Livelihoods, vulnerability, and adaptation to climate change

of small-holder farmers in Kilimanjaro, Tanzania

By

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Declaration part 1.

Acknowledgement

This is one of the most worthwhile journeys that I have ever undertaken. A journey that describes what my life has been during the last four years. I would like to express my appreciation to Almighty Allah, for giving me the protection and strength to carry out this research and to withstand the tough challenges associated with this journey.

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Finally, to my friends and loved ones, especially my office mates, who have supported me in diverse ways I greatly appreciate that. My Allah bless you all.

Dedication

This work is dedicated to my parents, my husband and my children. My father (Mr. Ibrahim Mwasha) and my mother (Zamzam Urassa) this is the fruit of your hard work. My Husband (Jabir Swai) my children (Abdillah, Abdur-Rahman, Maryam, Abdulhamiid, and Abdulmalik) you were very patient during this times. I sincerely appreciate and value this support.

Abstract

Climate change is expected to reduce food security in many African countries, and yield from rain-fed agriculture is projected to decline significantly. Future warming will persist even if current agreements on emission controls are put into action because of the significant amount of greenhouse gases already in the atmosphere. Many small-holder farmers in Sub-Saharan Africa farm and live in an extremely challenging environment, characterised by reliance on rain-fed agriculture, low economic diversification, and low livelihood outcomes. These small-holder farmers are increasingly being affected by increased climate variability, which threatens the capacity to meet their household's needs and the country's food security.

Addressing how small-holder farmers' livelihoods can be managed to adapt to climate change is vital for food security, livelihoods development as well as achievement of several of the UN Sustainable Development Goals. While farmers’ adaptation strategies in these environments have been widely studied, our understanding of how small-holder farmers’ livelihoods can be managed based on practical adaptation is less developed.

In this study, using a mixed methods case study design of different agro-ecological zones in the Kilimanjaro region of Tanzania, I explore small-holder farmers’ livelihoods vulnerability and how small-holder farmers' livelihoods can be managed (potential) to adapt to climate change. This work looks at: i) the implication of climate variability to five livelihood assets (financial, human, natural, social and physical) of small-holder farmers; ii) the environmental and social structures that increase livelihoods vulnerability; and iii) strategies to build small-holder farmers' livelihoods resilience through adaptation.

The results show that, climate variability directly or indirectly affect four livelihoods assets of small-holder farmers in the study area; Human, financial, social and natural capital and farmers’ capacity to make their living. The majority of the small-holder farmers manage their livelihoods in such away it affects environmental conditions that complicates living with climate variability. There are multiple stressors that affects farmers’ livelihoods, and existing social structures constrains farmers’ capacity to successfully responding to impact of climate variability to build resilient livelihoods. Building small-holder farmers' livelihoods resilience

that can ensure the desired levels of livelihoods outcomes in the face of climate variability and change, requires integration of strategies across household resource management as well as farm-based livelihood assets, and a holistic rather than piecemeal approach.

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1 Chapter One

1.1 Introduction

The inability of small-holder farmers to adapt to climate variability and change is one of the issues affecting the outcome of their livelihood practices. If the current practices are changed to recognize the impacts of climate change, the livelihoods will improve household income, improve wellbeing, reduce vulnerability and promote more sustainable use of natural resources. Although smallholder farmers' livelihoods have been facing many challenges, climate change not only brings new challenges, but also intensified existing bottlenecks making it more challenging to meet livelihood needs. Adapting to climate change brings an opportunity to address these problems, for the betterment of the individual farmer and community at large. This research intends to understand how small-holder farmers can build livelihood resilience through adaptation. This chapter presents the background context and rationale of this research, general research aim, research questions and the potential contribution of this research to knowledge.

1.2 Background and rationale

It is now evident that anthropogenic climate change is real and presents threats to human and environmental systems. Scientists have established that increasing concentrations of greenhouse gases such as carbon dioxide, methane, and nitrous oxide as a result of industrial activities, changes in land cover as well as agriculture activities are the main culprits of increasing global temperature (Henson, 2011).

The increase in greenhouse gas concentrations in the atmosphere has resulted in, and will continue to alter weather patterns across the globe. These alterations in weather patterns are characterized by temperature rise and increases in extreme events such as floods and droughts (Henson, 2011; Pachauri *et al.*, 2014). Future warming will persist even if current agreements on emission controls are put into action because of the significant amount of greenhouse gases already in the atmosphere (Di Falco and Veronesi, 2013).The impacts of climate change are expected to affect human and environmental systems across the globe but the more devastating impacts are projected to occur in developing countries because of the inadequacy of the resources needed to adapt to climate change and the people's reliance on natural resources for their livelihoods.

Small-holder farmers especially in Sub-Saharan Africa are the most vulnerable group to climate change (Whitfield, 2015; Serdeczny *et al.*, 2017). Many small-holder farmers especially in Sub-Saharan Africa farm and live in an extremely challenging environment. The production environment is characterized by reliance on rain-fed agriculture, a low level of economic diversification, and low livelihood productivity[1] (Di Falco and Veronesi, 2013). So there is urgent need for adaptation of the livelihoods of small-holder farmers to enable them to thrive in the face of climate change.

In Tanzania, climate change is associated with significant impact to farmers' livelihoods and the government has established planned adaptation approaches particularly in agriculture where there is a high level of dependence on it as a source of livelihood by most small-holder farmers. However, this does not mean that there is good implementation of existing adaptation plans or that they are immune from any shortcomings. Adaptation also involves decision makers at the farm level which are farmers themselves. However, although farmers may perceive the occurrence and impacts of climate change, their perceptions do not

[1] Output per unit of input (Yu, *et al*., 2002)

necessarily correspond to implementation of practices that help livelihoods adapt to climate change.

Addressing how to build resilient small-holder farmers' livelihoods through adaptation to climate change is vital for food security, livelihood development as well as achievement of several of the UN Sustainable Development Goals (Afifi *et al*., 2014). To address this, some researchers put considerable emphasis on describing specific locally relevant agricultural or natural resource management practices or innovations that could potentially deal with impacts of extreme events at farm/household level. However, it is important to note that application of these strategies is context specific and that several constraints exist that may limit farmers' capacity to optimize their benefits. Therefore, there is the need to develop adaptation tailored to the need of that community (Ebi and Burton, 2008). The context specific adaptations result from examining the vulnerability of the target community empirically, and utilising community experience and knowledge to examine exposure and sensitivity without presuming specific variables that represents vulnerability (Ebi and Burton, 2008). The context specific adaptation strategies or practices based on examination of adaptation needs of the specific community will generate relatively more practical measures that the community in question can use to build resilience in the face of climate change.

Howden *et al.* (2007) argued that to increase adaptation it is vital to deal with climate change issues together with other existing challenges and focus on integrated strategies without being bounded by disciplinary sciences; an approach adopted in this study. The main point that Howden *et al.* (2007) argues is the need for adaption measures to be more comprehensive through acknowledgement of multiple stressors even though they cut across multiple academic disciplines. Climate change adaptations do not only require response to extreme weather events or climate variability, but also response to factors that created vulnerability in the first place (Jerneck, 2018). However, the building of small-holder farmers' livelihoods which are resilient to climate change based on empirical studies exploring just exposure and sensitivity to climate change are lacking. This study fills this gap by investigating small-holder farmers' perceptions of exposure and sensitivity to climate change, and the adaptations needed to build livelihood resilience in the face of climate change. This study will make exposure to climate change and structures contributing to small-holder farmers' vulnerability to climate change and how to build resilience through adaptation better understood.

1.3 Aim and research questions

The main aim in carrying out this research is to explore livelihoods' vulnerability and measures to build resilience through adaptation amongst small-holder farmers across different agro-ecological zones in the Kilimanjaro region of Tanzania.

The following research questions are addressed:

i. What is the perception of small-holder farmers to both climate change and the impact of climate change to livelihood assets?

The literature about climate change impacts has established that, because of the low capacity to adapt, small-holder farmers are negatively affected by climate change through reduction in crop yields, increase in pests and diseases (Müller *et al.*, 2011; Munishi, *et al.,* 2015; Balama *et al.*, 2016) and decline of water resource availability (Mohamed, 2011; Conway *et al.*, 2015). However, these impacts are more focused on the ecological and direct agricultural impacts and less is known about how these translate into the lives of those within small-holder farming communities. The livelihoods framework approach puts poor people at the centre;

highlighting the importance of understanding how livelihood capitals (financial, human, natural, social and physical) are affected and the resultant impact on the farmer's capacity to make their living (DFID,2000; Turner *et al.,* 2015). However, because of lack of access to data that can quantitatively study the impacts of climate variability and change to small-holder farmers due to the lack of records from small-holder farmers, the study will be based on farmers' perceptions.

ii. What are the household farm production practices and their impact on environmental conditions?

This question seeks to understand farm production practices that households use and their impact on environmental resources particularly the natural capitals, soils and water. The intention is to understand what farm production strategies or practices increase livelihood vulnerability and which practices increase livelihood resilience to climate change. The question does not seek to understand existing adaptation strategies, but overall approaches used to manage these capitals as they all have an impact to livelihood outcomes. Since farmers are the main stakeholders in the management of their livelihoods, the results from this question will guide them to make insightful decisions regarding strategies and practices to make use of these resources in the impacts of climate change.

iii. What are the livelihood options and social factors contributing to livelihood vulnerability to climate change?

Livelihood diversification is a risk management approach for the poor. This question aims to understand the social structures that restrict the crop subsector, the livestock and off-farm income activities subsectors to adapt to climate change. The intention is to understand these barriers so they can be dismantled through adaptation in order for farmers to be able to more successfully diversify their livelihood and build resilience against weather-related shocks.

iv. How can small-holder farmers' livelihoods be managed to adapt to climate change?

This question intends to reflect on the first three questions to understand how the raised challenges could be addressed through adaptation.

1.4 Reflection on positionality

My interest in conducting this research is born out of my desire to improve the capacity of small-holder farmers in Sub-Saharan Africa to adapt to climate change. As I was born and raised in a small-holder farming community in the region of the study, I am in a position to engage with this topic as both an 'insider' and an 'outsider' (Bourke, 2014) in order to develop understanding into how small-holder farmers' livelihoods can be managed to adapt to climate variability and change.

Positionality, the state of being an 'insider' or 'outsider' partly determines the capacity and objectivity as the researcher talks about the researched (Bourke, 2014) . The process involves acknowledgement of our position as individuals and groups; and the social positions that both the researcher and researched hold (Greene, 2014) . As the research was conducted in the Kilimanjaro region where I was born and raised, I consider myself an insider with participants from the study region. The insider position, represents a researcher studying the social group s/he belongs or when s/he shares the self-identity with respondents (Greene, 2014).

Although I have moved out of the small-holder farming community in which I was raised, I still share a common bond with these communities, our place of origin, and hence in some regards, as a researcher I am an ‘insider’ with tacit knowledge (and potential bias) of aspects of these communities. I may also have achieved a greater sense of unity with farmers in this area, because I can speak our vernacular language, which helped maintained communication during the interview and farmers’ words in data transcription (Witcher, 2010). Other benefits of being an insider to this research include a lack of culture shock and the ability to understand participants in terms of their emotions (Greene, 2014).

On the other hand, I may also consider myself as an outsider, because I am not a farmer, and I do not live in the Kilimanjaro region but the Tanzania capital city, Dar es Salaam. Although I took part in some farming activities in my childhood, this did not give me a detailed understanding of the farming activities because I spent most of my time in school. Regardless of spending much of my time in Dar es Salaam, I still maintain contact with my relatives who are small-holder farmers in the Kilimanjaro region. The project was not carried out in the village where I was born and raised and where most of my relatives live, but there are similar characteristics between different small-holder farming villages in the region, in terms of social structure and livelihood characteristics.

I used my position as an insider to help communication and build trust between the respondents and myself, and my position as an outsider to give enough room to understand the responses from respondents and not present pre-determined ideas about issues happening around their livelihoods. As I recall from carrying out my fieldwork, immediately upon introducing myself using our language, the smile on their faces and the way they were at ease in giving detailed explanations of their lives showed the clear benefits of my insider position. Combining both positions helped to increase the rigor and, credibility of my research as it reduces the biases of an insider position on the methodology, designs and results (Greene, 2014).

1.5 Contribution to the knowledge

This research is situated in the field of sustainability science which is interdisciplinary and address real life complex problems (Kates, 2011). The research aims to explore how to manage small-holder farmers' livelihoods through adaptation to climate variability and change. There is a lot of research in Tanzania about what farmers do to adapt to climate change (Komba and Muchapondwa, 2012; Kihupi, et al., 2015; Below, et al., 2015; Komba and Muchapondwa, 2018). However, the research about how livelihoods can be managed to adapt to climate change is less developed. This research will contribute to existing literature on climate change in small-holder farmers' livelihoods in three ways. First, this research will explore the implication of climate variability to five livelihood assets; natural, financial, human, physical and social capital of small-holder farmers. Second, this research will uncover environmental and social structures increasing livelihoods vulnerability. Third, this research will explore potential strategies to build small-holder farmers' livelihood resilience as an adaptation strategy to climate change.

This study is carried out through a mixed methods case study. A survey of household heads, observation, gender-based focus group discussions and key informant interviews were used to collect data in three different villages across different agro-ecological zones. Multiple methods of data collections and perspectives serve to triangulate data.

The researcher is a member of a small-holder farming community and as such believes that this research has the potential to improve the skills of farmers in dealing with climate-related stress in the Kilimanjaro region. The findings and subsequent discussion as contained in this research will play a significant role in my own work helping farmers to improve their livelihoods as part of climate change adaptation.

Furthermore, as this study has a strong theoretical basis drawing on the lenses of vulnerability, socio-ecological resilience and the livelihoods framework, this research will make a small but significant contribution to case study research, bringing together the lenses of vulnerability, socio-ecological resilience and livelihood research. Tanner *et al.*, (2015) emphasized that, the use of vulnerability and resilience especially in the context of the poor people requires integration with the livelihoods framework as they insist that:

'the resilience concept requires greater attention to human livelihoods if it is to address the limits to adaptation strategies and the development needs of the planet's poorest and most vulnerable people. Although the concept of resilience is increasingly informing research and policy, its transfer from ecological theory to social systems leads to weak engagement with normative, social and political dimensions of climate change adaptation. A livelihood perspective helps to strengthen resilience thinking by placing greater emphasis on human needs and their agency, empowerment and human rights, and considering adaptive livelihood systems in the context of wider transformational changes' (Tanner *et al.*, 2015:1).

Moreover, the outcome of this research will be of significance to the Tanzania government, researchers and Non-Governmental Organizations dealing with small-holder farmers' development and adaptation in the face of climate change.

1.6 Thesis overview

This study explores small-holder farmers' livelihood vulnerability and how to build livelihood resilience through adaptation. The thesis itself is organized into nine chapters. The first chapter has laid down the justification for the research both personally and professionally;

the chapter also covers the background context for the research, the research aims, questions and a potential contribution of the research to theory and practice. Chapter Two reviews the relevant literature relating to this study. The review includes the field of sustainability science, in which this project is situated; global climate change, climate change indicators and impacts in Africa and particularly Tanzania; small-holder farmers, their livelihoods, and how they are impacted by climate change; climate change adaptation approaches for small-holder farmers and the constraints that affect climate change adaptation.

Chapter Three presents the methodology, where epistemological and ontological consideration. The research design, the research participants, methods and lastly ethical consideration. Chapter Four presents result on climate change impact to livelihood assets while Chapter Five presents results about household farm production practices and their impact on environmental conditions. Chapter Six expounds results about social structures increasing livelihood vulnerability to climate change. Chapter Seven puts forward result about building livelihood resilience to climate change, where factors increasing livelihood vulnerability presented in chapters four, five and six are discussed. Although a short discussion is presented in each result chapter, the more detailed discussion reflecting on the methodology is presented in chapter eight. The last part of the thesis presents the conclusion.

2 Literature Review

2.1 Introduction

This chapter presents the current state of knowledge about small-holder farmers' livelihood adaptation to climate change. The chapter will start by explaining key concepts related to this study such as sustainability and why this project is situated in the emerging discipline of sustainability science. Other concepts include climate change, mitigation and adaptation, and small-holder farmers. Thereafter, the chapter will examine the impact of climate change on the livelihoods of small-holder farmers by focusing on the effects of climate change on agriculture. The chapter then argues on the need to further explain the impact of climate change on livelihoods assets. The policy response to climate change in Sub-Saharan Africa is then outlined where the justification for focusing on adaptation more than mitigation is provided. The chapter describes livelihood adaptation strategies reported in the small-holder farmer literature and the need for integrating strategies that build social and biophysical conditions. The chapter ends by providing a synthesis of what is needed for a comprehensive understanding of small-holder farmers' livelihood adaptation to climate change.

2.2 Sustainability Science

This subsection explains the positioning of this research in the emerging field of Sustainability Science, drawing initially on the discussion of the underpinning concepts of sustainability/sustainable development; sustainable science; and the United Nation's Sustainable Development Goals.

2.2.1 Sustainability and Sustainable development

The term 'sustainable development' is believed to have been born from the report 'Our Common Future' published in 1987 by the Brundtland Commission which defined sustainable development as development that ensures inter-generational equity in access to human need

(Mebratu, 1998). The report intended to address the environmental concern which was also expanded more in Agenda 21 Of the Earth Summit in 1992 (UN, 1993). The Brundtland Commission report defines sustainable development as the development that ' ensures that it meets the needs of the present without compromising the ability of future generations to meet their own needs' (Imperatives, 1987,p.6).

The report urges that decisions made and actions taken in resource exploitation, investment, technological development and institutional change are considerate to the capacity for both present and future generations to meet their needs (Mebratu, 1998). The goal of sustainable development is meant to be achieved through employing 'sustainability' practices by 'living in harmony between nature and society' (Mebratu, 1998, 498; Kates *et al.*, 2001).

Sustainability guides how communities from different spatial scales (local to international) envision and pursue social and natural well-being (Miller *et al.*, 2014). So to some people the main difference between sustainability and sustainable development is, that sustainability is the means, and sustainable development is the goal (Mebratu, 1998).The concept of sustainable development has played a crucial role in stimulating discussion about the nature of human 'progress' and has made nations, companies and the general public accountable by taking actions to ensure that human development does not endanger the natural environment.

However, regardless of the benefits brought by improvements to social and environmental conditions, sustainable development has been criticized because of the ambiguities of the term development (Sneddon, *et al*., 2006). Some see it as an oxymoron as they perceive it difficult for continual development to be sustainable (Spaiser, *et al.,* 2017). Throughout this research, both concepts - sustainable development and sustainability will be used, where sustainable development denotes the goal and sustainability the process to attain it. The reason for using both concepts is because the focus of this research is on people who need to develop their livelihoods. This research therefore argues for development that is sustainable, and can be achieved by employing sustainability practices to meet the needs of the world's poor which the report (Brundtland Commission Report) also emphasise alongside environmental conservation (Barkemeyer *et al.*, 2014).

2.2.2 The United Nations' Sustainable Development Goals

The Sustainable Development Goals (SDGs) form the United Nations' roadmap to guide countries' development over a 15 year period (from 2015-2030) following the previous Millennium Development Goals (MDGs; Assembly, 2015). Unlike the MDGs which had goals such as eradicating poverty, mostly applicable to developing countries, the SDGs are relevant worldwide (Assembly, 2015) .'They reflect the moral principles that no-one and no country should be left behind, and that everyone and every country should be regarded as having a common responsibility for playing their part in delivering the global vision' (Osborn *et al.,* 2015,p.2).

The United Nations established 17 SDGs, which are shown in Figure 2:1 covering no poverty, zero hunger, good health and wellbeing, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry, innovation and infrastructure, reduced inequality, sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land, peace, justice and strong institutions, partnerships for the goals. Underlying these 17 goals are 169 targets. A closer look at these goals shows that, although they are relevant to all nations in the world, the Global South and Global North will have different priorities and these priorities will differ between regions, because different countries are at different stages of attaining those goals depending on their stages of economic development and other circumstances (Osborn *et al*., 2015).

Figure 2:1The United Nations Sustainable Development Goals
Source: United Nations Development Programme

The 'Global North' refers to a group of countries with very high human development, and there is general respect for political rights and civil liberties (Solarz, 2012). Based on this definition the Global North includes countries in Europe, North America, Australia and most countries in South America while the Global South includes countries mostly within the continents of Asia and Africa (Figure 2:2).

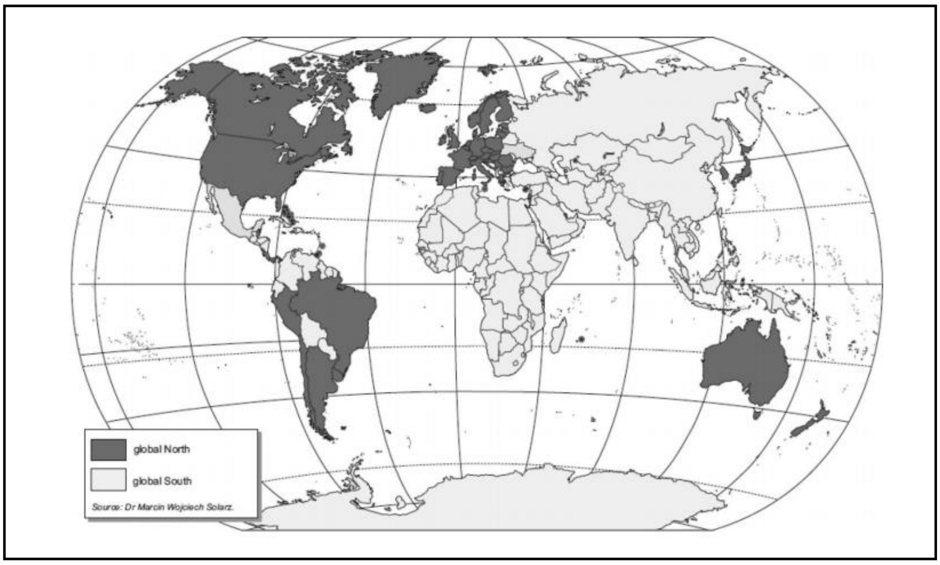

Figure 2:2 Distribution of countries classified as the Global North and Global South
Source: Adopted from (Solarz, 2012)

The Human Development report (2016) provided a definition of human development which emphasises the freedom to realise the full potential of every human life (Solarz, 2012). This definition leads to a reclassification of many South American countries from the Global North to the Global South (Figure 2:3). In this definition the Global North includes countries with very high human development and freedom and include countries in North America, Europe and Australia.

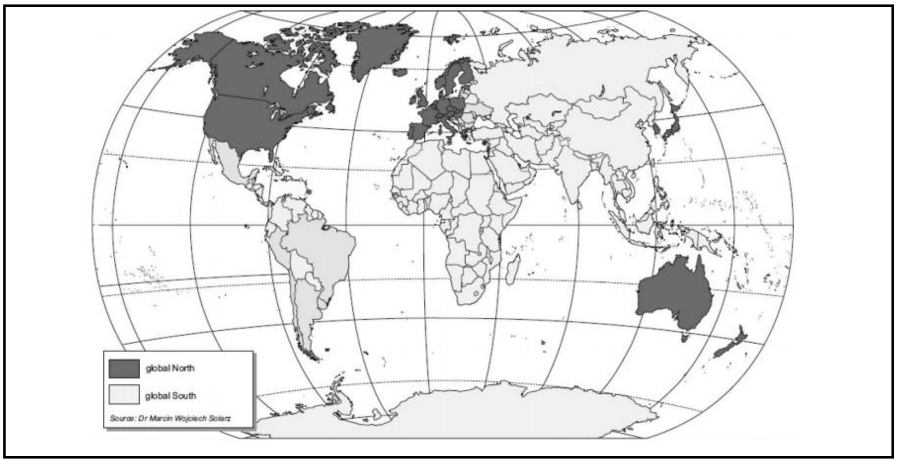

Figure 2:3 Distribution of countries in the Global North and Global South based on a reclassification based on the Human Development Report (2016)

Source: Adopted from (Solarz, 2012)

In other classifications, the major distinction between the Global South and Global North is the level of economic development only. In this understanding, the Global North incorporates countries which are economically developed, where South Africa is included in the list together with countries in Europe, North America and Australia while the Global South represents lesser economically developed countries, including other countries in Africa (except South Africa), and others like India, China, Brazil, Mexico (Odeh, 2010). Other synonyms used for countries in the Global South include poor countries, or developing countries, while the Global North is used synonymously with rich countries, and developed countries (Odeh, 2010; Solarz, 2012; Osborn *et al.*, 2015). The definition of the Global North and South that I support is based on the level of economic development and freedom of the people to fulfil their potential both for the present and future generations. This thesis would rather not focus on economic development only as an indicator of countries in the Global North or South as it may paint a picture that some countries such as South Africa have got no responsibility for achieving some sustainable development goals such as eradicating poverty for some of the population in the country. However, this thesis will use poor countries and developing countries interchangeably while referring to the Global South and use rich countries and developed countries while referring to Global North.

Social problems experienced in developing countries differ in degree from those in developed countries. For-instance, developed countries have relative poverty while developing countries have absolute poverty, the same applies to the problems related to health, education, and gender issues (Osborn *et al.*, 2015). So while developing countries may place more focus on addressing social and economic problems such as poverty and hunger, developed countries may focus more on environmental policies such as combatting climate change (particularly on mitigation), sustainable production, and consumption and sustainable energy *(Osborn et al.,* 2015).

2.2.3 Sustainability Science

The field in which this study is situated is Sustainability Science. This new science seeks to address fundamental problems facing human being while ensuring that social well-being is improved, and the basic earth systems continue to operate (Redman, 2014). This emerging field of academic scholarship focuses on understanding the dynamics of the complex, coupled human-natural systems, in order to provide solutions to (Miller *et al.*, 2014) the problems facing the human race today such as climate change. As summarised by Clark and Dickson (2003), some of the features of sustainability science research is the emphasis on equal attention on the dynamics between society and the environment as working on individual components does not provide comprehensive understanding of the system in question. Sustainability science research is problem-driven, with the goal of providing knowledge to decision makers on how to achieve sustainable development. Moreover, within sustainability science there is a firm belief in the importance of researchers and scholars involving local people such as local practitioners, in knowledge production that can contribute to understanding ways of addressing sustainability challenges in their local areas(Clark and Dickson, 2003).

Although the problems that sustainability science tries to address differ between those in the Global North and those in the Global South, the focus in both regions is on understanding significant processes across the full range of scales from the local to global level in addressing sustainability challenges (Kates *et al.*, 2001). As Kates *et al.*, (2001, p.641) put it, ‘a new field of sustainability science is emerging that seeks to understand the fundamental character of interactions between nature and society. Such an understanding must encompass the interaction of global processes with the ecological and social characteristics of particular places and sectors'. In a nutshell, sustainability science uses a holistic and interdisciplinary approach to address complex, real life human-nature challenges. Based on the complexity and human-nature relationships of small-holder farmers' livelihood adaptation to climate change, this project is situated within the field of sustainability science.

