	K14. If yes, what did you do? (key)	K15. If yes, how?	K16. If yes, who? (member id- C1)	K17 Indicate from whom you got information on how to implement the change Key: 1. Relative 2. Neighbor 3. Project/NGO 4. Government extension 5. Other (specify)
1. Change in planting dates 2. Change in crop variety 3. Change in crop type 4. Other (Specify)				1. Change in planting dates 2. Change in crop variety 3. Change in crop type 4. Other (Specify)			

Drought				**Flooding/Too much rain**			
If yes, what did you do? (key)	**If yes, how?**	**If yes, who? (C1-member id)**	**Indicate from whom you got information on how to implement the change Key: 1. Relative 2. Neighbor 3. Project/NGO 4. Government extension 5. Other (specify)**	**If yes, what did you do? (key)**	**If yes, how?**	**If yes, who? (C1-member id)**	**Indicate from whom you got information on how to implement the change Key: 1. Relative 2. Neighbor 3. Project/NGO 4. Government extension 5. Other (specify)**
K21. Diversification of crops from staple to: (Yes/No) If yes: 1. Fodder 2. Horticulture 3. Cash crops 4. Drought resistant crops 5. Trees for timber 6. Trees for firewood 7. Other (Specify)				K21.1 Diversification of crops from staple to: (Yes/No) If yes: 1. Fodder 2. Horticulture 3. Cash crops 4. Drought resistant crops 5. Trees for timber 6. Trees for firewood 7. Other (Specify)			
K22. Increase in land size under cultivation (specify unit of measurement)				K22.1 Increase in land size under cultivation (specify unit of measurement)			

K23. Decrease in land size under cultivation (Specify unit of measurement)				K23.1 Decrease in land size under cultivation (Specify unit of measurement			
K24. Change in fertilizer application (Yes/No) If yes: 1. Manure 2. Compost 3. Crop residue 4. Commercial fertilizer 5. Other (Specify)				K24.1 Change in fertilizer application (Yes/No) If yes: 6. Manure 7. Compost 8. Crop residue 9. Commercial fertilizer 10. Other (Specify)			
K25. Use of pesticides (Yes/No) If yes: 1. Organicl to Synthetic 2. Synthetic to Organicl 3. Mix of synthetic and Organic 4. Other (Specify)				K25.1 Use of pesticides (Yes/No) If yes: 5. Organicl to Synthetic 6. Synthetic to Organicl 7. Mix of synthetic and Organic 8. Other (Specify)			
K26. Implement soil conservation and water harvesting techniques (Yes/No) (See codes) 1. Terraces 2. Minimum tillage 3. Grass strips 4. Cover crops 5. Diversion ditches 6. Agro forestry 7. Irrigation 8. Zai Pits 9. Other (Specify)				K26.1 Implement soil conservation and water harvesting techniques (Yes/No) (See codes) 1. Terraces 2. Minimum tillage 3. Grass strips 4. Cover crops 5. Diversion ditches 6. Agro forestry 7. Irrigation 8. Zai Pits 9. Other (Specify)			
K27. Indicate change in agriculture and livestock production	**Fill in code from K27 as appropriate**			K27.1 Indicate change in agriculture and livestock production	**Fill in code from K27 as appropriate**		

3. Mixed crop and livestock production 4. Shift from crop to livestock production 5. Shift from livestock to crop production 6. Grow trees with crops (Agro-forestry) 5. Grow trees with pasture 6. Increase in shade trees on the farm 7. Change pattern of animal consumption 8. Increase the number of livestock 9. Shift from crop to fish farming 10. Crop production to fodder production 11. From staple crops to cash crops 12. Decrease the number of livestock (de-stocking) 13. Diversify livestock feeds 14. Change livestock feeds 15. Supplement livestock feeds 16. Change veterinary interventions 17. Change portfolio of animal species 18. Change animal breeds 19. Move animals to another site 20. Seek off farm employment 21. Migrate to another piece of				1. Mixed crop and livestock production 2. Shift from crop to livestock production 3. Shift from livestock to crop production 4. Grow trees with crops (Agro-forestry) 5. Grow trees with pasture 6. Increase in shade trees on the farm 7. Change pattern of animal consumption 8. Increase the number of livestock 9. Shift from crop to fish farming 10. Crop production to fodder production 11. From staple crops to cash crops 12. Decrease the number of livestock (de-stocking) 13. Diversify livestock feeds 14. Change livestock feeds 15. Supplement livestock feeds 16. Change veterinary interventions 17. Change portfolio of animal species 18. Change animal breeds 19. Move animals to another site 20. Seek off farm employment 21. Migrate to another piece of land 22. Set up communal seed banks/food storage facilities 23. Other (specify)			

land 22. Set up communal seed banks/food storage facilities 23. Other (Specify)							

L. Have any other events/shocks affected your household during the last 10 years? ___________________ (1=Yes, 2=No)
(*Has this household been affected by a serious shock—an event that led to a serious reduction in your asset holdings, caused your household income to fall substantially or resulted in a significant reduction in consumption?)*

L1. Type of shock *(See Codes)*	***L2. When was the shock (year in last 10 years)***	***L3. What did the shock result in?*** *(See Codes)*	***L4. Who in the household was most affected by the shock?*** (C1- member id)	***L5. What did you do? - Action?*** *(See Codes)*	***L6. Who took the action?*** (C1-member id)	***L7. How widespread was the shock?*** *(See Codes)*	***L8. Estimate of the amount of loss to the household***

Key for preceding question Other types of shocks (L1)

Production shocks

1. Insect pests attack on crops before harvest,
2. Other pest attacks on crops before harvest
3. Crop loss during storage,
4. Plant disease
5. Animal disease,
6. Wildlife damage to crops

Market shocks

7. Large increase in input prices,
8. Large decline in output prices,
9. Inability to sell agricultural products,
10. Inability to sell non agricultural products,
11. Inaccessibility to markets

Political and social shocks

12. Expropriation of land by government,
13. Ethnic violence
14. Forced migration/relocation
15. Discrimination for political reasons,
16. Forced contributions
17. Arbitrary taxation,
18. Discrimination for social reasons,
19. Corruption

Criminal shocks

20. Theft of crops,
21. Theft of livestock;
22. Destruction or theft of tools or inputs for production,

Idiosyncratic (personal) shocks

23. Loss of job by family member;
24. Death of family member (specify)
25. Illness of family member (specify)
26. Separation of family member[s],
27. Dispute with extended family,
28. Dispute with others in village;
29. Imprisonment
30. Other [specify]

Key for L3 - Outcome of shock:

1. Loss of assets,
2. Loss of income,
3. Decline in crop yield;
4. Loss of entire crop
5. Death of livestock;
6. Decline in livestock productivity
7. Food shortage/insecurity
8. Other, [specify________________]

Key for L 5Action

1. ***Did nothing,***
2. ***Sold livestock,***
3. Sold crops
4. Sold land/home
5. Sold assets
6. ***Borrowed from relatives or friends***
7. ***Borrowed from bank,***
8. Borrowed from private money lenders
9. ***Received food aid,***
10. ***Participated in food for work,***
11. ***HH head migrated to other rural area,***
12. ***HH plus others migrated to rural area,***
13. ***Migrated to urban area,***
14. ***Sought off-farm employment,***
15. ***Bought food***
16. ***Ate less;***
17. Ate different foods

18. Kept children home from school
19. Other [please specify_ __________]

Key for L7 – How widespread

1: Only my household
2: Some households in the village
3: Most households in the village
4: All households in the village
5: Many households in the region
6: Some households in the region
7: All households in the region

M. LAND TENURE, LAND CHARACTERISTICS, OWNERSHIP AND MANAGEMENT MODULE.

(For this section please ask the respondent to indicate the main parcel of land plus other additional land parcels)