2.3 Climate change

2.3.1 An overview of climate change

Climate change refers to changes in the average and the variability of climate parameters over a relatively long period, usually for decades or longer (Pachauri *et al.*, 2014). Climate change results from both natural and human-induced processes that alter the composition of the atmosphere or land cover (Pachauri *et al.*, 2014). Since 1958, the steady rising of carbon dioxide levels in the atmosphere has been measured, which together with other greenhouse gases in the atmosphere are the main culprit of anthropogenic climate change (Henson, 2011).

Greenhouse gases increase the temperature in the atmosphere by absorbing heat (long wave radiation) that is radiated by the Earth and releasing just part of that heat to space (Henson, 2011). Affirmation of the role of greenhouse gases in the atmosphere in warming the climate was possible through the development of the first computer model of the global climate in the 1960s and more complex models afterward (Henson, 2011) . However, the underpinning science behind understanding the greenhouse effect has its foundations in the work from the nineteenth century, from scientists such as Joseph Fourier, Eunice Foote, John Tyndall, and Svante Arrhenius.

Before the use of the term climate change, the term global warming was more popular. In the early 1980s, the term global warming was used to describe human-induced climate change (Henson, 2011). Global warming is defined as an overall increase in the amount of energy in the whole Earth system caused by the rise in heat-trapping greenhouse gases (Farmer and Cook, 2013). Global warming as a concept describes the average warming over the entire Earth (Henson, 2011). However, there is significant regional variation in the extent of warming. In order to avoid the inference of global warming as having the same effect over the whole Earth, the term global climate change has been preferred by some (Henson, 2011). More recently, other concepts that are used interchangeably with climate change include climate crisis (Bryant *et al*., 2015; Abarca *et al*., 2018) and climate emergency (Loftus, 2011), with 2019 seeing a significant shift in language towards this latter term, and declarations by governments and organisations around the world of a 'climate emergency' in recognition of the severity of the impacts of climate change and the urgency of the need for action.

There is evidence of climate change occurring across the globe, in different regions and in individual countries. It has been confirmed that each of the last four decades has been warmer than the last. Furthermore, the globally averaged combined land and ocean surface temperature (Figure 2:4) shows a warming of 0.85 [0.65 to 1.06] °C over the period 1880 to 2012 (Pachauri *et al.*, 2014).

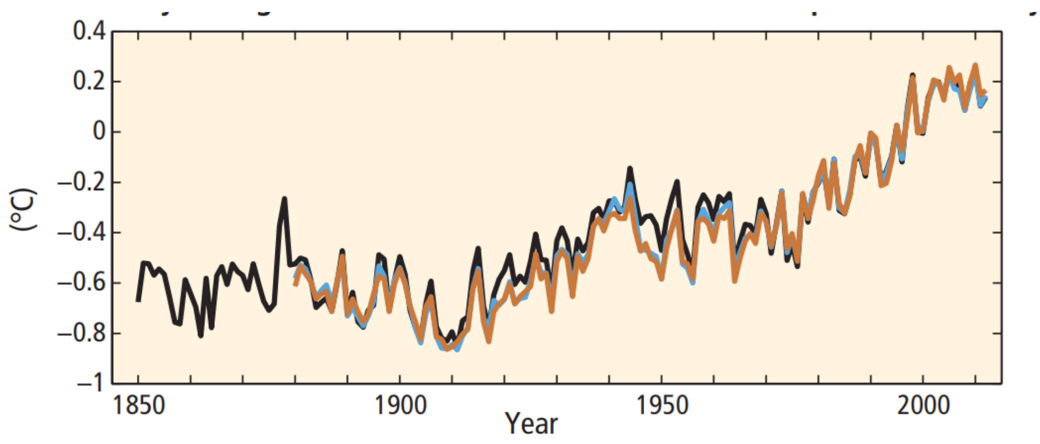

Figure 2:4 Globally averaged combined land and ocean surface temperature anomaly from 1980 to 2012

Source: (Pachauri *et al.*, 2014).

Climate change is becoming a global threat because of the potential risks it presents to different systems including dangers of death, injury, ill-health and disrupted livelihoods for mass urban populations associated with extreme heat (Friel *et al.*, 2011; Pachauri *et al.*, 2014). Other risks include inundation of low-lying coastal zones and small island states due to flooding, storm surges and sea-level rise (Barron *et al.*, 2012; Pachauri *et al.*, 2014). Risks of food insecurity, and breakdown of food systems as a result of warming, drought, flooding and precipitation variability and extremes, especially for the more impoverished populations in both urban and rural areas are also some other effects of climate change (Wheeler and Von Braun, 2013). Furthermore there is the risk of loss of rural livelihoods and income due to insufficient access to drinking and irrigation water and reduced agricultural productivity, particularly for farmers and pastoralist (Wheeler and Von Braun, 2013; Yaro, 2013) with minimal capital in semi-arid regions. There is also risk of loss within both marine and terrestrial ecosystems and the goods and services they provide to human beings and the environment (Burrows *et al.*, 2011). Reduced crop productivity associated with heat, drought stress, floods, and increased pests and diseases are also linked with climate change (Knox *et* *al.*, 2012; Bandara and Cai, 2014). The risks of climate change are therefore wide-ranging, but will affect the poorest communities, such as small-holder farmers in Sub-Saharan Africa the most (Pachauri *et al.*, 2014).

2.3.2 Climate change in Africa

The temperature increase in Africa associated with climate change has potential impacts on agriculture, particularly in the existing arid and semi-arid regions (Salinger et al., 2005) . The climate conditions in Africa vary a great deal as some places are moist while others are dry, and some areas are warmer than others (Kotir, 2011). West Africa and Central Africa are generally wet while the rest of Africa is mostly semi-arid to arid. As for the temperatures, West Africa, the Sahara, and East Africa are the warmest, whereas North Africa, Kenya, and Southern Africa are more temperate (Mendelsohn *et al*., 2000).

In the southern part of Africa, warming and variability of the weather, and an increase in drought events has been reported (Pachauri *et al.*, 2014; Filho *et al.*, 2018). This has influenced changes in rainfall pattern and amount in most of Africa, particularly from the 1940s. In West Africa for example, between the periods of 1961-1990, rainfall was reported to have declined by 30% compared to the period between 1931-1960 (Salinger *et al*., 2005). In West Africa, there has been persistent drought since the 1960s, while in the Sahel region, there has been increased rainfall variability and shrinking of the rain season (Sivakumar and Motha, 2008). Furthermore, future projections of climate change in the majority of climate models project the reduction of rainfall by 20%, especially in Southern Africa by 2080 (Conway *et al.*, 2015). In East Africa, it is predicted that there will be a general increase in the amount of rainfall (Pachauri *et al.*, 2014).

2.3.3 Climate Change in Tanzania

2.3.3.1 Rainfall distribution in Tanzania

Tanzania is situated in the east of the African continent. Tanzania's climate is highly variable and complex. The Tanzanian climate has rainy and dry season patterns which are influenced by the Inter Tropical Convergence Zone (ITCZ) as well as the El Niño. El Niño and La Niña years are associated with extreme flood and drought events. El Niño refers to the warm phase of the El Niño Southern Oscillation (ENSO) and La Niña refers to the cold phase of the ENSO (McPhaden, 2015). The ENSO is a 'coupled mode of variability in the tropical Pacific that grows through positive feedbacks between sea surface temperature and winds and influences seasonal climate almost everywhere', including Tanzania (Smith *et al*., 2012, p.1).

The country has two main rainfall regimes, bimodal and unimodal. The bimodal rainfall regime is experienced in the northern part of the country in areas like the Lake Victoria basin, North-Eastern Highland and North Coast. The rest, central, Southern and Western areas have prolonged unimodal rainfall beginning in November and ceasing in April (Wambura *et al.*, 2014).

To understand how rainfall is distributed in Tanzania, areas can be grouped based on altitude, precipitation, growing season, physiography, and soil average water holding capacity – producing different agro-ecological zones. As shown in Figure 2:5, Tanzania is divided into seven agro-ecological zones namely: coast zone, plateaux, Western and Southern Highlands, Northern Highland and Alluvial plain (NAPA, 2007; URT, 2014).

The coast zone receives annual rainfall ranging from 750 mm to 1200 mm with either unimodal or bimodal rainfall regimes and mostly with infertile soils. The arid and semi-arid zones receive unreliable unimodal rains, with the semi-arid zone receiving annual rainfall of

500 mm to 800 mm which is distributed across four months (from December to March). The arid zone receives annual rainfall ranges from 400-600 mm distributed across three months only (March-May) (NAPA, 2007).

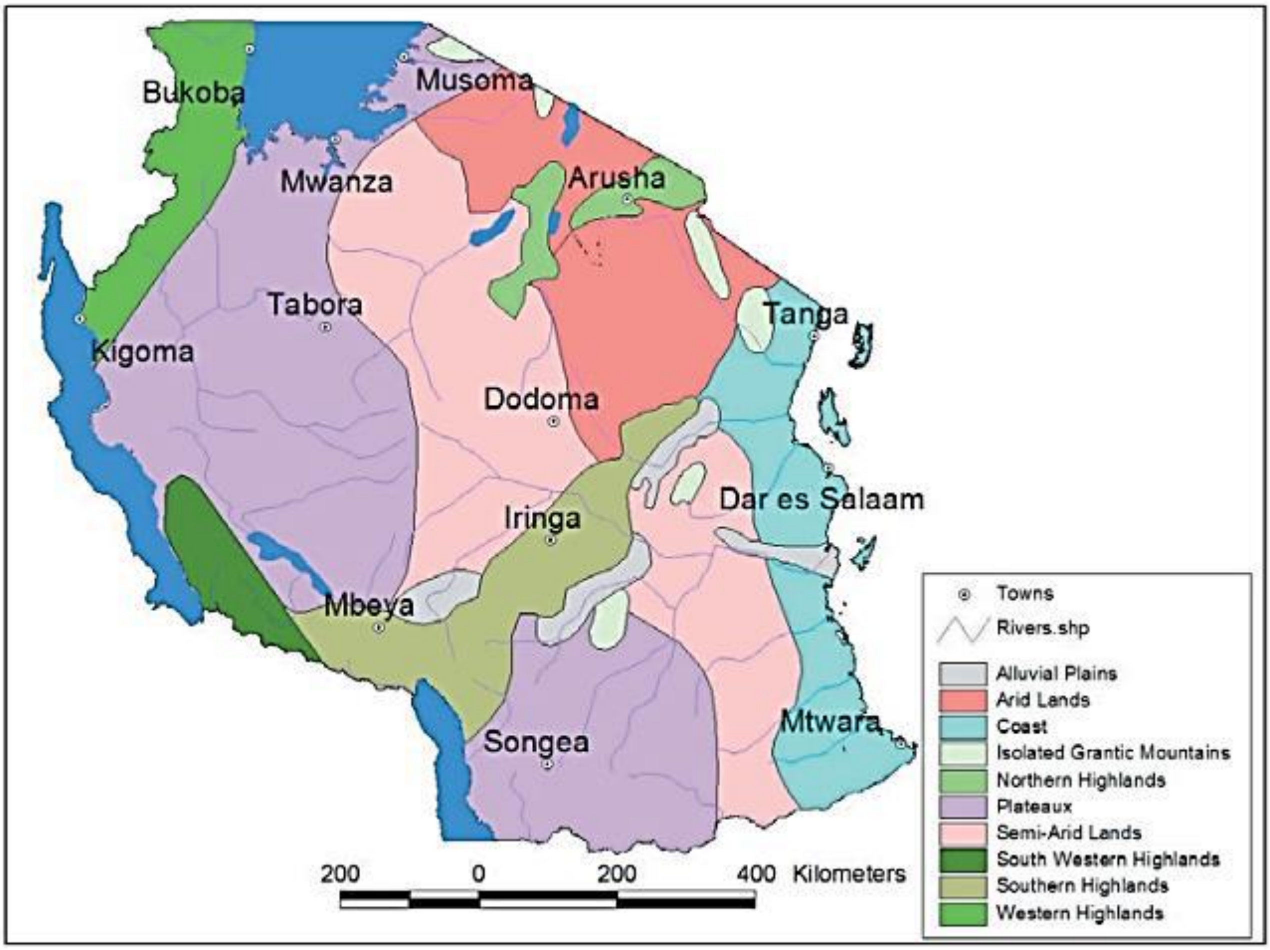

Figure 2:5 Agro-ecological Zones in Tanzania

Source: Sokoine University of Agriculture cited in Agriculture Climate Resilience Plan, 2014

Plateaux areas are characterized by unimodal rainfall ranging annually from 800 mm to 1300 mm which are very reliable especially in the southern part of the country. These areas have different levels of soil fertility; some areas are classed as infertile while others have high fertility. The Southern and Western Highland zones have places that receive unimodal or bimodal rainfall. Unimodal and reliable annual rains are experienced in Southern and

Southwest areas and range from 800 mm to 1400 mm. In the Western zone, the annual rainfall is bimodal and ranges from 1000 mm to 2000 mm. The last zone is the Northern Highlands which has very reliable annual rain in some places ranging from 1000 mm to 2000 mm (NAPA, 2007: NBS,2013). It is important to highlight that within the agro-ecological zones, there are some differences. For example, in the Kilimanjaro region where this study is located, and which is located in the Northern Highland zone, there are four distinct agro-ecological zones: The Highland, Midland and Lowland zones, and the Kilimanjaro mountain peak and forest reserve.

To understand climate trends in different regions in Tanzania, some researchers focus on a single region (e.g. Lema and Majule, 2009; Mongi *et al*., 2010; Otte *et al.*, 2017) while others chose to analyse trends in different regions (e.g. Conway *et al.*, 2017). It is difficult to make comparisons between studies because the studies cover different year periods; and some studies use regional station data while the others make use of international data sets which interpolate station data for temperature, and use stations and remotely sensed satellite data for rainfall (Conway *et al*., 2017).

In Tabora region for the period between 1973/78 to 2007/08, the rainfall was reported to decrease (Mongi *et al*., 2010). The same trend was also reported in Manyoni district in the Singida region between 1922 and 2007 (Lema and Majule, 2009). In Kilimanjaro region, particularly in the lowland zone, climate change is recorded in 'seasonal rainfall fluctuation, with a quite large intra-seasonal variability' and significant decline of long rains (Otte *et al.*, 2017, p.354). Conway *et al*. (2017) observed that across Tanzania as a whole, from an analysis of the rainfall data covering the period from 1981 to 2016 (Figure 2:6) a decreasing trend in annual and seasonal rainfall. However, there is no strong trend in all seasons. The year 2006 was the wettest while the years 2003 and 2005 were the driest.

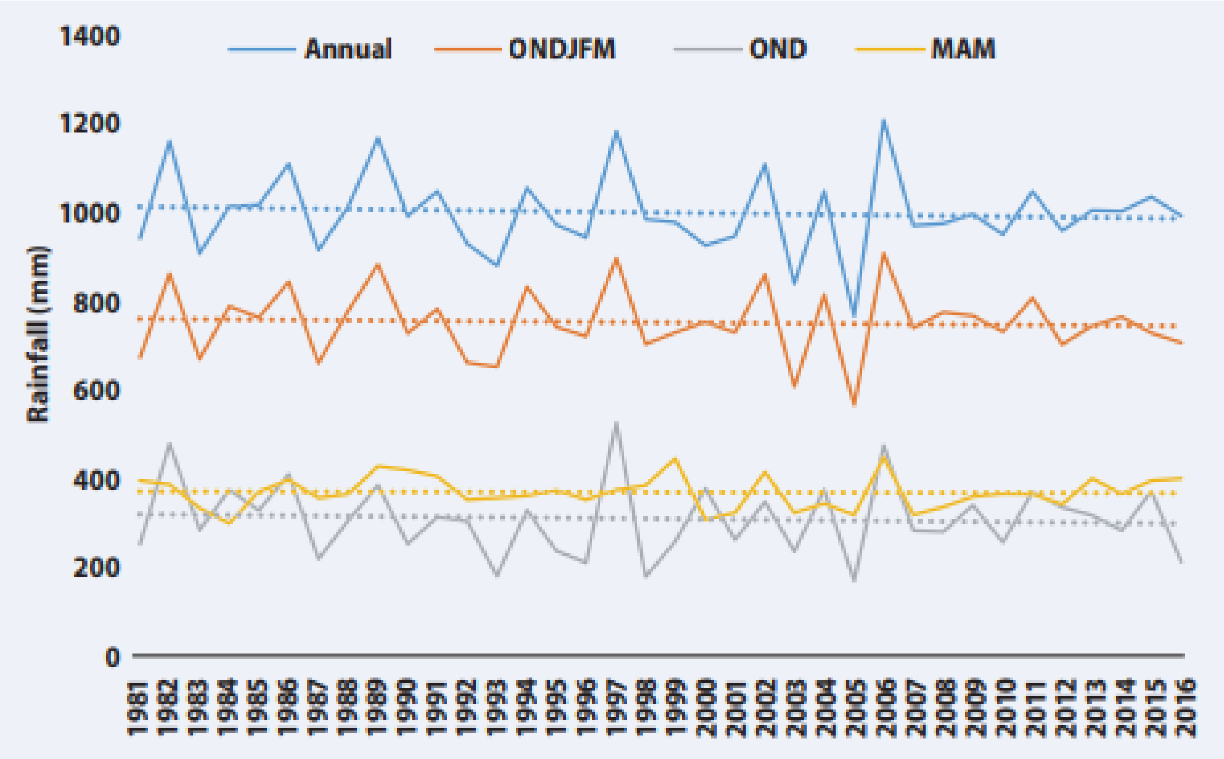

Figure 2:6 Observed annual and seasonal rainfall (rainfall total in mm) for all of Tanzania for 1981-2016. Seasons are March to May (MAM), October to December (OND), and October to the following March (ONDJFM). The dotted lines represent the trend over the whole period.

Source: (Conway, *et al*., 2017)

However, as shown in Figure 2:7, annual rainfall especially in the north-eastern and southern part of Tanzania has a drying trend while there is a moderate wetting trend in central Tanzania and stronger wetting trends in northwest Tanzania.

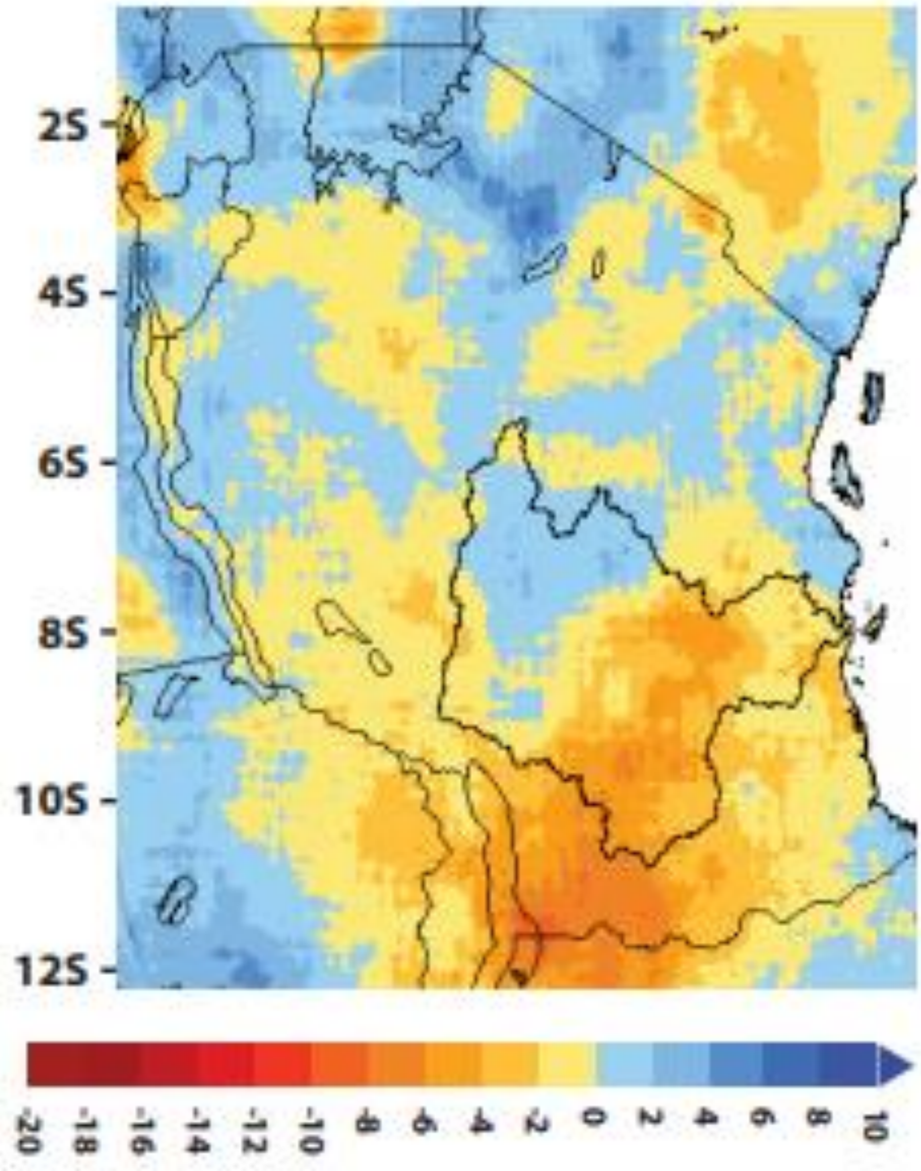

Figure 2:7 Observed trends in rainfall for each grid cell in mm per year for 1981-2016 across Tanzania
Source: (Conway *et al*., 2017)

Projection of future trends is essential for adaptation planning. Climate projections for rainfall in Tanzania show mixed results. After running simulations using 34 global climate models between the period 1976- 2005 and 2021-2050, Conway *et al*.,(2017) reported that, 11 models (32%) project reductions in annual mean rainfall in the 2030s and the rest (68%) project wetter conditions (Figure 2:8). Nine models (26%) project declining rainfall by the

2070s. The projections also show that, the changes in annual means of rainfall may decline by 12% or increase by 13% (Conway *et al.*, 2017). This shows that, there are a lot of uncertainties about the future climate which requires careful planning of the appropriate adaptation measures.

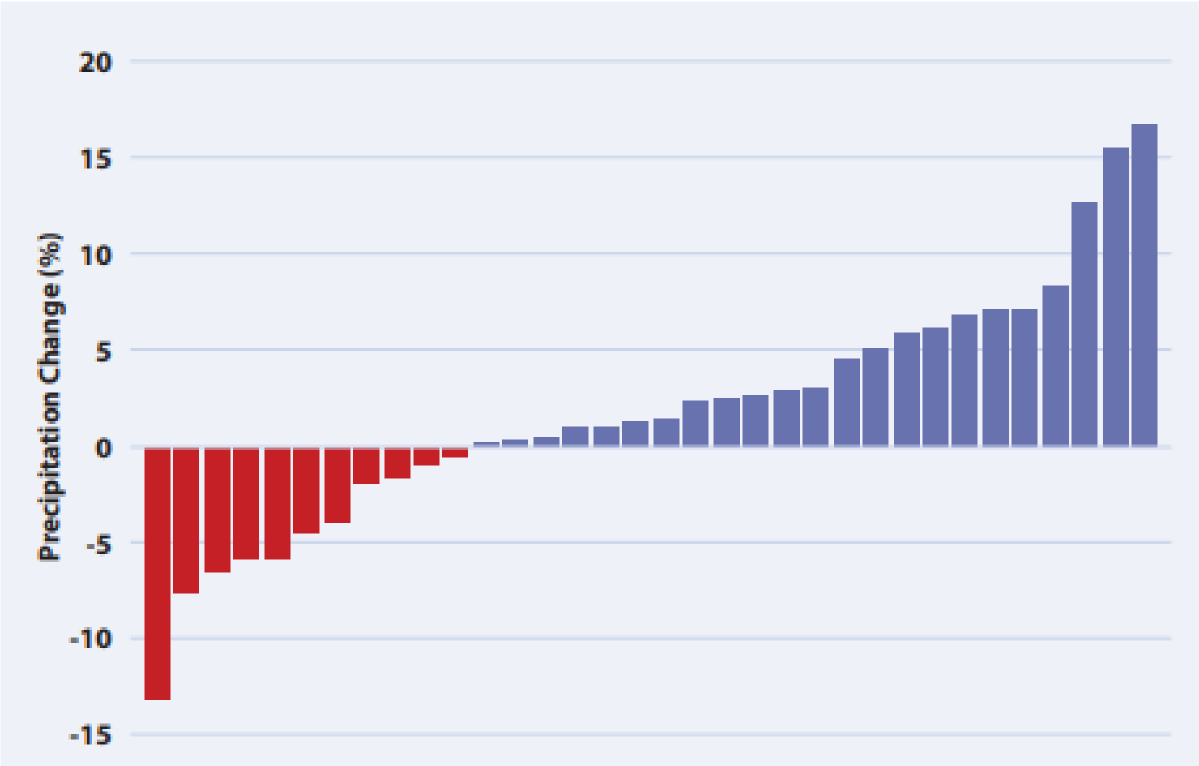

Figure 2:8 Percentage change in annual mean rainfall for all Tanzania between the GCM simulated current period (1976-2005) and 2021-2050 for 34 GCMs

Source: Conway *et al*. (2017)

2.3.3.2 Temperature in Tanzania

Temperature in Tanzania is influenced by location, topography and altitude. According to the Tanzania Metrological Agency (TMA) (2005), the average daily temperature is between 24^{o}C and 34^{o}C. Within the plateau zones, the average daily temperature is 21^{o}C to 24^{o}C while in the highland zone, temperature ranges from 15^{o}C to 20^{o}C. In the southern highland zone, the lowest temperature can be as low as 6^{o}C to 0^{o}C (NAPA, 2007). In coast regions and off shore islands, the temperature ranges between 20^{o}C and 30^{o}C. The months which are the warmest are December to February while the coldest months are June to August (TMA, 2005). As shown in Figure 2:9, annual mean temperature also varies; the country has warmer temperatures at the coast and the cooler temperatures in the high elevation areas such as Mount Kilimanjaro (Conway *et al.*, 2017).

Annual and seasonal temperature trends across Tanzania show increasing temperatures. As observed in Figure 2:10, the annual mean temperature, and seasonal temperatures for the month of October through to March (ONDJFM),) show increasing trends (Conway *et al*., 2017). The annual temperature is recorded to increase at the rate of 0.03^{o}C (Conway *et al*., 2017). Increasing temperature is reported to intensify land degradation because of inadequate land management practices and thereby increase vulnerability to weather-related shocks (URT, 2014).

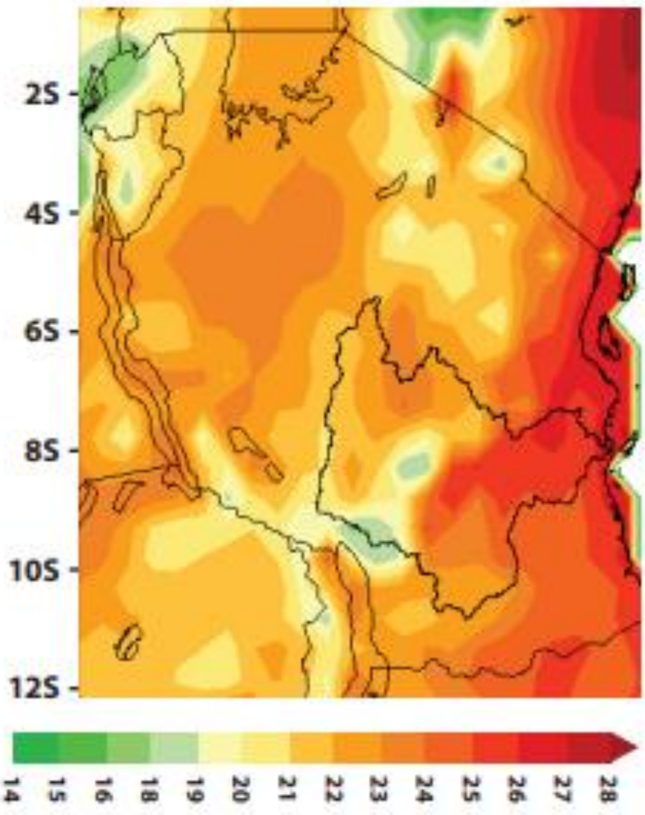

Figure 2:9 Observed annual mean temperature (°C) for 1976-2005 across Tanzania
Source: Conway e*t al.*, (2017)

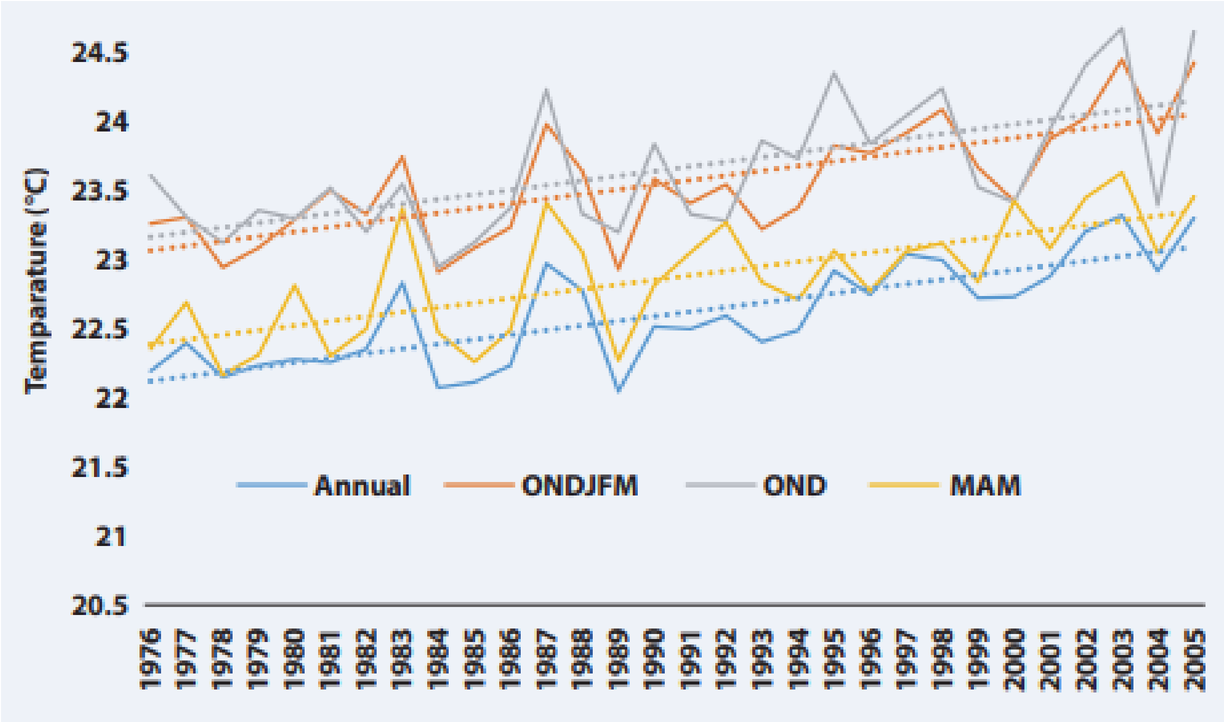

Figure 2:10 Observed annual and seasonal temperature (°C) for all Tanzania for 1976-2005. The seasons are March to May (MAM), October to December (OND), and October to the following March (ONDJFM). The dotted lines represent the trend over the whole period

Source: Conway *et al*. (2017).

2.4 Mitigation and adaptation approaches to dealing with climate change risk

To manage and reduce climate change risks, societies need to adapt to or mitigate climate change. Adaptation is the process of adjustment to actual or expected climate change and its effects to either lessen or avoid harm or exploit beneficial opportunities (Pachauri *et al.*, 2014). Mitigation is the process of reducing greenhouse gas emissions or enhancing sinks of greenhouse gases to limit future climate change (Pachauri *et al.*, 2014). This research project focuses more on adaptation because of the context in which this research is carried out, where small-holder farmers are required to adapt to climate change and are hit by the impacts of climate change, but have relatively limited effect on climate change through their own greenhouse gas emissions. Policy priority for these regions is more focused on ways to adapt to the consequences of climate change (Downing, *et al*., 1997) rather than how they can mitigate against further climate change. However, this paper considers that adaptation measures employed should not contribute to future climate change and it is important to embed mitigation within adaptation measures.

The target of adaptation is to reduce the vulnerability of social and environmental systems to climate variability (Pachauri *et al.*, 2014) and enhance resilience. However, scholars perceive climate change adaptation differently. Some consider adaption as measures to address risk resulting from climate change and thus call for strategies that can reduce the exposure and vulnerability of climate change (Pachauri *et al.*, 2014: Jerneck, 2018). Others see adaptation as responses to climate risks as well as social factors that create vulnerability to climate change thus requiring strategies that enhance social reforms or development and means to reduce vulnerability within the prevailing system (Jerneck, 2018).

Effective adaptation strategies do not consider the reduction of vulnerability and exposure to climate risk only, but these strategies also consider the way they link to socio-economic processes, sustainable development and climate change as well as increasing the capacity to resist or recover from the potential adverse impacts of climate extremes (Jerneck, 2018). Therefore, adaptation measures involve not only engineering and technological measures but also a broad range of ecosystem-based strategies, institutional and social actions (Pachauri *et al.*, 2014). In other words, if climate change adaptation is perceived as not just a response to hazard but goes a step further to consider other factors that create vulnerability in the first place, adaptation provides an opportunity to challenge the conventional development pathways and ask stakeholders to do more to reduce poverty and inequality (Jerneck, 2018). This broader interpretation of climate change adaptation is what this research has employed.

Adaptation offers a unique lens for understanding and influencing development, and can operate at different levels of engagement within specific social systems (Pelling, 2011). As shown in Table 2:1, Pelling (2011) identified three levels on which adaptation can intervene in development through enabling i) resilience, ii) transition, or iii) transformation. These levels will be briefly explained below.

As described by Pelling (2011), one of the outcomes of adaptation is to achieve resilience. Adaptation for resilience focuses on maintaining the activities perceived by an actor as necessary (Pelling, 2011) in order to ensure social, economic and natural capital are balanced (Pelling, 2011; Wilson, 2014). Although adaptation for resilience might involve technical and organizational changes, as opposed to transitional and transformational levels of adaptation, adaptation for resilience is seen as less politically challenging and is more comfortable and quicker to implement than adaptation as transition and transformation (Pelling, 2011).

Table 2:1 Attributes of adaptation for resilience, transition and transformation

	Resilience	Transition	Transformation
Goal	Functional persistence in a changing environment	Realize full potential through the exercise of rights within the established regime	Recognize the structures of development
Scope	Change in technology, management practices and organization	Change in practices of governance to secure procedural justice; this can in turn lead to incremental change in the governance system	Change overarching political-economy regime
Policy focus	Resilience building practices such as use of new seed varieties	Implementation of legal responsibilities by private and public sector actors and exercise of legal rights by citizens	New political discourse redefining the basis for distributing security in society and social-ecological relationships

Source: Adopted from (Pelling, 2011)

Adaptation for resilience emphasizes retaining what actors consider essential for their livelihoods while using social learning to adjust their technology, new information exchange and decision-making procedures (Pelling, 2011) to learn what is practical and useful and what is not for enhancing resilience.

The adaptation level that addresses concerns of the realizations of rights and actions in social equity and distributive justice within the existing governance regime is termed adaptation as transition (Pelling, 2011; Smucker *et al.*, 2015). Adaptation as transition focuses on implementing innovation and existing rights and responsibilities which might have been previously neglected without changing the existing regime (Pelling, 2011). The adaptation as transitions work on the governments with policies and strategies that has potential to contribute to climate change adaptation but need some improvements to effectively support adaptation initiatives. The target in adaptation as transition is to encourage governments to do more than what has been done to cope with natural climate variability and extreme weather events (Kates, *et al.*, 2012). Like other levels of adaptation, to achieve transition adaptation can involve changes to values, institutions, behaviour and assets within government (Pelling, 2011).

Adaptation as transition is an extension of adaptation for resilience that places greater focus on governance, but falls short of complete transformation adaptation aiming for or triggering cultural or political regime change (Pelling, 2011; Kates, *et al*., 2012). Governance systems are composed of multiple actors including public, private or civil society organizations held together through formal and informal institutions that reproduce the balance of power and direction of development pathways in society (Pelling, 2011). Transitional adaptation can be executed at various levels from an individual, community to any other relevant regime (Pelling, 2011) at various scales of governance (local, national and international) by uncovering complex power relations in political ideology, culture and behaviour that contribute towards resilience(Wilson, 2014).

Governance at each level influences the decisions affecting the access and the distribution of resources to support livelihood adaptation (Keskitalo and Kulyasova, 2009). The existence of multiple levels of governance with impact on adaptation does not necessarily involve only people in the position as a result of political processes of elections and selection, but also, the market mechanisms that control price actions through supply and demand of commodities and services (Keskitalo and Kulyasova, 2009). Adaptation may also be limited by the nature of the regulations and policies as executed by those in the position of governance. There may be conflicts over the interpretation of regulations, limited enforcement of regulations, or reduced regulation which may distribute resources unequally to different groups (Keskitalo and Kulyasova, 2009). For example, policies made specific to climate change adaptation and those policies that existed before can have an impact on adaptation actions (Urwin and Jordan, 2008).

'Transformational adaptation describes those actions that result in 'the overturning of established rights systems and the imposition of the new regime' (Pelling, 2011:85). The characteristics of these changes can be described in different forms, such as radical and for challenging the status quo, they may be painful and exhausting, and they may also require effective leadership to achieve changes (Lonsdale, *et al,*. 2015). The aim of undergoing transformational adaptations may vary. These reasons include the need to create a new system when the sustainability of the existing system is unbearable (Nelson, *et al.*, 2007; Folke *et al.*, 2010); the need to facilitate achievement of the desired outcomes (Park *et al.*, 2012), the need to address the insufficiency of the incremental or autonomous adaptation

(Kates, *et al.*, 2012: Thornton and Comberti, 2017) and the need to address the root of the problem (Revi *et al.*, 2014).

The main features of transformational adaptation as described by Kates, *et al.*, (2012); and these features are the one which differentiate this adaptation from others (adaptation for resilience and transitional adaptation). One of the features is the scale at which adaptation occurs. If the common adaptation is used at a greater scale, it becomes transformational. For example, if the use of early maturing maize was used in just one village in the region with 30 villages growing maize, and then it is scaled to all farmers, it becomes transformational adaptation. Another form in which it occurs is when new adaptation is introduced to a particular human or environmental system. An example is providing drip irrigation to the region which has never used it before. The third form is through transformation of places and shifting locations.

2.4.1 Climate change adaptation in developing countries

Generally, all human societies and activities are sensitive to the climate in some way or other (Adger *et al.*, 2003). One way of reducing climate risk is to adapt with it. However, some coping strategies are more technologically dependent and require access to both financial and knowledge resources, which are not equally available to all societies; making some communities more vulnerable to climate change than others (Adger *et al.*, 2003).

Since most people in developing countries already experience some social-economic and institutional problems, climate risks may exacerbate ongoing socio-economic problems and amplify challenges already facing the livelihoods of populations in developing countries (Adger *et al.*, 2003). Thus, climate change in developing countries may have more severe impacts than in developed countries (Nigussie *et al.*, 2018) particularly in communities where the majority of people are poor, reside in rural areas and rely on agriculture for their living and livelihoods (Downing *et al.*, 1997; Jerneck, 2018). That is why this research focuses on climate change adaptation strategies relating to the livelihoods of small-holder farmers in developing countries.

2.5 Understanding small-holder farming

2.5.1 Defining small-holder farmers

Many researchers have attempted to study small-holder farmers both in developing and developed countries. However, 'small-holder' means different things to different people. Some researchers use concepts such as 'family farm,' 'peasant's farms' or 'subsistence farms' interchangeably with small-holder farms. As observed by Lowder *et al.* (2014), these concepts can be quite different depending on their focus, but in some contexts, 'small-holder' may combine qualities observed in all these concepts. Before presenting the lens with which this research views the term "small-holder farms", these concepts will be described.

Family farms are used to describe farms which are owned and supply labour predominantly from within the family or household (Lowder, *et al*., 2014; Rigg, *et al*., 2016). Based on this criteria, the world is estimated to have 500 million family farms (Lowder, *et al.*, 2014). The use of the term 'family farms' to describe small-holder farms can be confusing, as both family farms and small-holder farms, depend mostly on family labour for agricultural production (Rigg, *et al.*, 2016). However, even in developing countries where small-holder farms are dominant, farm size continues to increase alongside access to agricultural mechanization (Rigg, *et al.,* 2016) which reduces the use of human labour in the farm. So the concept of 'family farms' will not pass the test of time alongside these trends in agricultural development in developing countries because it is characterised by using family labour (Morton, 2007).

The term ‘peasant’ or ‘subsistence’ farmer focuses on describing the subject - the farmer. Some authors define peasant or subsistence farmers by focusing on the use to which farm products are mainly put, while others consider many qualities that may characterise this social group. For example, elsewhere, peasants are described as ‘the farming class, which produce largely to meet their own subsistence needs’ (Rigg, *et al.*, 2016:121,). Subsistence refers ‘to the proportion of farm output, which is directly consumed by the household rather than sold in the market’ (Ellis, 1993, p.9). For peasant farmers, most of what they produce on the farm is for family or household consumption rather than for the market.

However, according to Ellis (1993), peasants are defined not only on their subsistence quality but also on their dependence on farming as their source of income, their limited access to resources, their restricted access and control over the market, and their inferior social-economic status which they occupy, being subordinated by outsiders. Since this concept (peasant) has derogatory connotations associated with its regular use (Ellis, 1993) and since this project is intended to improve livelihoods and protect the dignity of the rural farmers, this paper avoids the use of such term although this paper agrees with the characteristics of the small-holder farmers as described based on the same concept.

In many places in the world, farming groups who own land of fewer than two hectares are described as small-holder farmers (Lowder, *et al.,* 2014). Based on this criteria, it is estimated that there are about 570 million small-holder farms worldwide, thus contributing about 84% of global farms but covering only 12% of the worldwide farm land (Lowder, *et al.,* 2014). There are differences in the proportion of the small-holder farms in terms of number and area globally based on the level of the countries’ development. The more significant share of farmland in countries with lower levels of income are farms with less than two hectares which is the opposite trend to that of higher income countries. In countries in East Asia and Pacific regions (excluding China), South Asia and Sub-Saharan Africa, about 70-80% of farms are less than two hectares, occupying about 40 % of the farmland in these regions (Lowder, *et al.*, 2014). This main characteristic relating to the definition of a small-holder farm is therefore based on the threshold of farm size (two hectares).

However, in some regions such as Tanzania, the average size for most small-holder farms is sometimes more than four hectares. So defining small-holder farms based on farm size may obscure other characteristics which distinguish these group of farmers in some regard. For example, small-holder farmers in middle and high-income countries may have two hectare farms but have a high income many times larger than those in low income countries (Morton, 2007;Lowder, *et al.*, 2014). Also small-holder farmers in developed nations may possess the capability to transform farm produce into products and fully engaged in profitable market activities (Ellis, 1993).

An alternative to the focus on farm size, used elsewhere, is that small-holder farmers are defined as 'rural producers in developing countries whose farming activities rely primarily on family labour, who can be found on a continuum between subsistence- and market-oriented production, and who have limited resource endowments relative to other farmers in the sector'(Burnham and Ma, 2016:290). This definition summarises qualities that represent small-holder farmers in which this project is based, the key being producing for subsistence and market, and having limited resources compared to other farmers. And therefore, this research operationalises the term "small-holder farm/er(s)" in this context as opposed to other related terms and concepts such as family, subsistence and peasant farms.

2.5.2 Small-holder farmers' livelihood

This subsection defines what is meant by small-holder farmers' livelihoods. However, first it is important to define the concept of agriculture in the context of small-holder farmers, before discussing the relationship between agriculture and livelihood.

Agriculture is generally understood as the art of crop production and animal keeping (Salami, *et al.*, 2010). Some authors refer to agriculture as livestock keeping (Gebbers and Adamchuk, 2010) or crop production (Phillips *et al.*, 1980) only while others refer to agriculture as both crop production and animal domestication (Katayama *et al.*, 2008; Council, 1989; Garnett *et al.*, 2013). Agriculture also broadly includes forestry and fisheries besides crop production and animal keeping (Howden *et al.*, 2007). Therefore, agriculture may involve the science of cultivating the soil, growing crops and raising livestock, preparation of plants and animal products for people to use and the distribution of these products to the market. Some studies that explore agriculture in the context of small-holder farmers' focus on either crop production only while other studies explore both crop production and livestock keeping. Although this thesis considers agriculture as both crop and animal domestication, fisheries and forestry, this thesis does not use this concept (agriculture) in the study because it will leave out other fundamental means for making a living which are used by small-holder farmers.

Livelihood is the concept that has potential to replace agriculture, but has been used to represent different things. Studies of small-holder farmers have different interpretations of the concept of livelihood. Some authors use the concept of livelihood to represent agricultural practices as small-holder farmers' strategy for making a living (Akinnifesi *et al.*, 2002; Tigere *et al.*, 2006; Nkala, *et al.*, 2011; Makate *et al.*, 2016). However, this use of the term 'livelihood' faces the same weakness as the studies which focus merely on agricultural practices in understanding the lives of small-holder farmers.

On the other hand, there is a broader understanding of the term livelihoods which seeks to understand small-holder livelihoods as a portfolio of activities utilised to make a living. In this context, the term “livelihood” embraces all activities that the small-holder farmers (in the context of this study) utilise to survive. This is due to the fact that, small-holder farmers do not necessarily depend on a single means to get their living, they diversify their income strategies by increasing the number of income activities regardless of the sector or location (Alobo Loison, 2015). Most studies of small-holder farmers utilise the livelihoods concept in the narrow sense, including crop production, livestock keeping as well as other off-farm income activities in isolation or without giving weight to all of them. Given the importance of each livelihood strategy to small-holder farmers, and the risks associated with farmers focusing on crop production only, it is essential for studies of small-holder farmers to include all livelihood strategies. Thus this study utilises the livelihood concept rather than small-holder agriculture to capture broad range of activities used to make a living and how they can support adaption.

2.5.3 Sustainability in small-holder farmers’ livelihoods

Small-holder farming makes a significant contribution to social and environmental impacts in developing countries. Small-holder farming is generally characterised by high levels of biodiversity which provide ecosystem services such as food, energy source- to the local and global community (Altieri and Nicholls, 2012). However, despite the huge potential of small-holder farming, the system is increasingly unviable unless government policy changes and acts immediately to address the potential and social crisis in this sub-sector especially in Sub-Saharan Africa (Jayne, *et al.,* 2010).

These challenges result from the inability of this class of farmers to adequately ensure food and nutritional security, improve their well-being, reduce poverty as well as contribute to the country's development. Thus the existence of food insecurity and poverty (Arndt *et al.*, 2012) , environmental problems such as land degradation (Sivakumar, *et al.,* 2005), high reliance on rainfall(Peter *et al.,* 2009), weak government institutions such as policies and laws that constrain agricultural development (Ellis, *et al.*, 2003), and climate change impacts on agriculture in Africa, makes the sustainability of small-holder farmers' livelihoods in Africa a significant concern(Henson, 2011;Arndt *et al.*, 2012). This is therefore an area of concern for academic scholarship and policymakers in particular as every country in Africa is at risk of being affected by climate change (Mendelsohn, *et al.*, 2000; Müller *et al.*, 2011).

Due to these concerns, some scholars consider small-holder farming as an outdated means for economic growth, and they therefore advocate for the replacement of small-holder farming by corporate, large -scale, and mechanized farming (Rosset, 2000). However, alongside other equity issues such as the need to ensure equitable access to resources such as land, and the need for huge country-wide transition to ensure the population working in agriculture have access to alternative means for income, this argument ignores the potential for the significant contribution of small-holder farms to global food production, improving well-being and biophysical conditions (Rosset, 2000;Samberg *et al.*, 2016).

It is from this reality that investment in small-holder farms has been identified as an essential component in achieving the UN's Sustainable Development Goals particularly to address poverty and hunger (Samberg *et al.*, 2016) and address inequality in countries with a large proportion of the population employed in agriculture (Binner and Resnick, 2010). This thesis argues that for small-holder farmers in developing countries, if the potential of this sector is realized, it can contribute to other Sustainable Development Goals such as 'good health and well-being' and 'quality education' particularly for the children and relatives of small-holder farmers.

2.6 Climate change and small-holder farmers' livelihoods

2.6.1 Introduction

The literature on climate change impacts on livelihoods in developing countries has highlighted the effects of extreme weather events on livelihood strategies related to fisheries (Issahaku, et al., 2018), forest-dependent communities (Akinbile, *et al.*, 2018) and agriculture (Asfaw *et al.*, 2019). This section reviews the literature on climate change impacts on small-holder farmers' livelihoods particularly in developing countries. The impacts (actual and projected) can refer to impacts on river flows, crop production and price, and on livelihood assets (such as physical, social, financial, human and natural capital) as presented in detail below. This section summarises these impacts and the measures to deal with these impacts.

2.6.2 The impact of climate change on small-holder farmers' livelihoods

Climate change has affected small-holder farmers in different ways. One area relates to changes in river flow because river flow can be strongly linked to seasonal rainfall and temperature variation (Conway *et al.*, 2015). For the case of Sahel region and Southern Africa, a reduction of 10 percent water volume is expected with a 10 percent decline in precipitation particularly in the major Zambezi and Limpopo basins (Collier, *et al.,* 2008; Mohamed, 2011) affecting water supply for irrigation in countries like Botswana, Mozambique, South Africa, Zimbabwe and Sudan, as well as increasing flooding incidents (Serdeczny *et al.*, 2017). In Tanzania, Kangalawe (2017) observed that as a result of factors such as shrinking rainfall amount and shortened rainfall season, increased drought and increased temperature, there has been a continuous decrease of water flow and increasing seasonality of rivers and streams. Moreover, this has led to the drying of some wetlands in the Southern Highlands of Tanzania. Decreasing water volume in rivers and other water sources will amplify existing water stress in Africa by increasing demand for water for irrigation (Serdeczny *et al.*, 2017).

Climate change affects crop production in Africa. Some regions may experience positive effects resulting from increased rainfall while other regions will suffer the negative consequences of extreme weather events (Peter *et al.,* 2009). However, for the majority of regions in Africa, climate change is projected to affect agricultural production negatively, especially in small-holder farming systems, as currently evident in many parts of Africa (Müller *et al.*, 2011). The amount and quality of grains and straws production may be affected (Munishi, *et al.,* 2015: Balama, *et al.,* 2016) as well as cropping patterns and crop suitability (Descheemaeker *et al.*, 2016).

Climate change impacts on crop production partly influence the price of food and increases the number of people experiencing hunger (Pachauri *et al.*, 2014). Climate change impacts on crop-based agriculture will affect affordability and availability of nutritious foods particularly in area, such as South Africa, where the level of under-nutrition is already high because of lack of food (Serdeczny *et al.*, 2017).

Details about how climate change affects crop production can be found in the following literature. Rosenzweig *et al.* (2001) and Lin (2010) discuss how crop coping mechanisms to temperature rise reduce crop production. Collier *et al.* (2008) and Serdeczny *et al.*, (2017) argue that crop production in Africa is already above the optimal temperature for crops such as maize. Lal (2001) and Komakech *et al.* (2011) highlight that crop production on bare land may amplify the impact of wind and water erosion. The impact of excessive rains also affects crop production due to water logging and increased pest infestations (Rosenzweig *et al.*, 2001; Dhanush *et al.*, 2015). Other ways in which climate change affects crop production is through growth and development of insects, pests, and pathogens as a result of increases in temperature (Rosenzweig *et al.*, 2001;Dhanush *et al.*, 2015) and weeds (Rosenzweig *et al.*, 2001; Rodenburg, *et al.,* 2011).

Climate change impacts on crop production partly influence the price of food and increases the number of people experiencing hunger (Pachauri *et al.*, 2014). For example, Climate change is projected to reduce cereal crops such as maize and sorghum production in Tanzania by 25 percent due to increased temperature and rainfall variability (Msongaleli *et al.*, 2015). In the Sahel region, the temperature increase in this area has reduced food production and has resulted in severe consequences for the economic development and social stability (Mohamed, 2011). However, the main question remains how these impacts translate into the livelihoods of small-holder farmers particularly in Sub-Saharan Africa.

2.6.3 Impact on livelihood assets

Climate change also affects livelihood assets as shown in Table 2:2 which can be human, social, financial, natural and physical. These assets are the basic building blocks poor people combine to make their livelihoods. Climate change through increased floods and other extreme events can affect all areas of livelihood assets. For instance, Alam, *et al.* (2017) found that extreme weather events such as storm surges and floods in Bangladesh affect natural, social, physical, and financial capital. Sometimes the impact of climate change on livelihoods can indirectly affect natural capital both in terms of the stock and flow of resources, and later through feedbacks can affect other livelihood assets such as physical, human, social and financial capital (Reed *et al.*, 2013).