Land characteristics

M1. Area/Size of Parcel (Specify unit of measurement)	M2. Major land use type **(key)**	M3. Major crops (food/cash crop)*(list—one per plot or intercropping)*	M4. Distance from household (km)	M5. Soil type **(See Codes)**	M6. Soil fertility **(See Codes)**	M7. Change in soil quality in the last ten years 1. Improved 2. Same 3. Declined	M8. Reason for change in soil quality (key)	M9. Slope **(See Codes)**	M10. Erosion **(See Codes)**	M11. Who manages plot *(member id)* **(See Codes C1)**

Key for Major land use type (M2):
1. Crop production;
2. Agro-forestry
3. Livestock
4. Grazing land/pasture land
5. Kitchen garden;
6. Farm forestry
7. Fish farming
8. Fodder farming (e.g. solely napier grass on plot)
9. Tree farming
10. Horticulture
11. Other (pls. specify) ________

Key for - Soil type (M5):
1. Black,
2. Brown
3. Grey
4. Red
5. Yellow
6. Murram
7. Sandy
8. Clay
9. Other [pls. specify]________

Key for Soil fertility (M6):
1. Very fertile
2. Moderate
3. Poor

Key for Change in soil quality (M8)
1. Irrigation
2. Improved land use practices
3. Use on inputs
4. Floods
5. Drought
6. Other (specify)

Key for Slope (M9):
1. Flat,
2. Slight incline (up to 20 degrees),
3. Steep

Key for Erosion (M10):
1. No erosion
2. Mild erosion
3. Severe erosion

N. LAND OWNERSHIP AND ITS HOLDING IN THE LAST 12 MONTHS

N1. Land ownership **(key)**	N2. Land title at the parcel level **(key)**	N3. How was the land acquired? **(key)**	N4. If rented, what is the annual rent			N5. Who in this household acquired this parcel? (C1- Member id)	N6. Who has the right to give away this plot? (C1-Member id)
			Cash (*In local currency)*	In kind (units)	In kind (*estimate amount in local currency)*		

N6.1. Have your land holdings increased or decreased in the past 10 years? (1.Increase 2. Decrease 3. No change) ________________________________

N6.1.1 If there has been change, give reason ____

N6.2. What were your total land holdings in 2004? __________________ (*state unit of measurement)*

Key for N1 – Land ownership:
1. Own land and own use,
2. Renting out (cash rent),
3. Renting in
4. “Pure” Sharecropping in,
5. “Pure” Sharecropping out,
6. “Cost-sharing” Sharecropping in
7. “Cost-sharing” Sharecropping out
8. Communal land (traditional ownership),
9. Borrowed land in (Do not pay money or in kind for usage),
10. Borrowed land out (does not receive money or in kind payments for usage)
11. Other (pls. specify___________)

Key for N2- Land title:
1. Government title,
2. Communal tenure [clan, not written],
3. No title
4. Leased in from government
5. Private lease
6. Own title deed

Key for N3- How acquired:
1. Inherited
2. Purchased,
3. Received from the government,
4. Allocated by the community
5. Leased
6. Other [please specify]____________

N7. LAND MANAGEMENT (CROP AND GRAZING LAND)

N7.1 What type of soil and water management practices are you using on crop land? (key)	N7.2 Since when did you start using this practice? (year)	N7.3 What previous practices did you use? (key)	N7.4 Why did your practices change? (key)	N7.5 What management techniques are you using for grazing land? (key)	N7.6 Since when did you start using this practice? (year)	N7.7 What previous practices did you use? (key)	N7.8 Why did your practices change? (key)	N7.9 If using water harvesting, what type? (key)	N7.10 If using irrigation, what type? (key)	N7.11 What source of water do y ou use for irrigation? (Key)

Keys next page

N7.12. Are you leaving land fallow? ____________________________ (1=Yes 2=No)

N7.13. Do you consider your grazing land to be over grazed? ______________ (1=Yes 2=No 3= Don't know)

N7.14. What do you do with crop residues after harvesting? ____________________________________ (Key)

Key for N7.14

1. Slash and burn
2. Slash and leave it on the surface for livestock to graze on
3. Slash and store as forage for livestock
4. Do nothing and leave the residue as they are until the next season
5. Slash and sell the residue
6. Slash and use as thatch material
7. Slash and leave them lying on the surface until the next season
8. Use as firewood
9. Used for trash line making
10. Slash and use for mulching
11. Other (specify)