Table 2:2 Types of livelihood assets and their examples

Assets/capital types	Examples
Financial	Cash or equivalent
Human	Good health, physical capability, ability to labour, knowledge and skills
Natural	Air, soil, water, pollution sink, hydrological cycle
Social	Networks, social claims, social relations, affiliations, associations
Physical	Infrastructure such as transport, secure shelter and buildings, sanitation, energy and communication infrastructure

Source: DFID (1999)

On the other hand, climate change impacts on agricultural productivity can also indirectly affect livelihood capital of poor farmers in the global south. Unsustainable coping strategies can be employed in order to survive the impacts of climate change, for example important assets may be disposed (Berman, *et al.,* 2015) making them unavailable in the future, or the number and quality of meals may be reduced (Zemedu and Mesfin, 2014) thus affecting physical or human capital . While there are many studies in Africa that explore climate change impacts on livelihoods, there are limited studies about climate change impacts on the livelihoods *assets* of small-holder farmers. As livelihood assets are a fundamental aspect of strategies employed by poor people like small-holder farmers in developing countries to ensure a living, it is crucial to understand whether climate change has any impact on these assets to enable policy measures to address them.

The post-disaster livelihood assessment tool kit (FAO and ILO, 2007) is a tool to assess how disasters affect household livelihood assets. The tool uses sustainable livelihood framework as a guide to explore how disaster affects household livelihood assets. The tool studies the impact by collecting information about the nature of household's livelihood assets before and after the disaster. For example, to understand the impact of disaster to human capital the tool asks the head of household questions like; how many people resided in this household before the occurrence of disaster? How many people are living now in the household? Has anyone left as a result of the disaster? What impact has this had on the household's ability to make a living? This research will use this tool to guide interview questions to household heads to understand how climate change affect their livelihood assets.

2.7 Tackling climate change for small-holder farmers

2.7.1 Introduction to adaptation strategies

This section is informed by studies from agricultural development and rural development and climate change adaptation to understand strategies that increase livelihood vulnerability and those that can help small-holder farmers adapt to climate change. The section starts by presenting the literature about agricultural best practices that can help small-holder farmers adapt to climate change, then finishes with insights from rural livelihoods literature. I have categorised agricultural best practices that can help climate change adaptation into two main areas relating to techniques for rainwater harvesting and water management and to soil management. Livelihood diversification and social structures governing household resource use are also included as adaptation strategies.

2.7.2 Water management and improving water use efficiency

It is widely acknowledged that water scarcity is a major constraint for rain-fed agriculture (Bot and Benites, 2005). Poor decisions and practices made by farmers in different contexts such as the choice of inappropriate crop varieties to grow, inadequate management of water from rainfall and other sources, and inappropriate practices that affect water sources (Bot and Benites, 2005) can affect agricultural productivity particularly under weather-related stress.

This is due to the reality that crop failure in many places in Sub-Saharan Africa is not the result of a lack of rainfall but poor distribution and water management limitations (Biazin *et al.*, 2012). Collecting rainwater and using it during dry spells, using irrigation from other sources and improvement of water use efficiency can help address the water challenge in agriculture (Silva *et al.*, 2015).

One water management strategy to support agricultural productivity is to employ methods that improve water use efficiency, including the use of rainwater harvesting. Rainwater harvesting structures can be of different scales and costs. However, this review presents infrastructure that have been reported to be used by small-scale farmers in developing countries to cope with climate variability and change. These methods are crucial for areas with long dry spells of more than 15 days (Rockström *et al.,* 2003) for which on-field water conservation methods such as terraces, mulching, reduced tillage and agro-forestry (Yazar and Ali, 2016) are no longer helpful for soil moisture conservation (Barron and Okwach, 2005).

Rainwater harvesting in the context of small-holder farmers, is a process of rainwater collection, storage and efficient utilisation for crop production (Ngigi *et al.*, 2005). Detailed explanation about the techniques for rainwater harvesting which are also applicable to small-holder farmers can be found in (Biazin *et al.*, 2012). These techniques have been reported to be used by small-holder farmers in different places such as Dodoma region in Tanzania (Hatibu and Mahoo, 1999; Below *et al.*, 2012) as well as other developing world contexts including Bangladesh (Habiba *et al.,* 2012) and Nigeria (Tambo and Abdoulaye, 2013). Response farming strategies have been reported throughout Africa including in Uganda (Okonya *et al.,* 2013; Mulinde *et al.*, 2019), Nigeria (Ishaya and Abaje, 2008; Tambo and

Abdoulaye, 2013), Kenya (Bryan *et al.*, 2013) and Ethiopia (Belay *et al.*, 2017), as well as Tanzania (Lema and Majule, 2009).

For farmers to be able to produce enough crops for their own food security and to improve their wellbeing, it is not just access to irrigation water that is important but also the means to use water more efficiently. Postel *et al.*, (2001) have shown how drip irrigation can be made suitable for farmers with varying income capacities, with the lowest cost solution: a 'bucket kit' with the capacity of holding 20 litres which could irrigate 25m^2 while the largest solution could irrigate one acre. Therefore, different solutions to the challenges of water scarcity need to be available for farmers with different financial capital.

2.7.3 Soil management

Although the previous subsection about water harvesting and strategies to increase water use efficiency briefly mentioned the role of soil management because of the strong interlinkages between these areas, this subsection will discuss soil management in more detail because of the potential impact climate change may have on the soil fertility. Soil fertility in Sub-Saharan Africa is also under pressure due to increasing land degradation taking place in these regions, contributing to food insecurity in many countries (Sanchez, 2002; Vanlauwe *et al.*, 2010; Clair, and Lynch, 2010).

Soil fertility is under pressure from climate change through increased rainfall which may accelerate soil erosion and reduce crop nutrients. An increase in temperature may also reduce soil fertility by increasing organic matter decomposition which may have significant impact on crop nutrition (Clair, and Lynch, 2010). To address these problems, it is vital to consider soil management strategies which can help soil adapt to climate change as described by (Clair, and Lynch, 2010).

Although some of the techniques categorised under either water or soil management can have impacts on both areas, the division is important for analytical purposes and is used throughout this study. The list of agricultural practices and technologies for climate change adaptation included above is not exhaustive, and some strategies involve combinations of strategies. For example, the use of Conservation Agriculture which has been promoted in some countries in Africa, is generally practiced by combining three principles of minimum soil disturbance, surface crop residue retention and crop rotation (Thierfelder *et al.*, 2015) and in some contexts a fourth element; the appropriate use of fertilizer (Vanlauwe *et al.*, 2014). Thierfelder *et al.*, (2015) summarised the recorded benefits Conservation Agriculture in Southern Africa to include improvement of physical, chemical and biological soil properties, and increased soil moisture availability and agriculture productivity.

2.7.4 Livelihood diversification

Diversification is used by small-holder farmers to manage risk in their livelihoods (Barrett *et al.,* 2001). There are several reasons why individuals diversify their income activities. Barrett *et al.* (2001) describe motives for diversification to include unfavourable conditions such as existence of risks. This is because diversification represents peoples' survival strategy to stressors (Ellis, 2000). For example, if a small-holder farmer experiences crop failure, he may decide to sell his labour to get extra income. Other benefits of livelihoods diversification include complementary livelihoods activity for example performing crop production alongside livestock keeping where animal manure can be used in the farm and crop residue used for feeding livestock (Barrett *et al.*, 2001).

The strategy of livelihoods diversification, compared to many regions, is pervasive to poor people especially in Sub-Saharan Africa (Ellis, 2000). Livelihood diversification in Africa can take many shapes from off-farm income from agriculture, work in non-farm activities, and rural non-farm self-employment such as through trading and remittances (Ellis, 2000). Although livelihoods diversification in Africa has existed for a long period of time (Ellis, 2000), farmers can be unable to benefit from non-farm income sources because of lack of capital, skills and access to markets (Barrett *et al.,* 2001). However, diversification is not always productive, as it can contribute to lower economic return compared to more intensive engagement in a more limited number of livelihoods strategy (Paavola, 2008).

2.7.5 Social structures governing resource use in the household

The way households utilise their resources in terms of agricultural produce and income can also contribute to either adaptation (therefore increasing livelihoods resilience) or increased vulnerability. This section examines literature looking at social factors that govern how crops and their resultant income are used by households. Some studies report that small-holder farmers in some places have food storage systems that help households to save food to be used over a relatively longer time (Burnham and Ma, 2016) . Such strategies have been reported in studies in several locations including Bangladesh (Habiba *et al.*, 2012) and India (Mwinjaka,*et al.*, 2010).

In addition to food storage, other systems that govern ownership of resources and the nature of how household obligations are distributed between a mother and father in the household can contribute to adaptation or increase vulnerability to weather-related stress. Kiewisch (2015) observed in a study in West Africa that the division of household obligations, where the mother was responsible for ensuring food in the household and father was responsible for paying children's school fees and providing shelter contributed to household vulnerability to stressors. She argued for greater shared household obligation because the income from households was not necessarily used for the interest of the whole household. Shared household obligations imply the need for transparency on what is produced, the amount of income earned and joint planning on how the income will be spent.

In summary, this review about the adaptation strategies used by small-holder farmers shows that there are several strategies that farmers can use to adapt to climate change. These strategies include land and water management practices, diversification of on- and off-farm income streams, as well as having social systems that may more effectively govern resource utilisation. However, despite the fact that not all strategies are applicable everywhere as it depends on context specific factors, previous literature has established the significance of combining strategies that increase livelihoods productivity with those promoting the efficiency of household resource utilisation because in some contexts, vulnerability to climate change is not only the result of a lack of access to resources but also the way that resources are utilised (Kiewisch, 2015). This is a very critical consideration in the livelihoods approach to improving the lives of the poor (DFID, 1999).

Unfortunately, most studies about small-holder farmers' livelihoods adaptation to climate change report strategies that enhance livelihoods productivity only, with little attention to the strategies that can enhance household resource utilisation (Kiewisch, 2015; Burnham and Ma, 2016). This project intends to contribute to the knowledge about small-holder farmer's livelihoods adaptation strategies by integrating approaches that enhance livelihoods productivity and efficient resource utilisation.

2.8 Agriculture in Tanzania

Agriculture is a very important sector in Tanzania. Between 1981 and 2010, the sector contributed approximately 26% to the country's economy, thus making it the second largest after the service sector which contributes almost 44% (Chongela, 2015). The most important subsector in agriculture is crop production which contributes almost 19% out of the 26% (Chongela, 2015). The rest (7%) is supplemented by livestock keeping and fisheries. Food and cash crop production in the country accounts for about 70% of rural incomes (URT, 2012). Agricultural potential in Tanzania is yet to be realised. Despite the huge area of arable land in the country (88.6 million hectares), only 10 million hectares are cultivated, mainly by small-holder farmers (URT, 2014). This shows that the agriculture sector has enormous potential of transforming the country's economy if the potential arable land is fully utilized. The data from the most recent census in Tanzania shows that Tanzania had a population of approximately 45million in 2012 URT (2014) with three-quarters of households involved in agriculture, with the majority of them (95%) living in rural areas (URT, 2012).

Several crops are cultivated in Tanzania. The dominant food crop that is cultivated in large parts of the country is maize. The Tanzania National Bureau of Statistics (2014) reported that for the period between 2012 and 2013, maize was cultivated over an area of 4,120 thousand hectares. For the same period (2012/2013), the same report shows that, the largest crop by area was sunflowers for making sunflower cooking oil; surpassing maize by almost 2,490 thousand hectares. Sunflowers were followed by beans and rice in area. Other crops grown in the country include sorghum, millet, wheat, beans, cassava, sweet potatoes groundnuts, and simsim. While maize is the dominant crop cultivated, paddy is leading as the dominant crop under irrigation while sugar cane, tea and coffee are the major commercial crops (URT, 2014).

The Tanzanian government has taken several policy measures to improve agricultural development in Tanzania. In the 1970s period, the government had active plans to promote agricultural development through slogans such as Siasa ni Kilimo (Politics is Agriculture, 1972), Kilimo cha Umwagiliaji (Irrigated Agriculture, 1974) and Kilimo cha Kufa na Kupona (Agriculture for Life and Death, 1974/5). In the 1980s, several policies were enacted such as the National Food Strategy of 1982, the National Agricultural Policy (NAP) of 1983, the National Livestock Policy (NLP) of 1983, the National Economic Recovery Programme (ERP) (1986 to 1990) and slogans such as Mvua za kwanza ni za kupandia (first rains are for planting) of 1981/82 to empower farmers to actively participate in agriculture to increase production and prevent food insecurity.

In the 1990s, the government of Tanzania developed the Tanzanian's development vision 2025 (TDV 2025), to guide social and economic development of the country by the year 2025 with the ambitious goal of becoming a middle income country characterised by high quality livelihoods, peace, stability and unity, good governance, a well-educated and learning society, and with a semi-industrialised competitive economy and appreciation of the role of agriculture as the backbone of the economy (Monitoring African Food and Agricultural Policies (MAFAP), 2013).The Agricultural Sector Development Strategy (ASDS) was adopted in 2001 to support the realization of the TDV 2025 and achieve the sectoral policy objectives of the National strategy for growth and poverty reduction which, among other things, is aimed at reducing income poverty.

To achieve this aim, the ASDS was developed in order to create a favourable environment for agricultural productivity and profitability as well as raising rural incomes to reduce poverty and food insecurity. To raise investment in the agriculture sector, the government launched the slogan Kilimo Kwanza (Agriculture First) in 2009 to promote a green revolution in Tanzania by using several measures such as improving access to knowledge and agricultural technologies, promoting public-private partnership in delivering agricultural investments and services, accelerating land reforms, and removing market barriers to agricultural commodities (MAFAP, 2013).

Other policy decisions include the 2007 warehouse receipt system (WRS), provision of subsidies and export ban. The WRS was introduced to enable farmers to store their produce in warehouses and sell it when prices are higher. The scheme is implemented through primary cooperatives, farmers' organizations or savings and credit cooperatives (SACCOs) (MAFAP, 2013). Participating farmers are paid a percentage of the produce price (50 or 70 percent), from which the price of inputs for the following season are deducted (MAFAP, 2013).

Although general fertilizer subsidies were removed in the early 1990s, the government slowly introduced subsidies which took different forms. The period between 2003/2004 subsidies were provided to cover transportation, while in 2009 the National Agricultural Input Voucher Scheme (NAIVS) was introduced to support provision of fertilizer and improved seeds for selected crops (MAFAP, 2013). The vouchers distributed provide a 50 percent subsidy on a 100kg package of fertilizer (urea for nitrogen, and ammonium phosphate for the nutrient phosphorus pentoxide) and 10 kg of improved maize or rice seeds (MAFAP, 2013).

The United Republic of Tanzania has established trade restrictive measures particularly to maize. Two main justifications are provided by the government to justify implementation of the export ban: food security (to prevent food leaving the country when there are shortages in some areas) and price stabilization. This type of policy has the potential of favouring some groups especially food buyers mostly residing in large cities like Dar es Salaam which may have negative impacts on crop producers particularly poor farmers in rural areas (MAFAP, 2013).

Apart from policies, the government has enacted laws that govern issues related to agricultural inputs such as seeds, agrochemicals and fertilizers. The Seeds Act (2003) regulates the production and trade of all varieties of agricultural seeds including the mandatory provision of seeds for quality assurance. The Fertilizer Act (2009) provides for the regulation and control of the quality of fertilizer, either domestically produced or imported. The Fertilizer Act (2009) establishes the Tanzania Fertilizer Regulatory Authority (TFRA) which is responsible for the coordination of manufacture, trade, distribution, sale and use of fertilizers. The Tropical Pesticides Research Institute Act (1979) regulates research on pesticides for the purpose of ensuring their quality. However, regardless of the existence of several policies and laws related to agricultural development in Tanzania, the country remains poorly developed and vulnerable to rainfall variability.

Sensitivity of crops to climate change results from not only the stress from changes in average weather conditions but also the nature of the biophysical characteristics of the agricultural land including the level of soil fertility (Salinger, *et al.,* 2005). Agricultural systems as performed by these small-holder farmers are poorly developed. For example, although the low quality of agricultural soils in major parts of the country, there is little utilization of improved agricultural inputs like seeds, fertilizers and herbicides (National Panel Survey, 2012/2013). This is a concern because the use of fertilizer (chemical or organic), improved seeds and pesticides, insecticides, herbicides and fungicides is important in order to achieve high agricultural productivity.

Fertilizer use and pesticide application supports plant growth and contributes to the production of high crop yield if appropriately applied. Some of the fertilizers especially nitrogen fertilizers have been reported to encourage the activities of micro-organisms which decompose soil organic matter (Bot and Benites, 2005). However, the use of fertilizer in Tanzania is very small. Sheahan and Barrett (2014) note that only small percent of farmers use organic or inorganic fertilizers, representing 20.3 and 16.9 percent respectively. The amount which was reported to be used was an average of 16.2 kg/ha. This amount is very small compared to the optimum of 50kg/ha targeted by African heads of state in 2006 in the Abuja Declaration as a goal for 2015 (Sheahan and Barrett, 2014). It is acknowledged that the excessive use of chemical fertilize negatively affects the environment, so it is important that care should be taken when fertilizers are used.

In terms of nutrients especially primary elements required by plants such as nitrogen (N), phosphorus (P) and potassium (K), the amount applied currently is 32.0, 7.0 and 6.6 kg/ha respectively (Sheahan and Barrett, 2014). Even for already degraded soils, some farmers still do not use any type of fertilizer (Sheahan and Barrett, 2014). Although the government of Tanzania has established input voucher schemes for subsidizing these inputs, poor small-holder farmers have been unable to benefit from it because of their low income *(Hepelwa, et al.,* 2013). This situation is threatening the sustainability of agricultural soils which is the basis for food and cash crop production for the majority of households in Tanzania.

The type of seeds used is among the factors that determine the quality and amount of crop to be produced (Sheahan and Barrett, 2014). Improved seeds are developed to meet certain characteristics that are important in ensuring crop productivity. They might be contributing to achieving more grains compared to traditional varieties, and be able to withstand some harsh weather conditions such as drought. In Tanzania, the use of improved seeds is very small. The percentage of the farmers using improved seeds in the two major staple foods of maize and rice, was an average of only 27% and 1% respectively (NPS, 2012/13). It has been reported that the majority of farmers select some good seeds from the previous harvest for planting (Sheahan and Barrett, 2014).

Another set of enemies that potentially impact crop yield are pests, disease, insects and weeds. Although data on the use of herbicides, insecticides and fungicides are not available at the national level, comparison at the continent level shows they are not frequently used. For example, Zhang, *et al.* (2011) reported that only three percent of global pesticides are consumed in Africa, of which two thirds are used in South Africa. The National Panel Survey (2012/13) indicated that, only 14% of households use pesticides in Tanzania. Although it is important not to promote excessive use of agrochemicals, this does demonstrate the potential of using integrated pest management strategies and small percentages of agrochemicals used appropriately to enhance crop production alongside human and environmental health.

Agriculture in Tanzania is mainly rain fed. Despite the massive land area of 2 million hectares (NBS, 2014), with high irrigation potential (defined by soil type, availability of water and farmers cultivating crops that need to be watered because of the rainfall characteristics), a tiny percentage of farmers (3.4%) use irrigation in their farming activities (NBS, 2014). This implies that, when there are changes in weather stress leading to prolonged dry spells, drought, or changes in rainfall distribution during the growing season, almost 97% of farmers have the potential of being seriously impacted (NBS, 2014).

2.8.1 Small-holder farmers in Tanzania

Agriculture in Tanzania is dominated by small-holder farmers, but the size of land owned by individual small-holder farmers is relatively small. They own an average of three hectares, but most of them (84%) own less than four hectares (URT, 2017). Comparison of survey data over three years (2000/01, 2007 and 2011/2012) shows that, there are some slight changes in the land size holding of small-scale farmers, with trends showing a slight increase for the period between 2000 and 2012 (URT, 2013).

Small-holder farmers' agricultural productivity is very low. Therefore, as with other small-holder farmers in developing countries, most of the food produced by small-holder farmers is mainly used for household consumption and only one third of farmers are able to produce surplus for sale (NPS, 2012/13). The National Panel Survey 2012/2013 reported that 96% of the poor people in Tanzania live in rural areas and are small-holder farmers. They live with an average income of $1.9 per day for a family of five people. Because of this small income, almost all of what is produced Figure 2:11 is consumed and leaves no or very little for investment (Rapsomanikis, 2014).

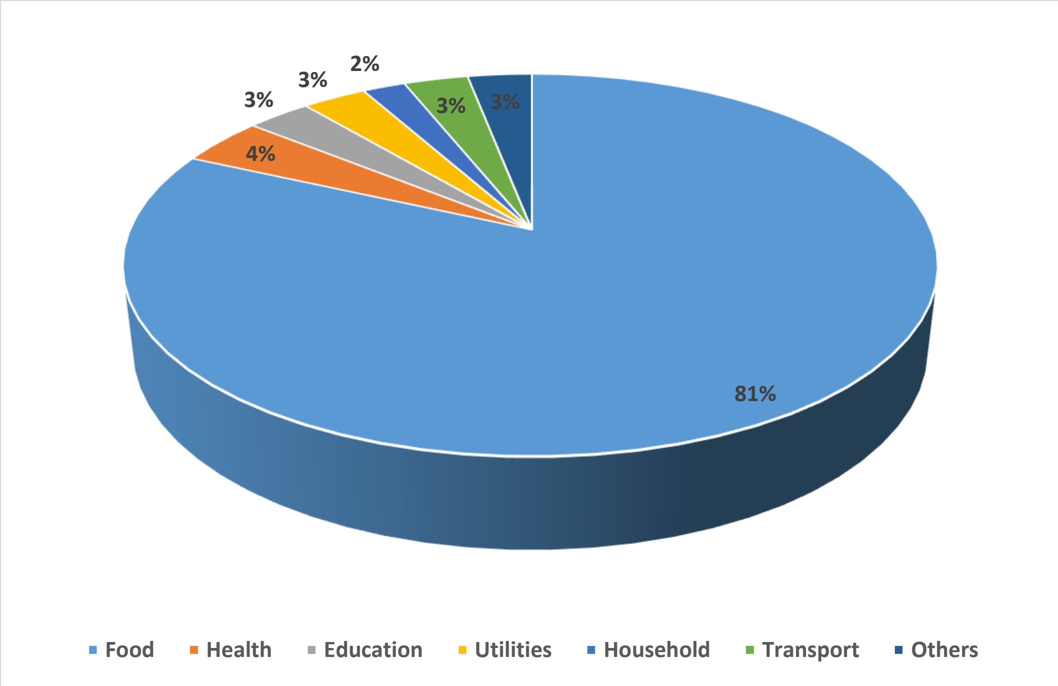

Figure 2:11The percentage distribution of small holder farm expenditure in Tanzania
Source: Rapsomanikis(2014)

2.8.2 Implication of climate change in Tanzania

Climate change impacts in Tanzania have already cost the agriculture sector at least $200 million per year (Wold Bank, 2013). The rainfall decrease of 10% has been correlated with a 2% decrease in national GDP (Seitz and Nyangena, 2009). Temperature rise of 2% could reduce maize yield by 13% and rice by over 7%; both of which are probable occurrences in Tanzania over the next century (URT, 2014).

Change in rainfall in Tanzania is expected to take different forms; higher or more concentrated rainfall, decreased rainfall and increased rainfall variability and uncertainty (URT, 2014). These changes may lead to different levels of impacts from severe negative impacts, moderate negative impacts, to bringing opportunities for some crop sub-sectors as summarised in Table 2:3, and changes in rainfall trends (Table 2:3).

Table 2:3 The implication of the temperature increase on agriculture in Tanzania

Scale of temperature rise: 1.5°C to 5°C by 2100	
Severe negative impacts	❖ Population and range increases for pest species and crop diseases ❖ Higher mortality rate of pollinators ❖ Reduced available water through evaporation loss ❖ Soil moisture depletion ❖ Increased maintenance costs of water infrastructure ❖ Reduced food crop yields
Moderate negative impacts	❖ Decreased base flow in perennial rivers ❖ Changes in soil chemistry ❖ Reduced soil fertility
Potential opportunities	❖ Population and range decreases in some pest species ❖ More favorable environment for some crops (e.g. sunflower)

Source: Adopted from Agriculture Resilient Plan, (2014)

Table 2:4 Projected rainfall trends and their implications on agriculture in Tanzania

	Higher, more concentrated rainfall	Rainfall decreases	Increased rainfall variability and uncertainty
Severe negative impacts	❖ Soil nutrient leaching ❖ Occurrence of microbial anaerobic conditions in non-water loving crops ❖ Flooding	❖ Soil moisture losses ❖ Reduced population of soil organisms ❖ Impaired crop growth and development ❖ Reduced water availability	❖ Higher uncertainty of planting times and reduced number of growing seasons ❖ Increased cost of production ❖ Longer season of drier soils
Moderate negative impacts	❖ Landslides ❖ Soil erosion ❖ Increased gully formation ❖ Physical damage to plants renders them more susceptible to pest attack ❖ Damage to water infrastructure	❖ Population and range increases by some pests ❖ Depletion of water sources ❖ Higher uncertainty of planting time ❖ Populations of bio-agents decrease	❖ Reduced soil fertility
Potential opportunities	❖ Increased seasonal soil moisture ❖ Reduced population of some pests ❖ Increase in food production for water-loving crops (e.g. rice)	❖ Decrease in food toxins due to reduced wet season/less moisture ❖ Possible introduction of new crop varieties and crop diversification	

Source: Adopted from Agriculture Resilient Plan, (2014)

2.8.3 Tackling climate change impacts in small-holder farmers' livelihoods in Tanzania

As noted in the introduction, understanding how small-holder farmers' livelihoods can adapt to climate change will significantly depend on the capacity to address factors increasing livelihood vulnerability through adaptation and how comprehensive the proposed and actual adaptation measures are in building livelihoods resilience. Although studies about small-holder farmers' vulnerability to climate change has been done in Tanzania, there is the need for further research which can conceptualise vulnerability in such a way that it comprehensively understands existing vulnerability to climate change. Before embarking on the studies about vulnerability of small-holder farmers in Tanzania, it is important to understand the climate risks and livelihoods in Tanzania.

2.8.3.1 Climate change risks and livelihoods in Tanzania

Climate risks are expected to increase water shortage and intensify pressure on water resources. However, the problem is compounded by an increase in water users and the use of low water use efficiencies (URT, 2014). Irrigation alone will not be sufficient to adapt to climate change if water resources are not well managed. Adaptation measures for improved water management are urgently needed to build resilience to current variability and future climate change by both small-holders and commercial farmers (URT, 2014).

Soil erosion and land degradation will be intensified by climate change, so adaptation measures for soil and land management are needed. The target needs to be to address soil and land degradation by promoting improved soil and land management practices; and promoting appropriate management practices such as conservation agriculture, soil and water conservation, resilient crop varieties, cropland management, soil fertility management, and agro forestry (URT, 2014) as shown in Table 2:5. Crop yields especially of cereal crops are expected to decline, and so climate-smart agriculture[2] that increases crop yields needs to be promoted. Better farming practices can increase the resilience of small-holder farmers to

[2]Technologies or practices that can increase agriculture resilience to climate change, (URT, 2014)

climate change (NCCS,2013); using strategies such as sustainable soil and land management, drought and heat tolerant crop varieties, water use efficiency and integrated pest management can help to achieve this (URT, 2014).

Ironically, existing land and water management strategies in the agricultural sector, contribute significantly to degradation of these resources and therefore reduce their capacity to support agriculture productivity. The management of land and water is a growing challenge that threatens agricultural productivity because of increased level of soil fertility depletion and erosion which is estimated at the rate of six to seven times greater than the rate at which they are replenished (Shetto and Owenya, 2007; URT, 2014). The same applies to the water sector, as strategies for water management for irrigation are poor (MAFC, 2012-2017). Therefore, understanding of these strategies is crucial to understanding better strategies that can replace them.

Household income diversification acts as buffer against climate-related income losses (Smit and Skinner, 2002). Some authors view this technique as the only effective way for African farmers to adapt to climate change (Collier, *et al.,* 2008). However, most small-holder farmers have limited access to other sources of income or are unable to fully exploit these activities because of low financial capital; and some of their activities are highly dependent on crop cultivation or animal keeping (Hertel, *et al.,* 2010). Therefore, improving agricultural productivity is also important to helping farmers diversify their income sources. Diversification options include selling labour and self-employment in sectors outside agriculture.

Table 2:5 Adaptation measures proposed to build resilience within the agriculture sector in Tanzania

Practice	Types of interventions	
Conservation agriculture	❖ Minimum tillage/direct seeding ❖ Cover crops ❖ Crop rotation ❖ Contour cropping	❖ Mulching / composting ❖ Intercropping with leguminous cover crops ❖ Crop rotation
Soil and water conservation	❖ Crop residues management ❖ Mulching ❖ Rainwater harvesting ❖ Pit and trench farming ❖ Ripping and subsoiling ❖ Raised beds	❖ Contouring ❖ Terracing ❖ Charco dams ❖ Bunding ❖ Composting ❖ Planting basins, tie ridges
Resilient crop varieties	❖ Drought tolerant varieties ❖ Early maturing varieties ❖ Water efficient varieties	❖ Pest and disease ❖ resistant varieties ❖ High yielding varieties ❖ Heat tolerant varieties
Cropland management	❖ Crop diversification ❖ Cover crops ❖ Bottom valley farming ❖ Green manuring	❖ Crop rotation ❖ Integrated pest management ❖ Reduced tillage ❖ Residue management
Soil fertility management	❖ Soil fertility evaluation ❖ Organic and inorganic fertilizer ❖ Integrated nutrient management ❖ Water conservation	❖ Improved manure handling ❖ Compost integration ❖ Mulch integration ❖ Soil conservation
Agro-forestry	❖ Establishing tree nurseries ❖ Agricultural friendly trees (N suppliers) ❖ Crop tree planting ❖ Woodlots in transition to renewable energy fuel use	❖ Land and catchment reclamation ❖ Alley cropping ❖ Windbreaks ❖ Fodder banks ❖ River and stream protection

Source: Adopted from the Agriculture Resilience plan in Tanzania (2014)

2.8.3.2 Studies about vulnerability assessment in Tanzania

This subsection discusses research about the vulnerability of small-holder farmers in Tanzania especially to climate change. This is important as vulnerability assessment contributes to understanding community specific adaptation measures.

Mongi *et al.* (2010) studied small-holder farmers in Singida region, Tanzania to understand the vulnerability of the farmers to climate change. In their research, vulnerability was taken to mean exposure to climate hazards such as decreasing rainfall amount and changes in rainfall distribution, increased dry spells, shrinking of the rain seasons and increasing temperature trends. These changes had significant impact on rain-fed agriculture, shrinking of the growing season, increasing moisture and heat stress to common food and cash crops, increased insects and pests leading to low income and food insecurity (Mongi, *et al.,* 2010). The study concluded that 'there is strong evidence demonstrating the vulnerability of rain fed agriculture to negative impacts of climate change and variability in the study area' (Mongi *et al*., p.371).

This could be taken to imply that vulnerability is solely the role of climate variability and there are no social factors that come into play. The same perspective of vulnerability is also used by Mwandosya *et al.* (1998) to understand vulnerability to climate change in Tanzania in different sectors including water, coastal resources, livestock, agriculture, forestry and human health. Other studies from Tanzania portraying this same perspective include Mnimbo *et al.* (2016) in their study about small-holder farmers in the Kilimanjaro region, and Lyimo and Kangalawe (2010) in the Shinyanga region.

On the other hand, O'Keefe, (2015, p.1) in his PhD thesis on the Kilimanjaro region reports that 'vulnerability is not necessarily caused at all by a changing climate, rather it is found in the daily struggles over social production and reproduction'. He came to this conclusion at the end of his research which began as an attempt to understand climate change impacts on livelihoods. Then, he realised that there were socio-economic and environmental factors which were happening simultaneously, which made it irrelevant to solely attribute households' vulnerability as the results of climate change. The main social factors identified were changing social relations including the coming of colonial power, the shift to growing crops that are sold on global commodity markets, the formation and dissolution of the local coffee producers union, and the relationship between the local population and the national government. However, O'Keefe (2015) also acknowledges the role of rainfall as what he describes as environmental limits that contribute to vulnerability, in addition to other environmental factors such as land shortage.

The most comprehensive framework to explore livelihoods responses and vulnerability to climate variability and other stressors is from Paavola (2008), working in the Morogoro region, Tanzania. In his study, vulnerability was the function of exposure to climate change, as well as social and environmental structures. He showed that exposure to climate change, and existing land management practices that farmers use in response to drought and other social factors such as low levels of income and dependency on rain-fed agriculture contribute to vulnerability.

However, Paavola's (2008) study was mainly based on literature review and a small number of key informant interviews and therefore lacked detailed from field work evidence of small-holder farmers' perception of vulnerability to climate change as a result of exposure to climate change and existing social and environmental structures. Thus missing the local community perspective of vulnerability, an aspect central in the studies of practical adaptation (Smit and Wandel, 2006). This study therefore fills the research gap by exploring climate change impacts, and social and environmental structures contributing to livelihoods vulnerability and adaptation measures needed to build livelihoods resilience drawing on the experiences and perceptions of the small-holder farmers themselves as well as key informant perspectives.

2.9 The political economy of Tanzania

Just as it might be relevant to other countries, the economic history of Tanzania shows that Tanzania economy has never been smooth. The country received independence in 1961. After independence, the government of Tanzania did not undertake drastic economic reform policies and thus maintained most of the policies used during the colonial period (Bigsten and Danielsson, 1999; Moyo *et al.,* 2012; Lofchie, 2014). For example, small-scale agriculture and industry development were encouraged without new radical measures (Bigsten and Danielsson, 1999; Moyo *et al.,* 2012). The per capital income for the period 1961-1967 grew by 2% per year. The post-independence period was also characterised by microeconomic stability and low inflation (Bigsten and Danielsson, 1999; Moyo *et al.,* 2012).

In 1967 the government enacted the Arusha declaration where the government decided to take total control of the economy and banking and almost all industries were nationalised (Bigsten and Danielsson, 1999; Moyo *et al.,* 2012; Lofchie, 2014). State agencies were formed to deal with international trade and retail businesses. This period was also characterised by moving rural people to settle into different villages as a means to promote co-operative agriculture (Bigsten and Danielsson, 1999; Moyo *et al.,* 2012). The 1970s oil shock affected implementation of the Basic industry strategy developed for import substituting industries, but later the policy (Basic industry strategy) was implemented following the coffee boom of 1975-1978. The per capital income at the pre-crisis period grew at 0.7% per year (Bigsten and Danielsson, 1999).

During the period between 1979-1985 the government underwent an economic crisis following the war with the nearby country of Uganda and decline of external aid from donors as a results of dissatisfaction with government policy (Bigsten and Danielsson, 1999; Moyo *et al.,* 2012; Coulson, 2013). In 1986 the government agreed on some of the conditions identified by the IMF and World Bank Structural adjustment programme. To revive the economy, the government continued measures to improve the exchange rate and stabilise the macroeconomic systems such as improving the banking system, agriculture marketing, government administration and the civil service, and reduced control over setting the exchange rate and left it for the market to decide (Bigsten and Danielsson, 1999). Until 1996 the Tanzanian economy was growing less than 4%, but after that growth rates steadily increased until 1996 reaching above 7% before slowing down in 2009 (Moyo *et al.,* 2012).

The Tanzanian economy was negatively affected in 1980 as a result of OPEC- induced increase in the oil price, and the associated global economic recessions that caused the decline of Tanzanian commodities. Other factors that contributed to the decline of the Tanzania economy in the 1980s included the International Monetary Fund and World Bank conditions (Coulson, 2013) which cumulatively affected the Tanzanian economy. The economic problems in Tanzania were amplified by failed industrial and agriculture policies and the government's commitment to pay the debts from the loan taken out in 1970s from donor countries (Coulson, 2013). Other causes of the dwindling Tanzania economy include the unfair global market where developing countries have no opportunity to set prices for the commodities they sell in the global market and have no say on the price of imported goods (Coulson, 2013).

In 1985 Tanzania agreed on other conditions set by IMF, including currency devaluation and reducing government spending which had significant social and economic impacts. Some of the consequence include devaluation of Tanzania shillings (Coulson, 2013).

In 2005 the Tanzania economy was already growing powered by the mining sector, tourism, the export of manufactured goods to other countries in Africa and debt relief (Coulson, 2013). Tanzania has sustained relatively high economic growth over the period between 2000 to 2010, averaging 6–7% a year. The economy has been doing fairly well, and the Tanzania National Bureau of Statistics reports that real gross domestic product (GDP) growth was 7.0% in 2018, slightly higher than 6.8% in 2017. This growth has led to the recategorisation by the World Bank of Tanzania in July 2020 as a lower middle income country from its previous position a low income country. The classifications are updated each year on July 1 by the World Bank's Development Data Group using the gross national income (GNI) per capita in current US dollars of the previous year. Tanzania's GNI per capita increased from $1,020 in 2018 to $1,080 in 2019, which exceeds the 2019 threshold of $1,036 for lower-middle income status.

Thus Tanzania is currently classified as a lower-middle income country. This achievement has made the country achieve part of the Tanzania development vision (TDV) 2025, five years earlier than anticipated (World Bank, 2020). However, the country is yet to attain the desired middle income country status as described in TDV 2025, characterised by high-quality livelihoods, peace, stability and unity, good governance, a well-educated and learning society, and a competitive economy capable of sustainable growth and shared benefits.

Another impact on Tanzania's development is the role of donors. However, there is disagreement among scholars on the role of donors to poor country's development. Some views donors as having a significant role in Tanzania's economy and development assistances with donors having a normal component in state budgets for many countries in Sub-Saharan Africa, including Tanzania (Green, 2014). The major donors support government through basket funding where financial resources are pooled and then used to finance development projects pre-defined by government (Coulson, 2013). Apart from donors, there are also a number of NGOs that support government initiatives to eradicate poverty, and improve education and health services (Ojoyi *et al.* 2017). These NGOs work in projects related to schools, hospitals, health campaigns, and other social problems such as orphans, people with chronic diseases, and drug addictions (Coulson, 2013). And so the increasing foreign aid could help countries to reduce poverty (Stiglitz, 2002; Sachs, 2009).

However, some writers ascertain that foreign aid has negative impacts through increasing dependency, increasing corruption, and currency overvaluation (Moyo,2010; Easterly, 2014) and unnecessarily utilising government human resources (Bigsten and Danielsson, 1999). Furthermore, substantial amounts of donor funds and aid are said to go to people outside the aid receiving country to cover their travel costs, salaries, housing and training (Green, 2014).

There is no doubt that government and facilitation through NGOs have a role to play in development of small-holder farmers. This includes development of physical infrastrure such as roads, electricity and communication to facilitate successful farming activities (Mbando *et al.* 2015: Gramzow *et al.,* 2018). However, since the majority of small-holder farmers in Tanzania are poor there is still more work for government and NGOs to do for small-holder farmers to have improved livelihoods (Ojoyi *et al.* 2017). Areas where government and NGO support is needed is through capacity building (Andrade-piedra *et al*., 2016) in areas such as market research, supply chain analysis and book keeping (Mbando et al. 2015; Gramzow *et al.,* 2018). In addition, small-holder farmers would benefit from support in the construction of water structures such as dams and the lining up canals (Mul *et al.*, 2011) as well as support for the establishment of non-farming income in order to diversify their livelihoods (Mnimbo *et al.* 2016). In Tanzania, NGOs both national and international, together with government through extension services and extension agencies may support farmers and seed producers, distribute seed and conduct training and extension with farmers (Andrade-piedra *et al*. 2016).

2.10 The Theoretical Framework

2.10.1 Introduction

The theoretical framework used in this study is informed by two concepts; vulnerability to climate change and socio-ecological resilience. This section begins by providing various ways in which vulnerability is assessed and outlining the ways in which vulnerability is conceptualised in this study. The second part will explore different meanings of resilience, types of resilience approaches and the rationale for using the socio-ecological resilience approach in this study.

2.10.2 Vulnerability

2.10.2.1 Introduction

The literature about vulnerability to climate change is presented differently based on different epistemic perspective (Hopkins, 2015). Since climate change impacts are widespread across different systems, studies of climate change vulnerability can be found across many different academic disciplines (Hopkins, 2015). These studies are concerned with identification and understanding of what puts people and places at climate change risk and what reduces their ability to adapt to climate change (Ford *et al.*, 2018). Therefore most studies of vulnerability analysis in relation to climate change identify places, the reasons, and the ways in which human and (environmental) systems are affected by climate change (Ford *et al.*, 2018). These aspects of a vulnerability analysis framework relevant to sustainability science where this research belongs are covered below, after discussion of some other frameworks which are used for vulnerability analysis and the reasons why they were not used.

2.10.2.2 Double exposure framework

The double exposure framework, focuses on understanding vulnerability as a result of exposure to environmental change and globalisation. As described by O'Brien and Leichenko (2000, p.221), 'double exposure refers to the fact that certain regions, sectors, ecosystems and social groups will be confronted both by the impacts of climate change, and by the consequences of globalization'.

There are different ways in which globalisation can be characterised, which include reference to international trade, foreign investment, integration of global financial markets, development of global communication systems, and global food systems and preferences (O'Brien and Leichenko, 2000). These globalised systems can interact with weather-related hazards and reduce the capacity of communities to thrive (Leichenko et al., 2010), such as in the ways that small-holder farmers have been described as vulnerable to the two exposures (climate change and globalisation). Silva *et al*., (2010) used the double exposure framework to explore how small-holder farmers in Peru were vulnerable because of the promotion of market policies that promote large-scale farmers and importation of products which creates a barrier preventing small-holder farmers from benefitting from farm production and encourages migration which has further negative impacts on their livelihoods. Silva *et al.* (2010) also explored in Mozambique how as a result of climate change and globalisation leading to structural adjustment policies, this created pressure on farmers to change their farming approaches, which intensified their inability to respond to climate change (Silva *et al*., 2010). This implies that the double exposure framework, bringing together the impacts of climate change and globalisation, is relevant to the analysis of vulnerability of small-holder farmers. However, I argue that the framework is not strong in the context where there are multiple stressors which are not linked to climate change and globalisation.

2.10.2.3 Entitlement framework

Some scholar's view vulnerability as the result of a lack of entitlement. Entitlements can be defined as 'the actual or potential resources available to individuals based on their own production, assets reciprocal arrangement…. that are realised or are latent' (Adger, 2006, p. 270). In this definition, entitlement is the function of actual or potential resource availability. However, Adger *et al.*, (2003,p.754), defined entitlement as 'the set of alternative commodity bundle that a person can command in a society using the totality of rights and opportunities that he or she faces '. Sen (1981) considers the question of resources that an individual can accrue based on rights and opportunities at the disposition of an individual and how the amount of resources can define levels of vulnerability of an individual. This is because Sen believes that the legal means of accruing resources available within a society, including the production possibilities, are partly controlled by factors outside of the the household (Sen, 1981).

Entitlement can therefore be measured by the resources which are available, actual or potential that can enhance an individual's means for living. So in this context vulnerability is the result of lack of access to resources or materials (actual or potential) needed to make a living using the totality of rights and opportunities available to an individual. As Sen (1983) argued, famine can occur in the absence of food scarcity when environmental stress, and other factors such as change in wage or access to employment, combined with high food means that some members of the community are unable to access food. Therefore, people can be vulnerable to climate change not because of a lack of technologies to adapt to but because of low levels of entitlement that limits individuals to exploit available adaptation options. In the case of livelihoods, the vulnerability of livelihoods to shocks occurs 'when people have insufficient real income and wealth, and when there is a breakdown in other previously held endowment' (Adger, 2006, p. 270).

The entitlement approach is best suited to studies of vulnerability where lack of access to resources has contributed to vulnerability, rather than vulnerability from environmental stress (Adger, 2006). Although the entitlement approach presents relevant elements applicable to small-holder farmers, it is not comprehensive enough for several reasons. Firstly, as climate change impacts are happening, and the livelihoods of small-holder farmers are already being impacted, to ignore the role of climate hazards and focus on the entitlement approach alone will not comprehensively address the vulnerability of this group. Secondly, the entitlement approach explores how a lack of access to resources can contribute to vulnerability but it does not go further to understand what caused the lack of entitlement in the first place (McLaughlin and Dietz, 2008).

2.10.2.4 Political ecology framework

Another approach for vulnerability analysis is informed by political ecology as an analytical tool. Scholars informed by this perspective consider the vulnerability of the human population as 'the function of where they reside, their use of natural resources, and resources they have to cope with' (Adger, 2006, p.271). In this approach, it is considered that, 'all types of natural hazards, and all social and political upheaval have many different impacts on different groups in society which are the results of political and structural factors ' (Adger, 2006, p.271). In this approach, the existence of hazards only is not enough to explain vulnerability of a community to climate change, is the function of hazards and vulnerability of the community which arise as a result of social and economic processes across various scales of interaction (from global to local). Therefore vulnerability and the hazards are given equal weight in the analysis (Adger, 2006; Eakin and Luers, 2006). This approach has been criticised due to a lack of clearly defined vulnerability outcome, and lack of demonstrating of differential susceptibility to harm (Eakin and Luers, 2006).

2.10.2.5 Vulnerability framework in sustainability science

Another perspective of vulnerability analysis is that utilised in sustainability science. to analyse the vulnerability of social-ecological systems (Turner *et al.*, 2003). This approach seeks to elaborate the mechanisms and processes in coupled human-ecological system and represents advancement in vulnerability analysis conceptual tool (Turner *et al.*, 2003;Adger, 2006). This framework holds the notion that vulnerability resides in the condition and operation of the coupled human–environment system, including the response capacities and system feedbacks to the hazards encountered (Turner *et al.*, 2003). This approach seeks to analyse the elements of vulnerability (exposure, sensitivity and resilience) (Figure 2:12) of a bounded system at a particular spatial scale, by focusing on interactions between properties of socio-ecological system (Adger, 2006).

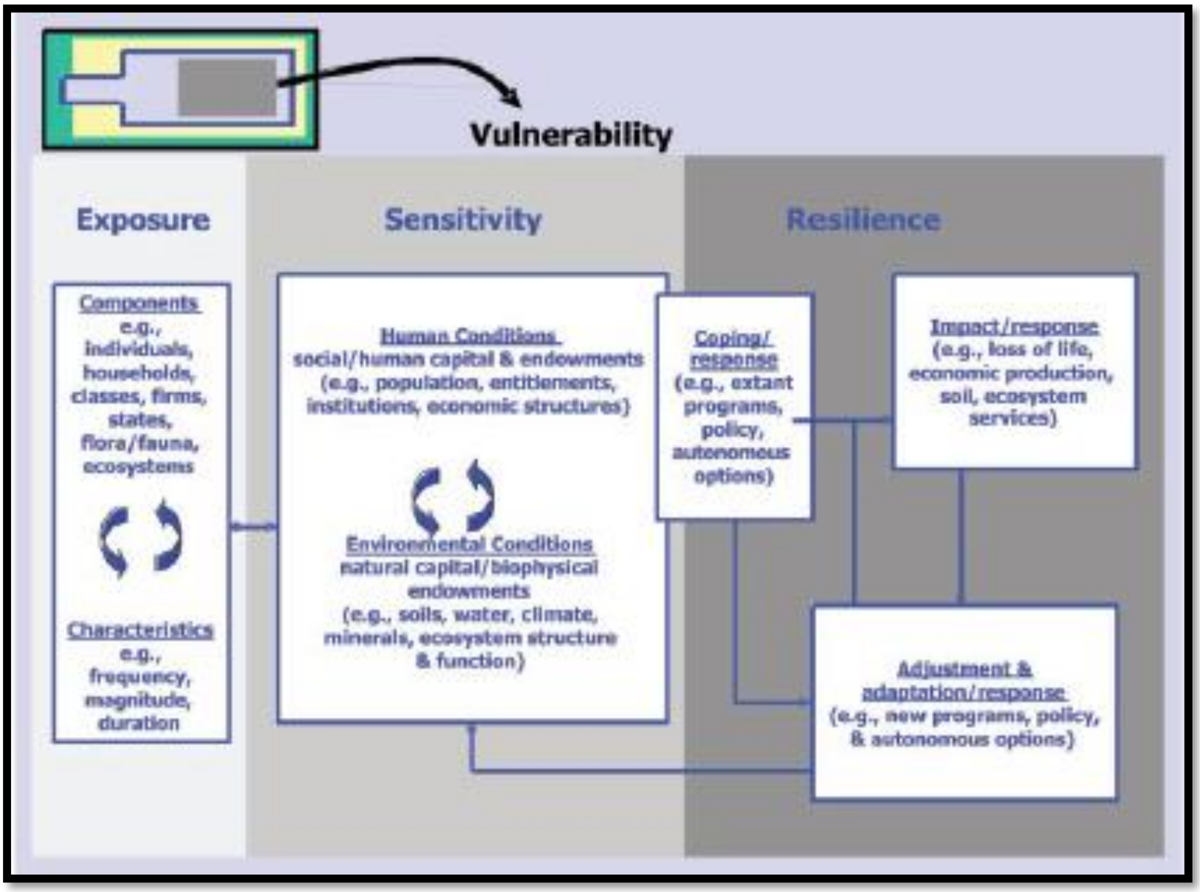

Figure 2:12 A summary of the Turner *et al.*, (2003) vulnerability framework

Source: Turner *et al.*, (2003)

Exposure describes the extent to which the individuals, households, classes, firms, states, flora/fauna, and ecosystems are affected by shocks or stress. Exposure to the hazards can be assessed based on both spatial and temporal dimensions (Pachauri *et al.*, 2014) and may involve quantitative or qualitative approaches in studying impacts (Hopkins, 2015). The dominant research methods in studying climate change impacts focuses on learning about the physical impacts of natural hazards which rely mostly on modelling and measurement techniques and neglects the human aspect in understanding impacts (Hopkins, 2015). Human perceptions, where affected communities articulate the existence of climate change impacts is crucial because this may influence affected individuals, communities, policy makers and funders to take adaptation measures (Hopkins, 2015).

Exposure components of vulnerability measure the frequency, magnitude and duration to which the study system is exposed to hazards. The hazards may include anything that can have the potential of causing impact to the system which may include droughts, floods, increased rainfall variability and temperature increase. Determining which aspect of the vulnerable system is important requires understanding the characteristics which are significant for the survival of societies or communities or the social ecological system exposed to weather-related hazards (Pachauri *et al.*, 2014). For example, societies that rely heavily on the quality of ecosystem services such as rural populations dependent on rain-fed agriculture will experience increased risk from climate change (Pachauri *et al.*, 2014). So for this population, it is significant to explore how weather-related shocks affect their livelihoods.

The second component is sensitivity which can be defined as the degree to which a system is instantly affected by a perturbation. The system's sensitivity to any hazard is determined by the conditions of the system in question. Turner *et al.* (2003) categorised two groups in which conditions of the system can be assessed - human and environmental conditions. The characteristics of both groups, human and environment, influence the capacity of the system to respond to hazards.

The human conditions are composed of social conditions necessary for survival and adaptation (Birkmann, 2006) determined by human behaviour and societal organisation (Pachauri *et al.*, 2014) and include social/human capital and endowments, institutions (ie. the role of governance) and economic structures (Turner *et al.*, 2003) such as national policies, international aid and economic globalisation (Birkmann, 2006). Environmental conditions focus on biophysical environment and include natural capital/biophysical endowments such as soils, water, climate, minerals, ecosystem structure, and function (Turner *et al.*, 2003) as well as topography and land cover (Birkmann, 2006).

The third component is the resilience of the system. The resilience component considers the coping and adaptation measures that can be implemented in order to reduce a system's vulnerability to hazards. In this framework, the resilience of the coupled system is determined by their capacity to adapt to shocks. These adaptation responses can be autonomous or planned, public or private, individual or institutional, tactical or strategic, short or long term, anticipatory or reactive (Pelling, 2011).

Coping and adaptive capacities are part of the aspects that determine system vulnerability (Pachauri *et al.*, 2014). Coping and adaptation determines vulnerability of the people exposed to the hazards because they do not have to respond to changing climate conditions only but also to multiple interacting stressors (Pachauri *et al.*, 2014). The limitation of Turner *et al's.* (2003) framework lies in the ability to make full assessment of vulnerability based on the complexity of factors, processes, and feedback operating within even relatively simple coupled human-environment systems (Turner *et al.*, 2003).

This study used the Turner *et al.* (2003) vulnerability framework to explore the extent to which small-holder farmers are vulnerable to the impacts of climate change and climate variability, so that, adaptation can be tailored to enable small-holder farmers in the Kilimanjaro region to adapt to the impact of climate variability and build resilience to projected climate change.