Key for N7.1 and N7.3 – Type of soil and water conservation:

1. Nothing
2. Fanya Juu terraces (soil bunds up slope)
3. Fanya Chini (soil bunds down slope) (creates a cut off drain or a retention ditch)
4. Bench terraces
5. Trenches
6. Irrigation
7. Stone bunds
8. Mulching/surface cover
9. Trash line
10. Log line
11. Slash and burn
12. Grass strips
13. Hedge rows (shrubs)
14. Conventional tillage
15. Minimum tillage
16. Infiltration ditches
17. Ridge and furrow
18. Fallowing
19. Improved fallowing
20. Composting
21. Farm yard manure
22. Green manure
23. Fertilizer (inorganic straight)
24. Fertilizer (inorganic compound)
25. Agroforestry
26. Shade trees
27. Cover crops
28. Crop rotation
29. Crop rotation with legumes (nitrogen fixing)
30. Intercropping
31. Small dams
32. Water pans
33. Others, specify_____________

Key for N7.5 and N7.7- Grazing land management

1. Enclosure of the land
2. Restriction on livestock numbers (destocking)
3. Maintain large stocks
4. Removal of unwanted bush
5. Periodic resting
6. Open grazing area
7. Zero grazing
8. Cattle routing
9. Common watering points
10. Supplementary fodder production
11. Others, specify_________________

Key for N7.4 and N7.8- Why has your crop land/grazing land practices changed?

1. To increase productivity/yield
2. To increase water holding capacity
3. To increase biological control of pests and diseases
4. To reduce conflict with neighbours
5. To increase soil fertility
6. To reduce erosion
7. Other, specify____________________

Key for N7.9- Type of water harvesting

1. Roof water harvesting
2. Earth dams
3. Tree crop ditches
4. Ridge and furrow
5. Retention ditches
6. Road water harvesting
7. Catchment tanks
8. Underground tanks
9. Rock catchments
10. Extraction from springs
11. Extraction from rivers
12. Extraction from lakes and reservoirs
13. Sand dams
14. Other, specify______________________

Key for N7.10 -type of irrigation

1. Flood irrigation
2. Ridge and Furrow irrigation
3. Drip Irrigation
4. Overhead irrigation
5. Watering Can
6. Other (Specify)

Key for N 7.11-Sources of Water for Irrigation

1. Public borehole
2. Private borehole
3. Springs
4. Lakes and reservoirs
5. Dams
6. Water Pans
7. River
8. Rainwater
9. Other (Specify)

O. AGRICULTURE PRODUCTION AND FOOD SECURITY MODULE

O1. Does your household normally undertake crop farming? 1. Yes-Rain-fed 2. Yes-irrigated 3. Yes R&I 4. No	O2. Did your household grow any crops during the last 12 months? 1. Yes 2. No		O3. If no in the previous question, what was the reason (See Codes)	O4. Name all crops that the h/hold farmed in the last 12 months by season and acreage				O5. Expected harvest in the last 12 months		O6. How much did h/hold actually harvest in the last 12 months from parcel planted (See codes)		O7. How much of the harvest was consumed by the household in the last 12 months		O8. How much of the harvest was sold in the last 12 months		O9. What was the total earning from the sales (*in local currency)*	O10. In the last 12 months has the household had to acquire land elsewhere for crop production (If yes, give reason) 1. Yes 2. No
	Long rains (LR)	Short rains (SR)		LR		SR		LR	SR	LR	SR	LR	SR	LR	SR	Amt	
				Crop	Acreage	Crop	Acreage	Qty	Qty	Qty	Qty	Qty	Qty	Qty	Qty		

Key for not growing crops (O3)

1. No seeds
2. Delay in seed reception
3. Poor seed quality
4. Inaccessibility to land
5. Insufficient land acreage
6. High/Low temperatures (*indicate the exact one)*
7. Inadequate/excessive rainfall (*indicate the exact one*)
8. Late onset
9. Early cessation of rainfall
10. Late onset and early cessation