2.10.3 Socio-ecological resilience

The concept of resilience is popular in a variety of academic disciplines, and government and non-governmental organisations interested in understanding interactions between people and nature (Carpenter *et al*., 2001). This is one of the major conceptual tools to analyse change and is applicable at varied spatial scales, from local to national to global (Berkes and Ross, 2013). Regardless of the popularity of the concept, its meaning is far from undisputed across academic scholarship. Like other approaches in sustainability science, resilience studies are fundamentally problem driven, and integrate a variety of disciplinary approaches and perspectives to help to address the considerable sustainability challenges facing society (Biggs *et al.,* 2015). Understandings of resilience can be differentiated based on the meaning attached to the term as well as the system where it has been applied Table 2:6. Based on the system to which the framework is applied, there are many types of resilience, including engineering resilience (Pimm, 1984), urban resilience (Vale and Campanella, 2005; Gunderson, 2010), ecological resilience (Folke, 2006; Cretney, 2014), social resilience (Adger, 2000), development resilience (Barrett and Constas, 2014), socio-economic resilience (Mancini *et al.*, 2012), community resilience (Norris *et al.*, 2008), psychological resilience (Tugade *et al.*, 2004) and socio-ecological resilience (Biggs *et al.*, 2012;2015). Regardless of the system or discipline applied, resilience can be defined based on whether the system is capable of absorbing disturbances and or returning to its original state following disturbance (Deppisch and Hasibovic, 2013).

Resilience measures the capacity of a system to respond to a disturbance. A resilient system can be explained by its ability to absorb disturbances, or the magnitude of perturbations which a system can handle before it changes its characteristics, or the speed in which a system can recover to its original conditions after disturbance (Adger, 2000; Carpenter *et al.*, 2001; Cretney, 2014; Quinlan *et al*., 2016; Eisenhauer, 2016; Marchese *et al.*, 2018).

Table 2:6 Summary of resilience definitions in different domains

Type of resilience	Meaning	Emphasize
Engineering resilience	System's speed of return to equilibrium following a shock	Return time to recover, efficiency, equilibrium
Ecological resilience	Ability of a system to withstand shock and maintain critical relationships and functions	Buffer capacity, withstand shock, persistence, robustness
Social resilience	Ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change	Social dimensions, heuristic device
Development resilience	Capacity of a person, household or other aggregate unit to avoid poverty in the face of various stressors and in the wake of myriad shocks over time	Vulnerability, robustness
Socio-economic resilience	Socio-economic resilience refers to the policy induced ability of an economy to recover from or adjust to the negative impacts of adverse exogenous shocks and to benefit from positive shocks	Economic response capacity
Community resilience	A process linking a set of adaptive capacities to a positive trajectory of functioning and adaptation after a disturbance	Adaptive capacity, disturbance, social
Psychological resilience	An individual's ability to adapt to stress and adversity. Resilience is a process and can be learned by anyone using positive emotions	Coping, adaptation, process
Social-ecological resilience	Amount of disturbance a system can absorb and remain within a domain of attraction; (ii) capacity for learning and adaptation (iii) degree to which the system is capable of self-organizing	Adaptive capacity, learning, innovation

Source: -Quinlan *et al.*, 2016,p.678

This research uses a socio-ecological resilience framework because it not only marries the interest of this research, that broadly look at how livelihoods can be maintained in the face of climate change, but also the livelihoods of small-holder farmers that have both the social aims of improving household well-being as well as improving the use of the natural resource base (Rosset, 2000; Samberg *et al.*, 2016).

There are several principles fundamental to the socio-ecological resilience frameworks, one of which is the 'basin of attraction'. Walker et al., (2004) describes the concept of the 'basin of attraction' as the region in which a system tends to remain based on the nature of the variables that make up the system. For example, for the case of small-holder farmers' livelihoods, the basin of attraction will mean the region where the livelihoods tend to remain, based on the nature of livelihoods assets, and existing structures influencing the way farmers make their living. The combination of these variables (the quality and number of assets, the role of institutions etc) that make the system remain in its equilibrium state create a zone that is called an 'attractor'.

The basin of attraction will constitute all initial conditions that will tend toward that equilibrium state to create an attractor. Human actions and decisions may change the condition of socio-ecological systems (SES) to move toward the basin of attraction, and there may be more than one basin of attraction which all together make a stability landscape. The nature of the basin of attraction with its stability landscape determines the capacity of the system to maintain its structures under perturbations. As shown in Figure 2:13 the nature of variables making up the system will also determine the latitude (L) which is the maximum amount a system can be changed before losing its ability to recover, the resistance (R)) which is the ease or difficulty of changing the system, and its precariousness (Pr) how close the current state of the system is to a limit or “threshold.” The depth topography if a basin is a measure of how difficult it is to move the system around within the basin - steep sides imply greater perturbations or management efforts are needed to change the state of the system (Walker, *et al.,* 2004).

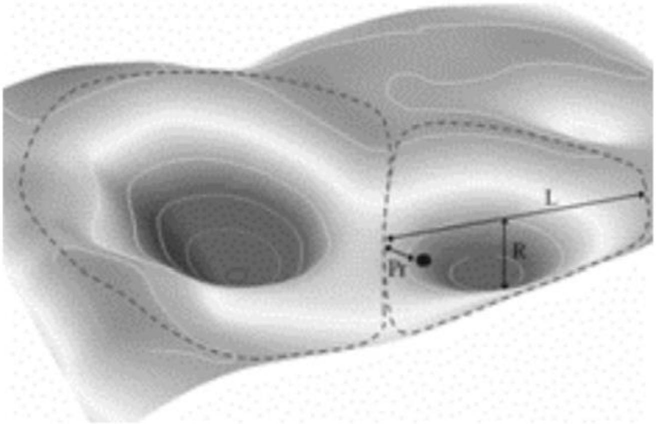

Figure 2:13 Three-dimensional stability landscape with two basins of attraction showing, in one basin, the current position of the system and three aspects of resilience, L = latitude, R = resistance, Pr = precariousness are shown.

Source: Walker *et al*., (2004)

As shown in Figure 2:14 socio-ecological resilience is about the integration of ecosystems and people within an integrated social-ecological systems in which social systems and ecosystems are recognised as coupled, interdependent, and co-evolving which makes them more than the sum of their parts (Berkes and Ross, 2013; Biggs *et al.,* 2015).

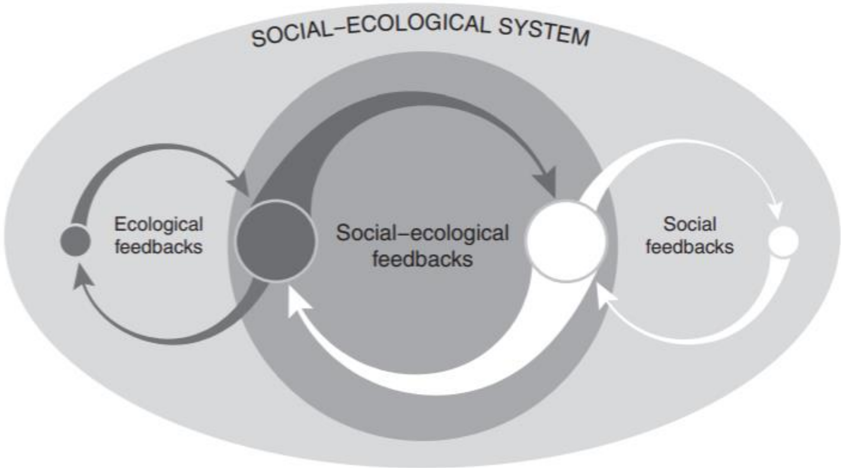

Figure 2:14 In the resilience approach, SES are not simply seen as social plus ecological systems. Rather they are viewed as systems centred on the feedbacks between ecological (grey) and social (white) system components, which lie at the interface of social and ecological systems.

Source: Biggs *et al.,* (2015)

There is a distinction between resilience as an approach and set of assumptions for analysing, understanding and managing change in socio-ecological systems, and resilience as the property of the socio-ecological system (Deppisch and Hasibovic, 2013; Biggs, *et al.,* 2015) 'Resilience as an approach' focuses on principles that build the capacity of socio-ecological systems to continue providing key ecosystem services that underpin human well-being in the face of unexpected shocks and gradual, ongoing change (Biggs, *et al.,* 2012; 2015). Ecosystem services are defined as goods and services provided by ecosystems (Locatelli *et al.*, 2008: Biggs *et al.,* 2012;2015). These services include *provisional services* such as food and wood, *regulating services* such regulation of water, climate or erosion, *cultural services* such recreational, spiritual or religious services and *supporting services* which support production of other services such as nutrient cycling and soil formation (Locatelli *et al.*, 2008; Biggs *et al.,* 2015).

Biggs *et al.* (2015) identified seven principles essential for building resilient socio-ecological systems. These principles are explained briefly as follows. The first principle is 'to maintain diversity and redundancy'. Diversity involves the provision of different options for responding to change. Diversity is achieved by ensuring variety (the number of different elements), balance (the number of representatives of each element) and disparity (how different the elements are from one another). Redundancy describes the replication of elements as a means of risk management in the system by allowing some system elements to compensate for the loss or failure of others. For example, growing more than one crop on the farm, to compensate in case one fails.

The second principle is 'to manage connectivity'. This focuses on 'the way in which parts of an SES (i.e. entities that have similar features such as species, landscape patches, individuals, organizations and so forth) interact with each other (i.e. exchange information, transfer material, transform energy' (Biggs *et al.,* 2015, p.81). The third principle is 'to manage slow variables and feedbacks'. Biggs *et al*., (2015) describes slow variables as the variables that change much more gradually than other 'fast' variables. They give an example of provisioning ecosystem services such as crop production and changes in quality of freshwater usually representing fast variables because changes are easier to notice in these variables, unlike slow variables which take time for changes to be noticed, such as soil chemical composition as partly influenced by land management practices (Biggs *et al*., 2015).

The fourth principle is 'to foster complex adaptive system (CAS) thinking'. CAS thinking seek to appreciate the interconnectivity of variables in the systems under the premise that a system is made up of many interacting components that are individually and collectively adaptive to change. Therefore, the intention of the CAS approach is to build the resilience of ecosystem services by emphasizing holistic rather than reductionist approaches that pay attention to just one part of the system.

The fifth principle is ‘to encourage learning and experimentation’. Learning can be promoted through a variety of approaches, including experimentation and monitoring, knowledge co-production, and collaboration. The sixth principle is ‘to broaden participation’. This can be achieved by actively involving relevant stakeholders in the management and governance process. The seventh principle is ‘to promote polycentric governance systems’. This principle emphasises the multiple interacting governing bodies at different spatial scales, and that power and authority can deliberately empower the governing bodies at different spatial scales to make and enforce rules within a specific policy arena (Biggs *et al.,* 2012;2015).

However, the use of resilience as a concept in studies of climate change adaptation particularly for poor people has been criticised. This is because of the complex nature of adaptation that requires a holistic approach that understands adaptation not as an exclusive environmental issue but also a question of politics and justice (Tanner *et al*., 2015). When climate change is viewed as an environmental problem, the adaptation measures proposed mostly focus on managerial and technical measures, while when perceived as a combination of environmental and politics and justice issues that appreciate the existence of marginalised and poor people who have a low capacity to adapt, this calls for the nation state’s government’s responsibility to address the problem alongside more localised adaptation measures (Tanner *et al.,* 2015). Furthermore, a resilience lens which focuses more on ecosystems may also emphasise how climate change affects just the ecosystems and may lose sight of how people inhabiting them are affected (Tanner *et al*., 2015).

2.10.4 Livelihoods frameworks

Some of the challenge of using the socio-ecological resilience framework can be addressed when resilience thinking is combined with a livelihoods approach to form livelihood resilience. Livelihood resilience is defined as 'the capacity of all people across generations to sustain and improve their livelihood opportunities and well-being despite environmental, economic, social and political disturbances' (Tanner *et al.,* 2015, p. 3). Although this approach considers inter-generational equity, and multiple sources of stressors that can affect livelihoods, it narrows down the objective of improving livelihoods into just one goal, improving well-being. While in reality, as described by DFID (1999) especially in the context of poor people, livelihoods outcomes include not only increased wellbeing, but also greater income, reduced vulnerability, improved food security, and more sustainable use of the natural resource base. From this reality, the ideal livelihoods resilience definition as used in this project is the capacity of all people across generations to achieve the desired levels of livelihood outcomes despite environmental, economic, social and political disturbances.

The livelihoods framework is generally effective in exploring what constitutes the livelihoods of the poor and how it can be achieved (Reed et al., 2013; Tanner et al., 2015). The livelihoods framework seeks to understand the livelihoods central to individual's and community's life and factors that influence their survival. The livelihoods framework puts people at the centre and ensures access to assets (financial, human, social natural and physical) which build the livelihoods (Reed *et al.,* 2013). These assets can be affected by climate change through extreme events such as floods and reduce capacity to make a living and future capacity to deal with stress (Reed *et al.,* 2013). The livelihoods framework appreciates the existence of multiple stressors that can affect livelihoods; such as shocks, seasonality, and economic or resource trends (Reed *et al.,* 2013), which highlights the importance of understanding multiple stressors that affect livelihoods. This framework also considers livelihoods diversification as a risk management strategy and the role of institutions, structures and processes in shaping peoples' livelihoods (Ellis, 2000).

Structures are the public and private sector organizations that set and implement policy and legislation. Processes embrace the laws, regulations, policies, operational arrangements, agreements, societal norms, and practices that, in turn, determine the way in which structures operate. One of the main problems the poor and vulnerable face are the processes which frame their livelihoods and may systematically restrict them unless the government adopts pro-poor policies that, in turn, filter down to legislation and even less formal processes (Serrat, 2017). Understanding of how structure and processes affect people's livelihoods is essential as adaptation offers opportunities for the government to implement existing rights and responsibilities to build resilience (Pelling, 2011).

Another important concept in the livelihood framework is the livelihood outcome. This is the end product or the goal of livelihoods which constitutes more income, increased well-being, reduced vulnerability, improved food security, more sustainable use of the natural resource base, and recovered human dignity, between which there may again also be conflict (Serrat, 2017). These livelihood outcomes show that livelihoods are performed for several reasons, and therefore measures to improve livelihoods resilience should put this into consideration.

Livelihoods resilience requires human actions that focus on empowerment, rather than viewing human actors as passive unable to take action, although not all individuals can take actions equally. This approach requires individuals being impacted as well as other relevant stakeholders to take actions that can help to address the problem, and places an obligation on governments to take action to promote the attainment of basic human rights such as food, secure shelter, property, and health (Tanner *et al.,* 2015) to their people. Livelihoods resilience therefore highlights the role of human agency, and our individual and collective capacity to respond to stressors.

2.10.5 Theoretical framework summary

This project utilises the lessons from socio-ecological resilience in combination with livelihoods resilience to understand how to build small-holder farmers' livelihoods resilience to climate variability and change. In this study I draw from socio-ecological resilience and livelihoods resilience scholarship as analytical tools, as small-holder farming livelihoods are underpinned by social aims such as improvement of well-being as well as environmental aims such as the sustainable practice of agriculture, and the fact that there are many actors at various scales with an influence on these farmers. The livelihoods resilience framework helps to put issues in the context of poor people, by putting poor people at the centre, to understand how they are affected by climate variability, what they need to change to reduce vulnerability to climate change and what government needs to do to help farmers adapt especially relating to the issues far from the farmers' capacity to deal with them.

Since this research is situated in the field of sustainability science, it is important to examine the relationship between sustainability science and resilience. The relationship can take different forms. Derissen *et al.,* (2011) described various relationships that resilience and sustainability can take. In some contexts, resilience of the system is necessary but not sufficient for sustainability, or it may be sufficient but not necessary for sustainability, it may be neither necessary nor sufficient for sustainability, and it can be both necessary and sufficient for sustainability. Awareness of these relationship is essential so to help researchers and other stakeholders focus on measures that do not jeopardise sustainability.

2.11 Conclusion

Climate change adaptation is essential as the impacts of climate change are already being felt in human and environmental systems around the world. Developing adaptation approaches helps communities to become more resilient to the effects of climate change Wilson, 2014; Eisenhauer, 2016). Understanding livelihoods vulnerability to climate change is needed to inform adaptation options. As described by (Turner *et al.*, 2003), vulnerability is the function of three concepts: hazard, sensitivity and resilience. Climate change hazards can be in the form of increased temperature, increased rainfall variability and extreme weather events. Climate change can impact small-holder farmer livelihoods particularly in reducing agricultural productivity, or through affecting livelihoods assets which are essential for poor farmers.

For a hazard to affect any system including livelihoods, it depends on the sensitivity of the system to the hazard, such as climate change. The framework by Turner *et al.* (2003) highlights the significance of exposure, human (social aspects) and environmental systems such as natural capital in increasing sensitivity to climate change. So understanding exposure and sensitivity of the livelihoods to climate change will help identify areas adjustments need to made in order to build livelihoods resilient to climate change which are not covered in detail in most livelihoods adaptation literature especially in Tanzania.

3 Methodology

3.1 Introduction

This chapter examines the theoretical underpinnings of the research and the procedures adopted for collection and analysis of the data. This discussion has been divided into ontological and epistemological considerations, research design and research methods, and ethical considerations.

3.2 Epistemological and ontological consideration

The philosophies that guide research can be broadly categorized into two: ontology which focuses on approaches to generate knowledge; and epistemology which focuses on what is the nature of truth or the knowledge. Ontology specifies what it is possible to know, 'the reality that exists and how it does so' (Martin and Huckle, 2001,p.25). Ontology is concerned with the nature of social entities, 'whether they should be considered objective entities that have reality external to social actors or whether they can and should be considered social constructions built up from the perceptions and actions of social actors' (Bryman, 2016, p.28).

Epistemology focuses on what is worth knowing. 'It specifies how that reality can be known by specifying the criteria for judging the truth of a statement' (Martin and Huckle, 2001,p.25). Bryman, (2016,p.24) defines epistemological issues 'as the question of what is (or should be) regarded as acceptable knowledge in a discipline'. The epistemology and ontology that underpin this research is rooted in critical realism (CR). CR presents the perspectives that guide a certain way of understanding what is reality or truth and how it can be arrived at. In order to understand the CR, I shall compare it with other two dominating perspectives, empirical realism and social constructivism.

Empirical realists believe that knowledge is based in experience and supported by verifiable evidence, therefore science is based on only what is empirically experienced (Bryman, 2016: Danermark, *et al.,*2019: Hoddy, 2019). So what exist are experiences supported by well-established regularities and connections (Danermark, *et al.,* 2019). The perspective seeks to conduct research in an objective way, and therefore does not influence the information gathered from the research. In order to find the what the truth is, they think the researcher has to stay as far away from the research as they can, so that they can get an objective measurement (Bryman, 2016).

Social constructivism on the other hand argue that, social reality such as people and their institutions must be studies using methods other than those used for studying the natural world (Bryman, 2016; Danermark, *et al.,*2019; Hoddy, 2019). So knowledge about society must be based on understanding, something that can only be accessed through interpretation, the insight not achieved natural science methods, because people and societies have characteristics that natural world do not have (Bryman, 2016: Danermark, *et al.,*2019: Hoddy, 2019). Based on this difference, social constructivists believe that knowledge is created subjectively in a world of meanings created by individuals and therefore what exist is that which perceive to exist (Bryman, 2016: Danermark, *et al.,*2019: Hoddy, 2019). The epistemology in this perspective says we have no single reality, so we have to interpret the reality from the context because the reality is context specific, and every context may have different reality (Bryman, 2016: Danermark, *et al.,*2019: Hoddy, 2019). The perspective thus emphasises getting the information from the context as means of understanding reality. So social constructivism believes on the multiple versions of reality because it is context specific, based on the meaning attached to truth. Thus requiring researchers to get into the societies to understand the reality from the context.

Epistemologically, the critical realists believe reality transcend what can be justified by observation alone (Bryman, 2016: Danermark, *et al.,*2019: Hoddy, 2019). Understanding reality on experience level alone does not take into 'account deep structure with its underlying mechanisms, and thus restricts our understanding of the world' (Danermark, *et al.,* 2019,p.9). What is observable can represent one level of reality but it may not necessarily represent every truth about the observable, and thus limiting our capacity to generate more knowledge. CR believe that there exist causal factors causing events to occur, referred to as 'generative mechanisms'. Generative mechanisms are defined as 'the entities and processes that are constitutive of the phenomenon of interest, although not directly observable but provided their effects are observable' (Bryman, 2016,p.25). The significance of capturing the 'generative mechanism' is to provide an opportunity to understand where adjustments need to be done in order to change an undesired situation (Huckle, 2019). As Bryman, (2016,p.25) states 'we will only be able to understand and change the social world if we identify the structures at work that generate those events and discourse'.

Ontological considerations in this approach hold that reality is broken into three main level (Danermark, *et al.,*2019: Hoddy, 2019). The 'real' which is made up of the natural and social objects, structures and their mechanisms; the 'actual' comprises events that happen when a generative mechanism is activated; and the 'empirical' reality which refers to our perceptions and experience of the events happening when a generative mechanism is in process (Danermark, *et al.,*2019: Hoddy, 2019) . The ability to access the reality decreases as you move from the empirical, actual to real realities (Hoddy, 2019). This means that, there many levels of truth and researchers have varying capacities to access them (Zachariadis, *et al.,* 2013). Researchers following a critical realist approach are interested more in the third level of reality, the 'real', even though it may not be observable (Houston, 2010).

The comparison between CR and empirical realists' ontology shows that, there is understood to be a reality that exists, but the earlier understand three domains of reality while the later believe about only one reality that is empirical reality (Danermark, *et al.,* 2019).On the other hand, while social constructivism understand reality to be socially constructed, a critical realist ontology is similar to positivist ontology in that there is understood to be a reality that exists independent from human understanding of it (Danermark, *et al.,* 2019).

The reasoning approach in critical realism which is used to identify the causal (generative) mechanism is neither inductive nor deductive (Bryman, 2016).'Deductive approach researchers seek to draw on what is known about in a particular domain and relevant theoretical ideas in order to deduce hypotheses that must then be subject to empirical scrutiny' (Bryman, 2016,p.21). For example, the researcher, following this perspective, uses established theory to establish the relationship between variables, and then conduct research to empirically test the theory (Danermark, *et al.,* 2019).On the 'Inductive approaches involve the researcher inferring the implications of his or her observations to the theory' (Bryman, 2016,p.21). In this approach, the 'research begins by unprejudiced observation of reality without being bound by specific theory, then develops concepts from the data itself' (Danermark*, et al.,* 2019,p.102).

The critical realism approach uses neither a deductive or inductive approach, a reasoning method called 'retroductive' (Bryman, 2016) where the researcher begins with the experienced results of something, such as a social problem, and then works backwards in an attempt to explain the cause of the problem, or what must have caused it to happen. The retroductive approach involves abstracting from empirical data to understand what makes the phenomenon what they are whilst drawing on insights from pre-existing knowledge and experiences of the same phenomenon elsewhere (Hoddy, 2019: Danermark, et al., 2019). This may involves questions like what constitute rituals, social solidarity, or what make occurrence of certain events possible by uncovering certain structures and mechanism that make them up (Danermark, *et al.,* 2019).

Critical realism avoids the conflict about studying social entities using methods in social science by taking some elements from positivism and constructivism (Hoddy, 2019) to guide understanding of the world, making it relevant to mixed methods studies such as this. The strength of the approach is in its ability to develop novel methodologies that empirically guide researchers to understand causal factors that result in the occurrence of events over a variety of social phenomena (Hoddy, 2019) making it 'the most appropriate philosophy for studying issues around nature and society and realise the more sustainable form of development'(Martin and Huckle, 2001,p.25).

3.3 Research Design

Having explained the theoretical background for this research, in this section I examine the practicalities of the research design. The section begins by explaining the use of case study research, the types of case study research and the type used in this project, and the reasons for selecting small-holder farmers in the Kilimanjaro region of Tanzania.

3.3.1 Case study approach

This research adopted a case study research design. The research design logically guides the whole research-process from the stage of determining the research questions to the stage of deriving the study conclusions. Before I go further to explain the rationale for using the case study approach and the specific type of case study used in this research, I will first define what a case study research approach is.

There are many definitions of case study research, some focusing on describing the size of the case study unit chosen for investigation, while others describe what is investigated, the level of investigation and where the investigation takes place. For instance, Silverman (2014) defines case study research as a research approach that selects one unit amongst others for investigation. For example, investigation about childhood, may use a single child, a classroom or clinic or a charity concerned with the welfare of children as a case. This definition does not cover the complexity of case study research assuming a simplicity to the selection of the case study unit.

A case study is defined as *'*an empirical study that investigates a contemporary phenomenon in depth and within its real life context especially when the boundaries between phenomenon contexts are not clearly evident' *(*Yin, 2013, p.18). This definition highlights the nature of the phenomenon investigated (the contemporary phenomenon), the details of investigation (in depth), and where the investigation should be done (the context). However, it does not say whether the whole population of a phenomenon is investigated or just part of it. Therefore, I have constructed my own definition of case study research as used in this study based on the two above definitions. This is an empirical study that investigates a contemporary phenomenon in depth and within its real life context by choosing part of (a) case(s) among others for investigation.

To some people, case study research can be contrasted based on the paradigm orientation of the researchers particularly between positivism on the one side and naturalism on the other in terms of epistemological considerations, and interpretivism or constructivism in regards to ontological considerations (Gomm, *et al.,* 2000). A series of methodological issues arise from these different points of view about the purpose and nature of case study research, and these haves been subject to debate around issues on generalizability and the nature of theory. It is sometimes argued that the aim of case study research should be to capture cases in their uniqueness, rather than to use them as a basis for wider generalisation or for theoretical inferences of some kind (Gomm, *et al.,* 2000).

As prediction is frequently taken to be an aim of science (Gomm, *et al.,* 2000) many scientists believe that the end result of scientific inquiry is to establish generalisation and if that cannot be achieved, they doubt the reason for conducting the research in the first place. To such researchers, if generalisation cannot be achieved, then what is available is knowledge of the particular, leading to questioning of the value of knowing the unique (Gomm, *et al.,* 2000). The inability to generalise from case study research stems from the common definition of the concept 'generalisation'. Generalisation is defined as 'assertions of enduring value that are context free' (Gomm, *et al.,* 2000,p.27).This means that, generalisations made from the research are supposed to be unbounded by spatial differences. However, I argue that, case study research helps to understand social processes, and since behaviour varies in different contexts, we need to understand how any one setting may be different from others (Silverman, 2017).

There are many approaches used to classify case study research based on its design. Some writers divide case study research into two major categories, holistic and embedded studies (Rowley, 2002;Scholz *et al.*, 2006). 'Holistic case studies examine the case as one unit … and embedded designs identify a number of sub units (within a single context) each of which is explored individually'(Rowley, 2002,p.20). The embedded case study is used to capture changes in the unit of analysis rather than assuming uniformity in the case under study (Rowley, 2002).

However, Yin (2014) simplifies the complex typologies of case study design into two main groups; single case design and multiple case designs. Single case designs are subdivided further into two types, holistic and embedded designs, and multiple case design categorised into multiple cases within multiple contexts, and multiple cases with multiple units of analysis within multiple contexts.