Key for types of crop in h/hold (O4)

1. Maize
2. Sorghum
3. Millet
4. Cowpeas
5. Pigeon peas
6. Beans
7. Green grams
8. Fodder crops
9. Cassava
10. Yams
11. Avocado

O6-O8 (Indicate the quantity e.g. 500/1 (Quantity/unit of measure)

1. Kilogram
2. 50 kg bag
3. 90 Kg bag
4. Bunch
5. Piece
6. Heap
7. Debe
8. Gorogoro/kasuku (2 kg)
9. Basket
10. Crate
11. Others(specify)

of rainfall 11. Drought 12. Floods 13. Inadequate extension services 14. Cultural belief and practices 15. Insect pest attacks 16. Plant diseases 17. Wildlife conflict 18. Land not arable 19. Soil erosion 20. Others(specify)	12. Sweet potatoes 13. Arrow roots 14. Bananas 15. Vegetables (Specify) 16. Coffee 17. Others (specify)

P. FARMING PRACTICES

P1. What is the major cropping system on your farm? 1. Mono cropping 2. Intercropping 3. Mixed cropping 4. Agro forestry 5. Crop rotation 6. Other (specify)	P2. Methods of land preparation 1. Ox plough 2. Tractor 3. Manual (jembe) 4. Other (specify)	P3. Do you have any cover crops on your farm? 1. Yes 2. No If yes, specify	P4. Do you mulch your crops? 1. Yes 2. No	P5. Are you aware about conservation agriculture (CA)? 1. Yes 2. No	P6. How did you get to know about CA 1. Relative 2. Neighbor 3.Project/NGO 4.Government extension 5. Other (specify)	P7. Do you practice it on your farm? 1. Yes 2. No	P8. If no, what are the reasons? 1. Lack of knowledge 2. Small farm size 3. Expensive 4. No specific reason 5. Not profitable (explain) 6. Risk prone e.g. pests and diseases 7. Other(specify)

Q. HOW DOES THE HOUSEHOLD OBTAIN SEEDS FOR THE MAIN STAPLE CROP FOR PLANTING?

Q1. Staple Crop	Q2. Means of obtaining seeds 1. Buy seeds 2. Save seeds 3. Receives seeds for free	Q3. Mention Source 1. Own seed 2. Government 3. Agro-vet	Q4. How often? 1. Always 2. Sometimes 3. Never

	4. Borrow seeds 5. Other (specify)	4. Neighbours 5. Relatives 6. Farmers' Associations 7. NGOs 8. Other (Specify)	

R. AGRICULTURAL INPUTS FOR CROP PRODUCTION

R1. Inputs for coffee *(For use in Ethiopia and Tanzania only)* 1.Commercial fertilizer 2. Compost 3. Crop Residue 4.Fungicides 5. Manure 6. Pesticides 7. Irrigation facilities 8. Hired manpower 9. Improved coffee variety 10. Other (Specify)	R1.1 Type of coffee farm 1. Shaded 2. Non shaded	R1.2 No. of Coffee Plots (*indicate size and specify unit of measurement)*	R1.3 No. of coffee trees (Total)	R1.4 Current Season (See codes in R 1) Did you have access Yes/No		R1.5 Previous Season (See codes in R1) Did you have access Yes/No		R1.6 In use for more than 10 years (See codes in R1)	R2. Name of Crop	R2.1 Inputs 1.Commercial fertilizer 2. Compost 3. Crop Residue 4.Fungicides 5. Manure 6. Pesticides 7. Irrigation facilities 8. Manpower a)Hired manpower b)Household manpower 9. Improved coffee/seed variety 10. Other (Specify)	R2.2 Value inputs *(In local currency)*
				Expected	Actual	Expected	Actual				