3.3.2 The case study as used in this research

This study is the case study of small-holder farmer adaptation to climate change in, Tanzania. Small-holder farmers are found in almost every region in Tanzania. However, the small-holder farmers in Kilimanjaro region was chosen not because they are extreme or unusual compared to other regions, but because they represent a less researched region, as most studies about small-holder farmers' livelihoods and climate change in Tanzania have been dominated by regions in arid and semi-arid areas. And some have concluded that, climate change is the Kilimanjaro region, do not present a significant threat to farmers' livelihoods, compared to other stressors such as existing social relations (O'Keefe, 2015). The results from this region will provide information about livelihoods exposure and sensitivity to climate change in this region as well as measures that can be taken to adapt to climate change to build livelihood resilience. The result from this region are not expected to be generalised to other region in Tanzania. Another reason for choosing this region is accessibility in terms of the ability to easily access the villages in these remote areas, as well as the ability of the researcher to understand the native language in case the respondents could not speak the national language (Swahili), and familiarity of the researcher as I grow up in this region given me additional 'insider' background context.

3.4 Details of the Kilimanjaro region case

Before giving a detailed description of the units embed in this case (as found in the Kilimanjaro region), I describe the general conditions that surround small-holder farmers in the Kilimanjaro region. This discussion focuses around issues relating to small-holder farmer's livelihoods in the region as described in the regional socio-economic profile (2014) unless otherwise cited. The socio-economic profile (2014) data includes data on sources of livelihoods, socio-economic infrastructure, irrigation, crop storage, land scarcity and financial services.

Apart from agriculture, other important sources of income in the region include manufacturing and trading activities, tourism services, carpentry (Bee, 2009) and remittances (Meena and O' Keefe, 2007). Meena and O'Keefe (2007) reported that remittances contributed 17% of sources of income in the Kilimanjaro region, surpassed only by banana production which accounted for 28 percent of income and other off-farm activities, which contributed to 27 percent of family sources of income. Other sources of income include coffee, milk sales and livestock sales, which contributed 15%, 7% and 4% respectively (Meena and O'Keefe, 2007). However, the region is yet self-sufficient in food production. This is because agriculture is facing many constraints, including depletion of soil fertility, inadequate extension services, failure by small-holder farmers to use high yielding seed varieties, improper crop husbandry, and adverse weather condition.

Socio-economic development can be facilitated and accelerated by the presence of socio-economic infrastructures (Familon, undated). According to Familon, these infrastructures provide the basic foundation on which superstructures of development and growth can be erected. When compared to other rural areas in Tanzania, economic infrastructure in the Kilimanjaro region is generally good and adequately serves population clusters in the region (Bee, 2009). Moreover, the residents of the Kilimanjaro region have relatively greater access to social services and utilities, such as water, health services and education when compared to other regions in the country (URT, 2002). Although other Tanzanians regard people in Kilimanjaro as a relatively wealthy group because of their natural resource endowment and entrepreneurial activities, there is still real poverty and recurrent food insecurity. In Kilimanjaro region, women have lost control of the resources that were traditionally their income, particularly food crops. Timber products, coffee, honey and livestock were male income products but, with a collapse in the value of these products, men have moved into controlling products that were traditionally in the women's realm (O'Brien, 2008).

Kilimanjaro region has a long experience of irrigation. People in this region have practiced irrigation for more than 150 years. The traditional irrigation systems include canals (*mifongo*) and small scale dams. The main sources of irrigation water are river water, underground water and dams. However, by 2009/2010 only 39.9% of potential irrigation area was utilized. By 2012 it was estimated that there were 454 irrigation schemes in the region. The area under traditional irrigation was 31,139 hectares while the potential area for traditional irrigation was 92,949. The area potential for modernized irrigation in the region is 54,417 hectares of which only 8,630 hectares have been utilized (Kilimanjaro region socio-economic profile, 2014).

There are both traditional and improved storage facilities in the region. The most popular at the household level are metal or plastic containers, pantries (vihenge), pots, gourds, sacks and ceilings. Most of the storage facilities available at the household levels are small, catering mainly for household use only. Storage facilities for horticulture are inadequate. As a result, farmers are forced to sell their crops once harvested or use local preservation methods such as smoking, salting and drying.

There are formal, semi-formal and informal financial institutions in the region. The formal financial institutions include commercial banks, community banks, and non-bank financial institutions. Semi-formal financial institutions include Savings and Credit Co-Operatives Societies (SACCOS), Savings and Credit Associations (SACAs) and non-governmental financial organizations. There are also numerous types of informal financial institutions in the region such as Rotating Savings and Credit Associations (ROSCASs), Village Community Banks (VIKOBA) and money lenders. By 2012, the region had 27 banks of which 23 were commercial bank branches, three community banks (two were branches) and one co-operative bank. About more than half (59.3%) of all banks in the region are located in the Moshi urban Figure 3:1. During the same period the region had 221 SACCOS of which 51.6% were in the Moshi Municipality. This shows that, most of the formal and non-formal financial institutions are in urban areas and therefore far from small-holder farmers making them hard to access for these groups.

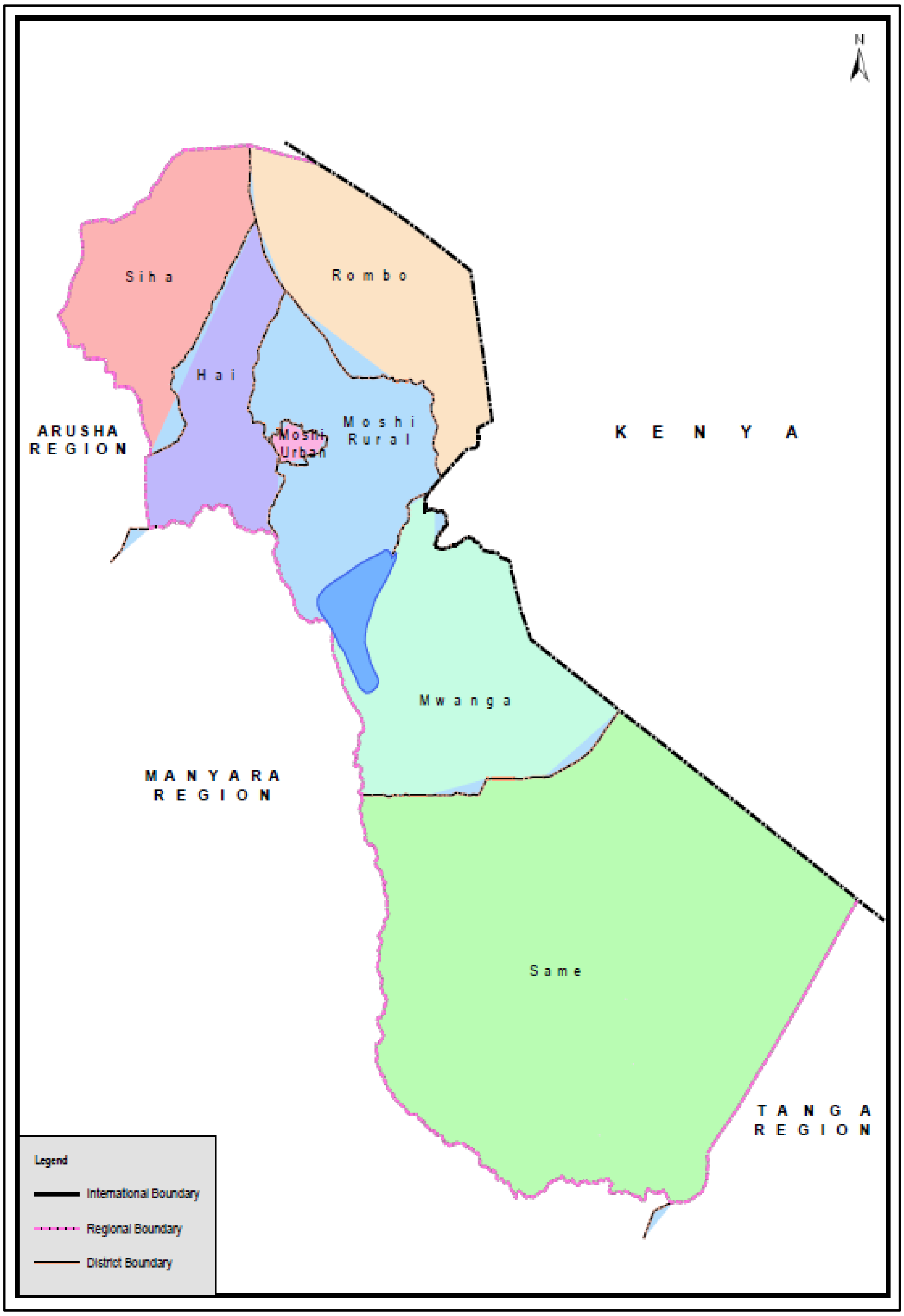

Figure 3:1 The map of Kilimanjaro region

Source: Kilimanjaro region socio-economic profile, 2014

Holler described four factors that contribute to the vulnerability of livelihoods in Kilimanjaro region. These include climate change, land and forest degradation, economic changes associated with structural adjustment and globalization, and natural population increase.

Climate change affects livelihoods in many ways. The reduction in annual precipitation reduces water flows in rivers in the mountains (Holler, 2014) which is the main source of surface water for livelihoods in the region. Climate change is also blamed for contributing to the disappearance of glaciers on Mount Kilimanjaro and reducing water volumes in the rivers (Soini, 2005). Water stress in this region is high during the dry months (June to August) when irrigation sustains crops until the short rains arrive in October (Holler, 2014). However, Soini, (2005) reports that, not only climate change has contributed to a reduction in water volumes in surface water sources, but farmers' themselves have partly contributed, particularly by changing the indigenous trees to exotic species in home garden areas and due to cultivation near the river banks.

Natural population increase in this area is not proportional to available land for cultivation (Soini, 2005;Holler, 2014). Kilimanjaro is the third most highly populated region in Tanzania, after Dar es Salaam and Mwanza. Given its small area, the region faces high levels of land scarcity. Farms have become so small that this now challenges their ability to sustain family needs (Soini, 2005). Within just a ten-year period between the 2002 and 2012 census, there was a 19% increase in population density with a population density increase from 104 to 124 people per square kilometre. Within the region the highest population density is in the highland zone.

One of the adaptation strategies to cope with land scarcity is migration, especially youth migration, which works for some but not for others (Mbonile, 2004). Successful migrants find good jobs or engage in entrepreneurial activities that help them to development themselves and send back remittances (Holler, 2014). Challenges to small-holder farmers in the region have been accentuated by the structural adjustment program[3] and globalization trends which have in particular had a significant impact on the coffee industry (Holler, 2014) which was the main source income for many farmers in the Kilimanjaro region.

3.4.1 Embedded units of analysis

This study utilises an embedded case study design, with the units of analysis the three separate agro-ecological zones - the Highland, Midland and Lowland zones. Based on altitude and amount of rainfall, the Kilimanjaro region is categorised into three agro-ecological zones where small-holder farmers are located. The fourth zone in the region is formed by the Kilimanjaro mountain peak and the forest reserve and no farming activities take place in this area Figure 3:2. There are two primary reasons for using an embedded case study design: 1) small-holder farmers in the Kilimanjaro region can be found in the highland, midland and lowland zones; 2), these zones have different environmental characteristics and therefore peoples' experiences of climate change impacts and coping strategies may be different, therefore given a greater understanding of the issues across the whole of the Kilimanjaro region.

[3] In 1980s the government of Tanzania was given conditions by the World bank and IMF to remove subsidies from farmers which were used to support farmer's agriculture productivity as a means to revive their economy which was dwindling (Hepelwa, *et al.,* 2013).

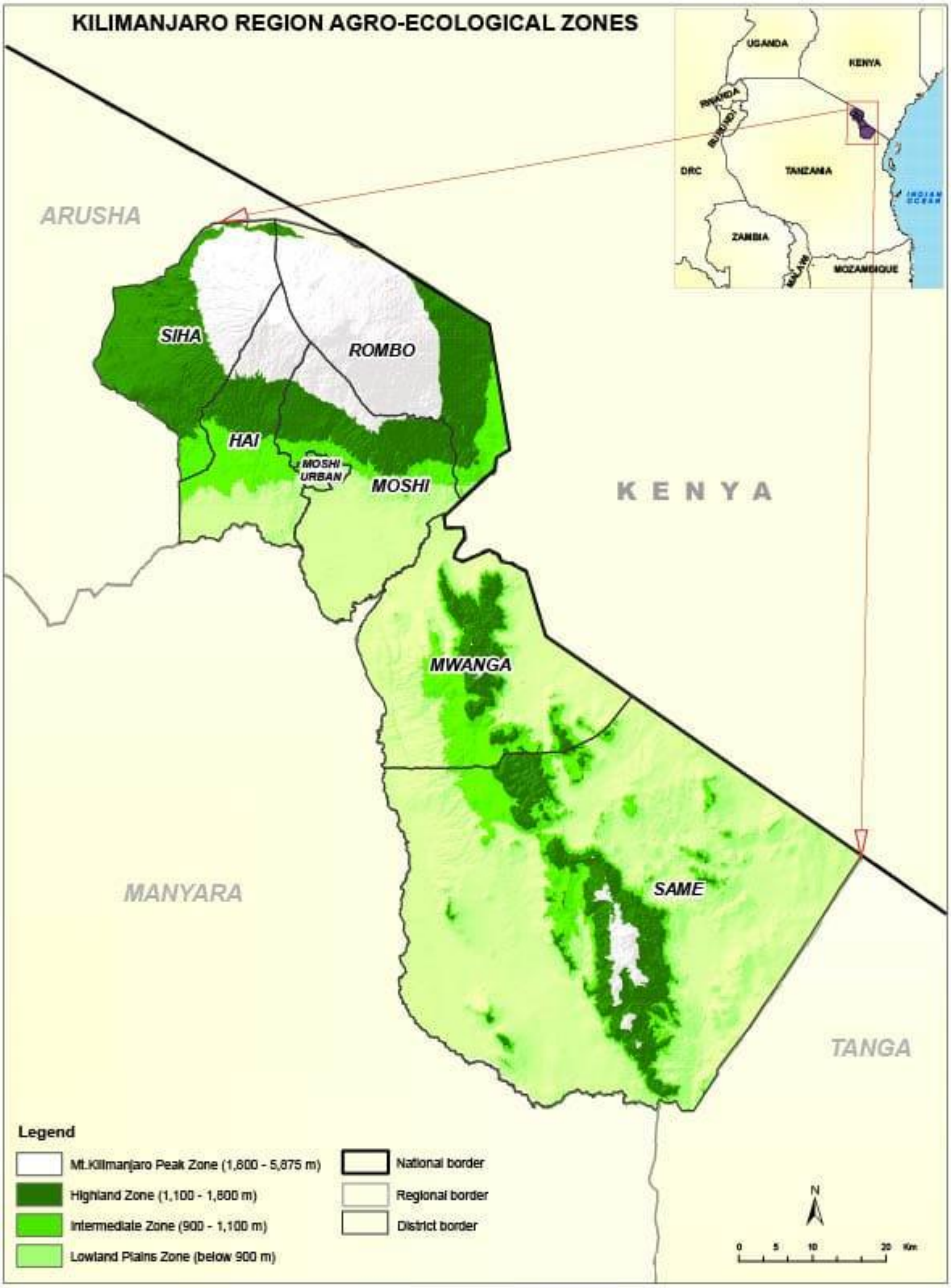

Figure 3:2 The Kilimanjaro region showing the different agro-ecological zones forming the region. (Source: Author)

3.4.1.1 Embedded unit of analysis 1: The highland zone

The highland zone lies between 1,100 and 1,800 meters above sea level. The main distinction of this zone compared to others is the higher soil fertility, higher amounts of rainfall (although less than the mountain peak zone), and the highest population density (Kilimanjaro region socio-economic profile, 2014). The soil in this zone is relatively more fertile than in the midland and lowland zones also as a result of the underlying volcanic geology (Soini, 2005). If the onset, intensity and length of short and long rain periods is good the area receives an annual average rainfall that ranges between 1,250 and 2,000 millimetres, while temperatures range between 15^{o}C and 20^{o}C (O'Brien *et al.,* 2008; Kilimanjaro region socio-economic profile, 2014). The major crops grown include wheat, beans and barley, coffee, banana, fruits and round potatoes. The area is highly populated with a population density of 650 people per square kilometres (Kilimanjaro region socio-economic profile, 2014). The majority of livestock kept in this zone tends to be stall-fed, and some families from this zone own or rent plots of land in other zones particularly in the lowland zone (Soini, 2005).

3.4.1.2 Embedded unit of analysis 2: The midland zone

The intermediate or midland zone lies between 900 and 1,100 meters above sea-level and receives an annual rainfall ranging from 800 and 1,250 millimetres if the onset, intensity and length of short and long rain periods is good (O'Brien *et al.,* 2008). The area has moderate soil fertility which is good for coffee, banana, maize, and beans (Kilimanjaro region socio-economic profile, 2014). The area also supports dairy cattle, goats, pigs, rabbit and poultry farming. The area has a population density of 250 people per square kilometres (Kilimanjaro region socio-economic profile, 2014).

3.4.1.3 Embedded unit of analysis 3: The lowland zone

The lowland zone lies below 900 meters above sea level and has an average annual rainfall of between 700 and 900 millimetres if the onset, intensity and length of the short and long rain periods is good (O'Brien *et al.,* 2008). The average annual temperature in this zone is above 30^{o}C. The major crops in this area are maize, cotton, rice, sorghum, cassava, and pigeon peas while beef cattle, goats, pigs and sheep are domestic animals that do well in this area (Kilimanjaro regional socio-economic profile, 2014). The area provides the best fodder in the form of grasses and straws for animals of all the zones (Kilimanjaro regional socio-economic profile, 2014). The population density is comparatively low, 50 people per square kilometres and livestock in this area is mostly freely grazed because of the availability of open spaces especially after crops have been harvested (Soini, 2005;Kilimanjaro regional socio-economic profile, 2014).

3.5 Methods

3.5.1 Sampling and recruitment procedures

3.5.1.1 Sampling of the study villages

Sampling is the process of selecting part of the population to be used in the study (Bryman, 2012). Three different zones each represented by one village were used as the embedded units of analysis in this study. There are four different participant groups in this study. Within each village the participant groups included the household heads, and separate female and male focus group participants. A fourth participant group are 'key informants', these were made up of appropriate representatives from the different stakeholders referenced in section 3.6.1. Given the diversity of stakeholders, different types of sampling strategy were used for the different participant groups, as explained below.

In order to conduct research in Tanzania it is necessary to gain different levels of governmental approval. After consent had been given from the regional administration officer to allow me to enter the region (Appendix A), the first step was to select the study district in order to be able to select study villages from each zone. Since there are many villages at the regional level, which are located in each district, the first step was to select a district with the three agro-ecological zones so that villages can be picked from one district but across the three agro-ecological zones (as summarised in Figure 3:3. The Kilimanjaro region has seven districts, and some districts have three ecological zones (highland, midland and lowland) and others have two agro-ecological zones.

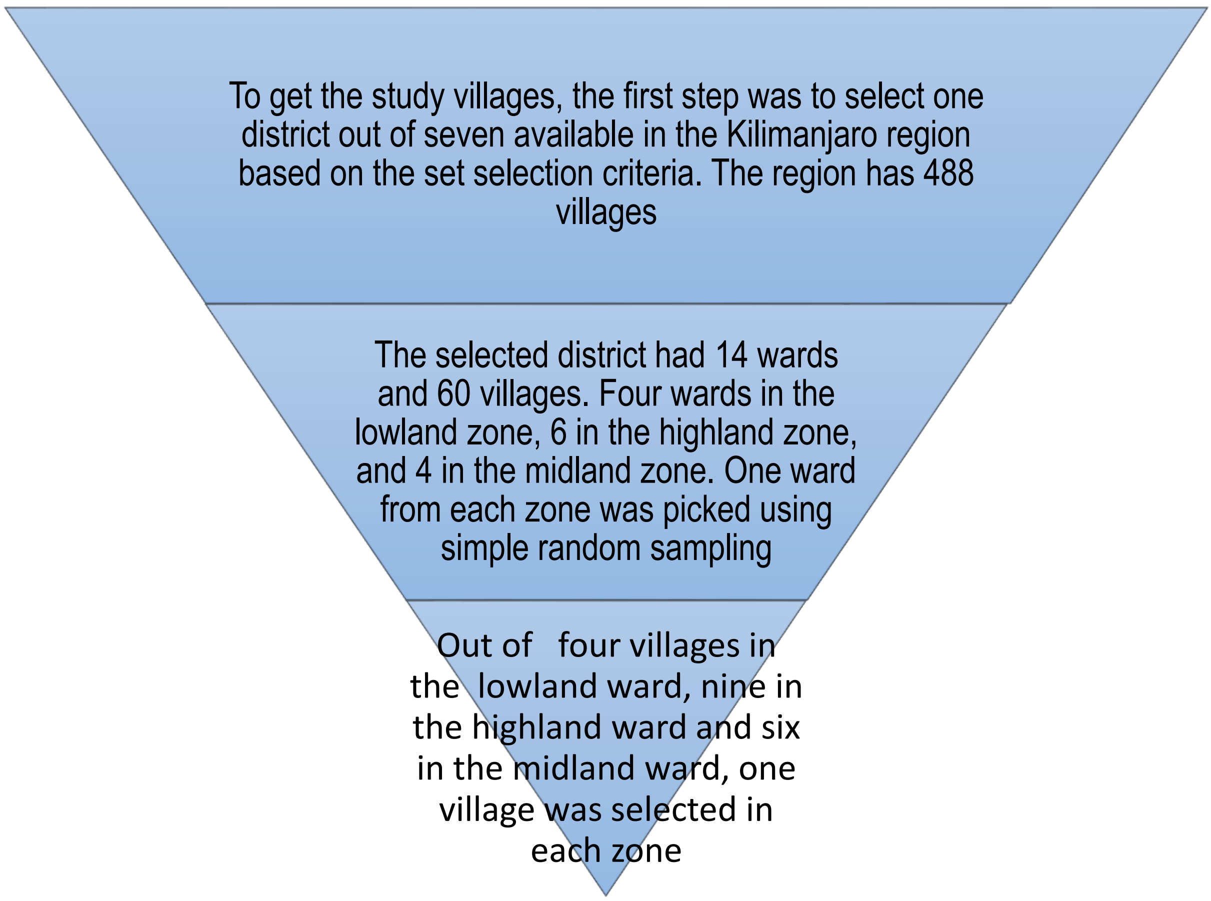

Figure 3:3 Summary of the approach used to select three villages across the three agro-ecological zones.

Purposive sampling was used to pick the study district. One type of purposive sampling is criteria sampling, where 'the individuals or units are selected based on particular criteria' (Bryman, 2012, p. 409). Together with the regional environmental officer I selected one district based on pre-set criteria. The regional environmental officer oversees all activities related to the environment in the region. The selection criteria which I used for selecting the district included accessibility, evidence of climate change (as observed in the region), the presence of the three agro-ecological zones. After selection of the study district, I submitted a research approval letter to the district commissioner of the respective district in order to gain access to the villages.

Before selecting the villages to be involved in the study, I first used a simple random sampling method to select one ward from each agro-ecological zone in the selected district. The selected district has 14 wards and 60 villages, four wards are in the lowland zone, six wards in the highland zone, and four in the midland zone. The practical steps I used to randomly pick the study ward in each zone started by separately writing the names of wards in each zones in small equal size piece of paper, folded them and mixed them up on the table and then picked one in each zone. The selected ward in the lowland zone has four villages, nine villages for the ward in highland and six villages for the selected ward in the midland zone. Simple random sampling was used to pick one village in each ward, using the same procedures I used for picking a ward from each zone. village M was picked in the midland zone, village L from the lowland and village H for in the highland zone. This village, ward and the district studied are not mentioned in order to maintain the anonymity of the villagers and key informants as agreed through the Keele University ethical approval process.

3.5.1.2 Selection of the household heads

The household was used as sampling frame in order to access household heads. A sampling frame is a list of units of population over which samples will be selected (Bryman, 2015). The sampling frame in this study are the households within selected three villages in Kilimanjaro region. The list of households was accessed through the village register[4] in respective villages. According to the 2016 village register, the number of households in each village was 702, 483 and 946 in villages H (Highland village), L (Lowland village) and M (Midland village) respectively. The study used stratified random sampling to select the five percent of the households from each village to be involved in the survey. Since the study villages are in three different agro-ecological zones, the need to ensure the sample drown from each village are proportional to the population in each village, the study used the stratified random sampling (Bryman, 2012).

The choice of five per cent of households were chosen for inclusion in the study for a number of reasons: 1) The data saturation, as there was no new information were coming out of the data. 2) limitation on time and financial resources for data collection on household heads in the villages; 3) the number of other activities that also had to be done in the field which were part of the data collection process (conducting interviews with key informants, focus group discussions to enrich the data obtained from households). Five percent of households was deemed sufficient to provide good quality data which was then triangulated through focus group discussions and key informants interview.

The sample size was calculated by calculating five percent (5%) of the total households in all three villages which was approximated to 106 households. Since these villages are distributed

[4]The paper based document

unevenly between the three zones the use of stratified random sampling helped to ensure that the sample selected is distributed in the same way as the population.

After identifying the total number of households to be involved from each village, specific households from the village register in each village, were selected using systematic random sampling. The number of sampled households in each village was divided by the total number of households to get an interval at which the sample will be picked up (Bryman, 2016) as shown below;

$$Village\ M,\ \ 702\ /35 = 20$$

$$Village\ L, 483/24 = 20$$

$$Village\ H, 946/47 = 20$$

Simple random sampling was then used in each village to determine the starting point from which every 20th household in the list of village register was selected, in order to give every household an equal opportunity to be involved in the study (Bryman, 2012). I wrote numbers from one to twenty on a small pieces of paper, mixed them thoroughly and picked one. The household in the register list under the number picked was the starting point for picking each subsequent 20th household in each village.

After identification of the household through numbered selection on the village register, the gate keeper used in the village to access participants took the researcher to the individual houses to provide the invitation letter and information sheets. The gate keeper was the village chair person or appointed representative. The use of gatekeeper assisted to gain access to selected research participants.

3.5.1.3 Selection of focus group participants and key informants

Focus group participants for both male and female groups were selected using criterion purposive sampling methods. The members of all the focus groups were selected by the village leaders for each village using the criteria given by the researcher. Members of focus groups all deemed to be household heads, and were purposively selected using inclusion criteria including varying age groups and varying level of education. All members of both the male and female focus groups were farmers. The maximum number of participants in each focus group was 12 (Bryman, 2012). It did not happen that the list of participants selected for household survey to came up in the focus group discussion list.