S. CAUSES OF CROP DAMAGE AND LOSS

S1. Major causes of crop losses (in the past 12 months)	
S1. List crop(s) (use key)	**S2. Causes (use key) – if possible name the species e.g. coffee berry borer**
Crops 1. Maize 2. Sorghum 3. Millet 4. Cowpeas 5. Pigeon peas 6. Beans 7. Green grams 8. Fodder crops 9. Cassava 10. Yams 11. Avocado 12. Sweet potatoes 13. Arrowroots 14. Bananas 15. Vegetables (specify) 16. Coffee **17.** Others (specify)	**Causes** 1. Insects 2. Diseases (*name species where possible*) 3. Weeds *(name species where possible)* 4. Poor seed quality 5. Drought 6. Floods 7. Inadequate rainfall 8. Soil Erosion 9. Land not arable (soil fertility/moisture) 10. Frost 11. Excessive rainfall 12. Late onset of rainfall 13. Early cessation of rainfall 14. Strong winds 15. High/Low temperatures 16. Wildlife damage (*Indicate species where possible*) *17.* Domestic animal damage *(Indicate species where possible)* **18.** Others (specify)

T. IF DAMAGE WAS CAUSED BY INSECTS WHICH INSECT PESTS CAUSED THE MOST LOSSES?

T1. List Crop(s)	T2. Name pest(s) –(*if English name is not known use local name*)		T3. Estimate amount of damage (%)			
			Pre-harvest loss		Post-harvest loss	
	Pre- harvest pest(s)	Post-harvest pest(s)	LR	SR	LR	SR

Crop	Acreage	LR	SR	LR	SR				

U. CROP PEST CONTROL PRACTICES

U1. Traditional methods 1.Crop rotation 2.Trap cropping 3.Early planting 4.Mixed cropping 5. Using ash 6.Sanitation 7. Other (Specify)	U2. Biological methods 1.Predators 2.Parasitoids 3.Microbial agents/Bio-pesticides 4.Botanicals 5. Other (Specify)	U3. Mechanical methods 1.Handpicking 2.Shaking 3.Spraying with water 4. Other (Specify)	U4. Chemical methods 1.Insecticides 2.Fungicides 3.Bactericides 4.Herbicides 5. Other (Specify)	U5. Do you practice integrated pest management? 1.Yes 2.No *(If no, answer the succeeding table)*	U6. If Yes, indicate the sources of information about the practice 1. Relative 2. Neighbor 3. NGO 4. CBOs 5. Barazas/chief's meetings 6. Media (TV, radio, newspaper) 7. Research institutions/universities 8. Government extension 9. Farmers' associations 10. Other (specify)

U7. BARRIERS TO PEST MANAGEMENT

U7 Barriers to pest management	
Option	**Barrier (specify)**
Traditional	
Biological	
Mechanical	
Chemical	

IPM	
	Key 1. Lack of technical information 2. Affordability 3. Lack of technical know-how 4. Lack of/inadequate extension services 5. Inaccessible methods 6. Cultural/religious barriers 7. Other (specify)

V. PESTICIDE USE

(*Ask the farmer what pesticides are used to control insect pests, plant diseases and weeds)*

V1. List Crop	V2. Name pesticide used	V3. Others (specify)	V4. At what stage do you apply the pesticides? **(Key)** 1. Before pests attack 2. Once pests appear on some plants 3. When majority of plants have been attacked 4. When all plants are pest-infested	V5. Effectiveness of the pesticides (**Key**) 1. Very effective 2. Moderate **3.** Ineffective

W. PEST MONITORING

	Response (use key)
W1. Do you practice monitoring of pests on your farm? 1.Yes 2.No	

W1.1 If yes, how often do you monitor? 1.Once a week 2.Twice a week 3. Twice a month 4..Once a month 5.Twice a season 6. Once a season 7.Other (specify)	
W2. What monitoring method(s) do you use? 1.Visual 2.Traps 3.Other (specify)	
W2.1 If no, give reasons	

X. Have there been any changes in pest management practices in the last 10 years? 1. Yes 2. No ______________________________

X1. If yes, please give reasons for the change

X2. If damage was caused by diseases, indicate the disease and the amount of damage/loss caused

X2.1. List Crop(s)		X2.2. Name disease(s) –(*if English name is not known use local name*)		X2.3. Estimate amount of damage (%)	
		Pre- harvest diseases		Pre-harvest loss	
Crop	Acreage	Long Rains	Short Rains	Long Rains	Short Rains

Y. POLLINATION

Y1. Does your household own any beehives 1. Yes 2. No

Y1.2 If yes, how many beehives does your household own? ___________________________

Y2. Apart from honey production, what other benefits do you derive from honey production?
____
____

Y3. How many kilos of honey do you produce per year? ______________________________

Y4. Has the honey production in your household increased/decreased/remained the same in the past 10 years?

Y5. If yes, indicate the reason for change
____
____
____

Y6. What is the main reason for producing honey in your household?

1. Domestic use
2. Domestic use and sales
3. For sale only
4. Other (Specify)

Y7. Do you have access to wild honey? 1. Yes 2. No _____

Y7.1 If yes, how do you access it?

1. Collected by household member
2. Bought
3. Received from neighbor/relative
4. Other (Specify)

Z. WILDLIFE DAMAGE

Z1. Have you experienced any wildlife damage in your farm? 1. Yes 2. No _______________

Z1.2 If yes, what kind of damage?

Z1.2 Type of damage **(Key)**	Z1.3 Change in frequency **(Key)**	Z1.4 Estimated loss (*In cash or in volume)*	Z1.5 Species responsible for damage	Z1.6 Crop Species damaged	Z1.7 Actions taken 1. Yes 2. No.	Z1.8 Measures taken to prevent damage

Key for Z1.2 Type of damage
1. Damage to staple crops
2. Damage to cash crops
3. Damage to fruits/horticulture
4. Damage to assets/property
5. Damage to humans
6. Other (Specify)

Key for Z1.3 Change
1. Increased
2. Decreased
3. Remain the same

FOCUS GROUP DISCUSSION GUIDE

1. Soil and crop management systems

1.1. What type of soil management practices do you employ on your farms and why?
1.2. Since when have you been using these management practices?
1.3. Before these practices, what other practices were you using and what is the reasons for the change of these practices?
1.4. How is the effectiveness of these practices?
1.5. Do you plan to change these practices in the near or far future?

2. Farming system and farm preparation

2.1. What farming practices do you apply on your farms? And why?
2.2. Did you practice these systems in each farming plot and planting season?
2.3. For how long have you used the preferable practices?
2.4. What were the previous practices were you using? And if you have changed, why so?

3. Crop pests and diseases and its management

3.1. Which crop pests and diseases frequently attack your crops from ten years back?
3.2. What is the spatial scale of these pests and/or diseases?
3.3. When do these pests and/or diseases started or increased?
3.4. What management practices do you use in managing these pests and/or diseases?
3.5. How is the effectiveness of these management practices?

4. Crop input vis a vis output and marketing

4.1. What are the necessary inputs do you use from farm preparation to storage of agricultural crops?
4.2. How is the availability of these inputs within and outside your local area?
4.3. How could you compare the inputs on farm and the output ratio?
4.4. How do you compare the market of [CROP] in past ten years compared to present time?
4.5. If there is a change in market of these crops, what could be reasons?

INTERVIEW CHECKLIST FOR KEY INFORMANTS

1. CONSERVATION AGRICULTURE

1.1. Does conservation agriculture existing in this region? If yes how?

1.2. When conservation agriculture started in this region? Who introduced?

1.3. Do you normally provide trainings about conservation agriculture? If yes how?

1.4. How do farmers respond to conservation agriculture trainings?

1.5. What do you consider advantages and disadvantages of conservation agriculture?

2. SOILS ACROSS AND FARMING ACROSS THE TRANSECT

2.1. How is the nature of soils across the transect and the inputs on crops?

2.2. What are implications of those inputs on crops in the soils over time?

2.3. What are the farming systems practiced across the transect?

2.4. How could you explain the social economic status of the farmers and its implication on agriculture?

3. PESTS AND DISEASES ACROSS THE TRANSECT

3.1. What are the common crop pests and diseases on maize across the transect, how is their trend and implications over time?

3.2. What are the common cop pests and diseases on banana across the transect, how is their trend and implications over time?

3.3. What are the common crop pests and diseases on coffee across the transect, how is their trend and implications over time?