The snowball method was mainly used to recruit key informants for interviews. After the district commissioner introduced the researcher to the district agriculture extension officer, the latter gave the contacts for other people that worked with in the district in matters related to small-holder farmers' livelihood. One key informants; The representative of small-holder farmers network group (MVIWATA) was mentioned by farmers during the interview. Participants included in interviews in this study were those who are related to small-holder farmer's livelihoods within the district. Key informants I interviewed are agriculture extension officers, agriculture research officers, representatives of non-government organisation and community development officers. Livestock officer who deal with issues related to livestock subsector was not interviewed because of unforeseen circumstances. Other two officers related to water sector and the environment was interviewed but I did not analyse their data because of ethical reasons as explained in detail in subsection 8.5.

3.5.1.4 **Stakeholders in the small-holder farmer's livelihoods in the Kilimanjaro region.**

There are a variety of stakeholders of relevance to this this project. However, the main focus for this study is the small-holder farmers themselves, and the household members particularly the heads of the household. Within the households in these regions, the heads of the households are mostly men if the household is made up of couples, but where there is a single head of household, as a result of any reason including death of the partner, a man or woman can be the head of the household. The main reason for focusing on the heads of the households is because they are the owner and primary manager of the farm and other livelihoods activities within the household (HBS 2011/2012). If there is an impact of climate change on their livelihoods they are in the best place to know about this. Within households with two parents and children, mother and children are involved in some activities related to farming as well as household livelihood strategies, and therefore also have an insight into farming activities. So when a father was not available for families with both parents, the mother took part in the interview. However, as will be seen in the data collection methods, it is essential in some contexts to create conditions for the women's voices and perceptions about livelihoods to be heard. This was achieved by having gender based focus group discussion.

There are many other stakeholders who may be involved indirectly in small-holder farmer's livelihoods. Before I explain these stakeholders, I will first briefly present the administrative structure of Tanzania Figure 3:4. The hierarchical administration structure in Tanzania has the national government at the top and villages at the bottom. The country is divided into regions, and then regions are sub-divided into districts and districts into divisions (known as *tarafa* in Swahili) and the later divided into wards (*Kata* in Swahili). The wards are then subdivided into villages.

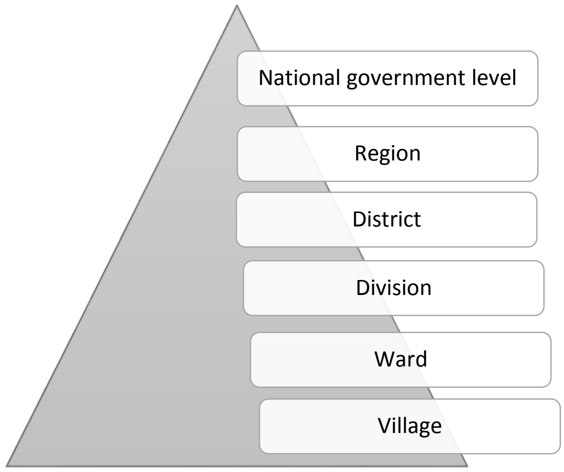

Figure 3:4 The administrative structure in Tanzania

Key stakeholders were included in this study through what are referred to as 'key informant interviews'. The key informants involved in this study include MVIWATA Kilimanjaro which is part of MVIWATA Tanzania, a non-governmental organization that brings together small-holder farmers in Tanzania to defend their socio-economic interests. MVIWATA Kilimanjaro was formed in 2006 as part of 17 middle levels networks of MVIWATA across the country. This organization is funded by member groups and donors. The role of MVIWATA is to strengthen communication between local groups, networks, institutions, and partner organizations that are working with farmers and governments within the region and enabling small-scale farmers to come together to address pertinent challenges.

A Community Development Officer was also a study 'key informant'. They are a public servant who supports programmes aimed at improving quality of life for various groups in the community. They form a bridge between different stakeholders both public and non-governmental organizations interested in community development. Apart from working with some groups in the community such as women, youth and entrepreneurs to help them realize their full potentials in contributing to development they also support the wider community on how to solve the problems they are facing.

The Tanzania Coffee research institute (TaCRI) is another key stakeholder and key informant involved in this study. The institution researches technological innovation and provides advice to improve productivity and quality of coffee in Tanzania. The TaCRI performs research in the following areas: good agriculture practices research programme; technology transfer; crop breeding; and socio-economic aspects which seek to understand the applicability of the technologies to farmers. TaCRI is owned by the stakeholders who receive their services - small and large-scale coffee farmers, co-operative societies and unions dealing in coffee. Other owners include coffee processors, coffee traders, relevant NGOs, the private sector, and the Tanzanian government. It is non-profit organisation funded by members' voluntary contributions, government, donor contributions as well as internal generated income through the selling of materials produced by the organisations and service provision to its stakeholders.

District and Village agriculture extension officers were also key informants. These are public servants are employed as the government response to the meet the need to deliver extension services to primarily small-scale farmers. The officers provide farmers with agricultural knowledge and skills to improve their farming practices and eventually productivity. The district agriculture extension officer oversees agriculture extension officers working directly with farmers in the village or ward level. These officers are also responsible for taking part in the formulation and implementation of government policies, programmes and action.

Other stakeholders which also relate to small-holder farmers include livestock officers, forestry officers and environmental officers but some were not accessible for interviews and others were interviewed but because of ethical reasons (presented in section 8.5) I did not analyse their data.

3.5.2 Data collection methods

Several methods have been used to collect data in this study. The rationale for using multiple sources is for triangulation purposes a process where several sources are used to gather information on the same topic. As described by Yin (2013) this process helps to create what he calls 'converging lines of evidence'. Further detail on each data source is given below. The methods used in this research were informed by a mixed methods case study approach using critical realism as the underpinning philosophy. The data collection methods used were interviews, focus group discussions, and researcher observations.

As summarised in Table 3:1 the study conducted two types interviews with research participant; the semi structures interviews and closed ended interview. While all interview question with focus group participants (Appendix B) and key informants (Appendix C) were semi structure, the interview question in the household survey Appendix D were both semi structures and closed ended questions. The semi-structured nature of the interviews with key informants, focus group participants and parts of the householder head interviews meant that the researcher was capable of posing additional questions to further clarify answers on the topic under discussion. I will briefly explain key informants' interviews, focus group discussion, and household survey as used in this research.

The key informants' interviews are often conducted with key informants relating to the fact of a matter under research as well as their opinions about events (Yin, 2013). In this study key informants were interviewed to provide an understand of the climate change in the study area, the role of their organisation in helping farmers adapt to climate change and factors that constrain small-holder farmers in the Kilimanjaro region to build resilient livelihood.

Focus group discussions as defined by Bryman (2015) occur when more than four people are interviewed at the same time. In this project a maximum of 12 people was involved in any one focus group discussion. The study conducted gender based focus group discussions in highland and midland but because of unforeseen circumstances, the lowland focus group was mixed gender. The gender based focus group were intended to uncover the differences in perception in of climate change and adaptation options for building livelihood resilience to climate change (Mwongera *et al.*, 2017).

Table 3:1 Research questions and corresponding data sources, data collection and analysis methods

Topic covered	Type of interview	Participant group	Research question	Data analysis method
Perception of climate change and its impact to livelihood	Semi structure interviews	Key informants	1) What factors affect the livelihoods of small-holder farmers in the Kilimanjaro region? 2) Are impact of climate change to small-holder farmers actually being seen in this area? 3) How is future climate change likely to affect the livelihoods in Kilimanjaro region? 4) Does climate change have any impact on performing your roles in Kilimanjaro Region?	Thematic analysis (Coding using magnitude coding, In vivo /descriptive coding, recommendation coding)
		Household in the survey	1) How have small-holder farmers' livelihood assets changed over time? 2)How do changes in livelihood assets mostly affect farmers' ability to make a living?	In vivo or descriptive coding, Saldana, (2009) and descriptive statistics in SPSS
		Focus group participants	1) How have temperature and rainfall changed over 30 years? 2) Does climate change have any impact the livelihoods in Kilimanjaro region?	Thematic analysis (Coding using magnitude coding, In vivo /descriptive coding, recommendation coding)

	Structured interview	Household in the survey	1) What is farmers' perception on rainfall variability and its impact	Descriptive statistics
Livelihoods management practices/strategies and their impact to livelihood resilience	Semi structures interviews	Focus group participants	1) What are agricultural activities and cropping calendar in this area? 2) How crops produced by each gender is used? 3) What is historical calendar of; livestock ownership, soil fertility, tree cover, crop produced 4) What lessons are there relating to climate adaptation based on historical agricultural trends?	Thematic analysis (Coding using magnitude coding, In vivo /descriptive coding, recommendation coding)
		Household in the survey	1) What measures do small-holder farmers' use to enhance land productivity?	In vivo or descriptive coding, Saldana,(2009), followed by multiple response in SPSS
Social factors affecting livelihood resilience	Semi structures interviews	Focus group participants	1) What are the problems that face livelihood of small-holder farmers in this area? 2) How do you think they should be addressed?	Thematic analysis (Coding using magnitude coding, In vivo /descriptive coding, recommendation coding)
		Key informants interviews	1) What factors affect the livelihood of small-holder farmers' in the Kilimanjaro region? 2) How do policies relating the work of your organization address the problems? 3) What challenges are there facing your organization especially in addressing problems related to climate change?	Thematic analysis (Coding using magnitude coding, In vivo /descriptive coding, recommendation coding)
	Structured interviews	Household in the survey	1) What is the most difficult problems facing crop, livestock and off farm income activities?	Descriptive statistics

3.5.3 Data Translation and Transcription

Data transcription is the process that involves the transfer of the questions and respondents' answers from a recording into a written (Grbich, 2013) in order to ease analysis. Data translation from the Swahili language to English Language was carried out by the researcher, conversant in Swahili and English at the same time as carrying out transcription. All interviews were carried out using the Swahili language as English was less popular for most of the respondents. The close ended questions from household survey were translated as they were transferred into an excel sheet for analysis.

3.5.4 Analysis and interpretation

This section presents the framework used to guide the data analysis and interpretation. Data analysis consists of examining, categorizing, tabulating, testing or otherwise combining evidence, to draw empirically based conclusions (Yin, 2013). I used three major types of data analysis: thematic analysis, thematic network analysis, and descriptive statistics.

The types of data consist of closed-ended questions, open-ended question with brief answers (from the household survey semi structured questions), and open-ended questions with detailed explanations (key informants and focus group data). Before I carried out the analysis of this data, I read the transcribed data several times in order to gain a deep understanding of the responses provided by respondents (Taylor-Powell and Renner, 2003). Details of the analysis methods used on all categories of data are given below.

For the closed-ended questions respondents were asked to pick an answer from pre-defined options by picking the letter or number that represented the most relevant response for them. The analysis of this type of data was done using SPSS descriptive statistics tools such as frequencies and cross tabulation, after the data had been transferred to excel and imported to SPSS.

Data from short answer open-ended questions were manually coded (Basit, 2003) using in vivo or descriptive coding Figure 3:5. This was possible because the data from semi structured question collected in the household survey mostly had short responses requiring only a single code for each response (Campbell *et al.,* 2013) except on the question about agricultural practices that household use to manage water and soil fertility which had multiple responses (more than one answer to a single question) and therefore more than one code in a single question. The coding method used in multiple response question were either combination of in vivo and descriptive coding or one of them. Descriptive coding is the coding method that uses a word or short phrase to summarise the basic topic of a passage of qualitative data to identify the topic covered (Tesch, 1990:Saldana, 2009). In vivo coding uses a word or phrase as used by the respondents themselves (Strauss, 1987: Saldana, 2009). After codes were created, data were grouped under the themes identified and then entered into SPSS for analysis. Tools used in the analysis include frequencies, cross tabulation, as well as multiple responses. The descriptive analysis and multiple responses were used to understand the frequencies of the themes as reported in all members involved in the interviews. Notes were taken on the decisions made on every stage of the analysis.

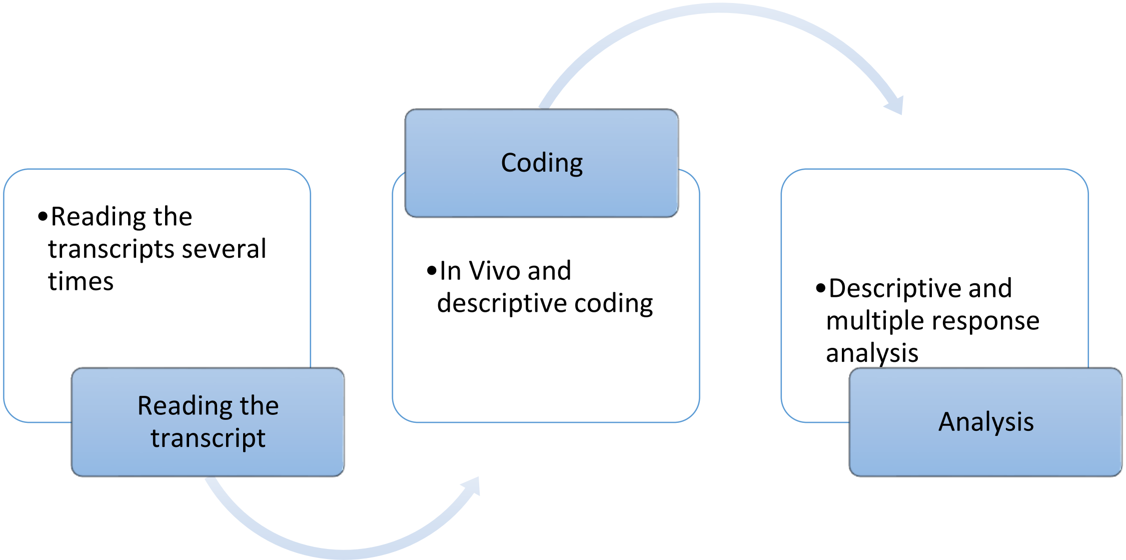

Figure 3:5 Summary of the analysis method used to analyse the semi-structured interviews conducted through the household surveys

Open-ended questions with long explanations such as those from the key informant interviews and focus groups were manually analysed (Basit, 2003) using thematic analysis Figure 3:6. Each transcript was read several times first, and the impressions I got from the data was noted down (Taylor-Powell and Renner, 2003). I then reviewed my research questions and focused my analysis to how all individuals or groups responded to the questions at the core of the research (Taylor-Powell and Renner, 2003).

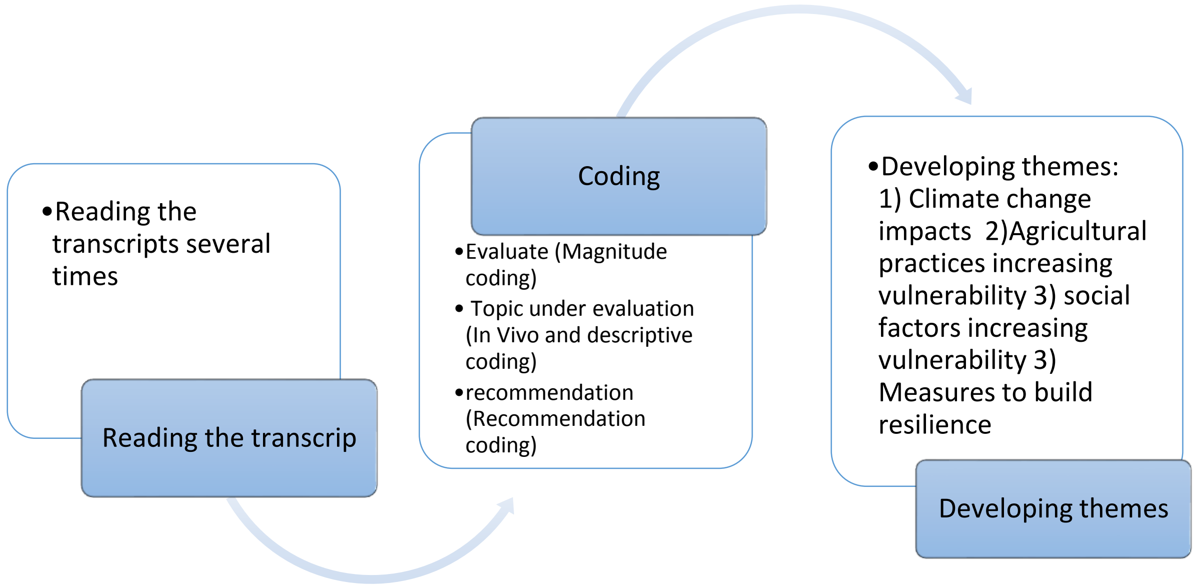

Figure 3:6 Summary of the analysis methods used to analyse data from focus group discussion and key informants interviews

Each interview transcript from individual key informants, or each focus group was read and a word, sentence or paragraph that responded to the research questions was manually coded using evaluative coding to summarise what has been said in the text (Basit, 2003; Smith and Firth, 2011). Evaluation coding is the coding method that assign non-numeric code to represent judgement about a programme or policy (Saldana, 2009) The evaluation coding as employed in this research included a combination of magnitude coding to note whether the practice or strategy make a positive (+) or negative (-) impact, descriptive or in vivo coding to note the topic under which evaluation was done, and recommendation coding to note the recommendations made (Saldana, 2009). The evaluation coding is relevant to this research as it aims to understand what is implication of climate change to livelihood and what is working and what is not in relation to management of small-holder farmers' livelihood to build resilience to climate change.

From the focus group and key informants' interviews the coding was carried out to cover the topics such as: impact to financial, natural assets, agricultural practices affecting soil fertility, agricultural practices affecting water use efficiency, factors constraining three livelihood options, and their recommended solutions. The codes developed under the mentioned topic were linked to form themes (Saldana, 2009; Smith and Firth, 2011). The themes were climate change impacts to livelihood assets, factors increasing livelihood sensitivity to climate change, and measures to build livelihood resilience.

The approach used in data analysis is an inductive approach in which data analysis is carried out with little or no pre-determined theory, structure or framework other than the actual data itself to decide the structure of the analysis (Burnard *et al.*, 2008; Grbich, 2013). Contrasting the inductive approach is the deductive approach (Taylor-Powell and Renner, 2003;Burnard *et al.*, 2008). The deductive approach uses a pre-determined structure or framework to analyse data. Using this method, the researcher uses a pre-determined structure to analyse data such as interview transcripts. For example, theories show that climate affect livelihoods by reducing yield and increasing the prevalence of diseases. Therefore, when analysing data using the deductive approach, the research will look at transcripts to identify whether those impacts were mentioned. Although this approach is quicker I did not use it because of its potential bias to the whole analysis process (Burnard *et al.*, 2008), reduced credibility from the research results, and the potential to miss key themes emerging from the data that were not part of the deductive framework. Although the inductive approach is time consuming, it increases the rigour of the research by giving due weight to respondents' ideas rather than the theory or framework.

3.5.5 Validity of the data analysis

This study contains both qualitative and quantitative data. Arguably the analysis of qualitative data can be more subjective than quantitative data. To ensure validity of the qualitative data analysis, three methods can be used: the use of respondents; the use of peer review; and ensuring the whole process of data analysis is systematic and rigorous (Burnard et al., 2008). As far as this research is concerned it was not possible to use the first two methods due to limited time and financial resources. Therefore, I have tried to describe in detail the way I analysed the data, and care was taken during the analysis to cover all information that was provided by each respondents (Burnard et al., 2008), to demonstrate the systematic and rigorous nature of the data analysis.

3.5.6 Data presentation and interpretation

Data analysed through descriptive statistics were presented using tables and graphs. Some data analysed qualitatively were presented using tables summarising key ideas presented by respondents and supported by quotes from research participants.

Data interpretation provides meaning from the data analysis (Taylor-Powell and Renner, 2003). Data interpretation was carried out by first developing a list points or important findings emerging in each category of data, for example the lessons obtained relating to the evidence and impact of climate change. The summaries of the key conceptual findings of each data segment were joined together into a connected story by relating them to the research questions and the theoretical framework of the study (Attride-Stirling 2001) to understand how the finding relate to research questions. New findings from the data, and findings of most relevance and interest to the users of this research were identified and prioritised for presentation and discussion (Taylor-Powell and Renner, 2003).

3.5.7 Research stages

The data collection phase of this research took two months of intensive data collection from July to September 2017. The data collection was scheduled to conduct focus group discussions first in each village. In the highland and midland villages, the male focus groups were carried out first then followed by the female focus groups, based on the suggestions given by the village leaders in both villages. The lowland focus group was mixed gender. Before going to meet the potential focus groups participants and give them information sheets and consent forms, I asked the village leaders the best timing to carry out the focus groups based on the general timetable of people in that village. The village leaders suggested that the male focus group should be the first and start at 0900, followed by the female focus group, as women were said to have chores to do in the morning, and it would be difficult to get the men together once they had left to make their living later in the day.

After the focus group discussions in all three villages, some of the strategies which were reported in the focus groups to be beneficial for livelihood adaptation to climate change but were said to have low uptake were then added in the survey to understand farmers' perceptions of these strategies. After the focus group discussions, the second stage was to conduct the detailed structured interviews with household heads in respective villages. The village agriculture extension officer if available was interviewed after the household surveys in the respective villages to check officers' views about issues that may arise from farmers' interviews. The third stage was to conduct key informant's interviews in the district and other stakeholders as proposed by key informants or mentioned by respondents during the interview. For example, MVIWATA was mentioned by respondents in the survey and were added to the list of key informants to be interviewed. This approach helped to triangulate information and input into additional information to ask particularly in the survey and key informants interviews.

3.6 Ethical considerations

Ethical considerations are essential in research. As Yin (2013. p. 73), emphasizes '……. you need to obtain formal approval for your plan. Such approval should not merely be viewed as an insight process, because you should always conduct all of your research with the highest ethical standard'. This study involved human subjects and the matter investigated is a real life phenomenon, so ethical consideration was at the heart of this project. The ethical issues to be considered can be discussed under four main concepts: harm to participants; lack of informed consent; invasion of privacy; and involvement of deception (Bryman, 2015). This section will cover the concepts of harm to participants.

In the process of doing this research, I ensured safety to myself as the researcher as well other research participants. To ensure my safety, I requested the company of another person whom I trust and ensured I had reliable transport to take me to and from the field. The protection of the respondents from harm was mainly done through maintenance of anonymity and care in record keeping. Bryman (2015, p. 127) emphasizes 'the issue of harm to participants is addressed in ethical codes by advocating care over maintaining the confidentiality of records. This means that the identities and records of individuals should be maintained as confidentiality'. In this project the names of the respondents were only used on the consent forms which were kept separate from the interview sheets.

Additionally, as the study involved interviews with key informants, who could be easily identified by their roles, I implemented two things as part of the study's ethical considerations: 1) I informed key informants about the potential of them to be identified because of their roles; 2) I have not included names of the district and villages involved in this project to reduce the risk of identification of some key informants.

The voice recorder used in the interviews was kept in a locked bag in the field together with interview sheets. In the UK all consent forms are kept in my office in a locked cabinet to which only I have access. At the end of data collection, the research participants were thanked verbally and assured their anonymity and confidentiality.

Ethical approval to carry out the research was gained from the Keele University Ethical Review Panel dated 10 May 2017 (reference number 2326) Appendix E. Several documents were reviewed and approved to be used in this project by the ethical review panel. Some changes to data collection to that covered in the ethical review documentation were required in the field and the researcher had to be flexible in order to accomplish the study on the allocated time. The study planned to interview only household heads due to their role in determining the use of household resources for livelihoods. However, I was missing frequently the household heads at home so I decided to interview the wife for families with both parents. This decision was arrived at after realising that for most activities both parents participate, so women were also capable of providing reliable answers. Other changes that happened were being unable to conduct separate male and female focus groups in the lowland zone village. This was necessary as potential focus group participants were part of a village environmental meeting that took a long time, preceding the focus groups. In order to avoid losing potential participants after this meeting the planned male and focus groups were combined into one. Although both gender was combined, the discussion involved 12 participants, six in each gender. All of these changes were communicated to the Keele University ethical review panel and were approved retrospectively on 18thJan 2018 Appendix E.

Carrying out research in Tanzania requires different levels of approval. In order to meet farmers and key informants to carry out the interviews, the following procedures were taken. After getting ethical approval from Keele University, I travelled to Tanzania to carry out the research. In Tanzania I went to the University of Dar Es Salaam (where I work) to ask for a research clearance letter which is compulsory to have before conducting any research in Tanzania. This clearance letter was circulated from the region to the village level. The village leader then acted as a gatekeeper to individual members of the village, and took the researcher to the households selected to particpate in the study.

Potential research participants were given time to process information about their potential participation in the study in order to be able to make an informed choice as to whether to participate in the research or otherwise. Bryman (2015, p.129) in his discussion about informed consent argues that a '…prospective research participant should be given as much information as might be needed to make an informed decision about whether or not they wish to participate in a study'. For potential participants, such as focus group participants and household members to take part in the survey the practical steps I used to provide information included reading the invitation letter and information sheet to them and left the written information sheet with them. Follow-up for their consent was made after a day or two days to give them time to discuss and digest information provided. For key informants, some were physically visited to their respective offices and provided with consent and information sheets, and for some I sent the documents out through emails. Those who were happy to take part were requested to complete a consent form before starting the data collection. All key interviews were happy for the interview to take place in their respective offices. Village agriculture extension officer was interviewed in her office located in the village. I took care not to invade participants' privacy and I was honest to research participant and no deception of any kind was involved. I also provided contact details to the prospective participants to ask any further questions about the project.

3.7 Conclusion

In this chapter the over-arching methodology, positioning and theoretical framework, research design, data collection and analysis, and ethical issues are explored to demonstrate the steps I used to address my research questions. The next four chapters present the research results, discussion, and recommendations. Before I explain what the chapters are about, I would like to reiterate that, the study intends to explore practical adaptation measures small-holder farmers in Kilimanjaro region could use to adapt to climate change and build livelihood resilience. And it is essential to reiterate that, the study begin by exploring livelihoods vulnerability to climate change, based on the Turner et's vulnerability framework, stressing the exposure and livelihood sensitivity to climate change as components of vulnerability. The exposure represents the impacts the climate change presents to the livelihood, and sensitivity to climate change is determined by social and environmental condition.

Based on above explanation, chapter four presents results relating to the climate change impacts on livelihood assets. Chapter five presents household farm production practices and their impact to environmental resources. Chapter six presents livelihood options and social factors contributing to livelihood vulnerability to climate change. Chapter seven presents measure to build livelihood resilience in the face of climate change. Chapter eight presents discussion and chapter nine provides the conclusion.

4 Small-holder farmers’ perceptions of climate change and its impact on livelihoods

4.1 Introduction

This chapter presents the results from this study drawing on the household surveys and focus groups and key informants on the impact of climate variability on the livelihood assets of small-holder farmers. The chapter begins with data describing the characteristics of the households involved in this study and proceeds by presenting how climate variability affects the five livelihood capitals such as human, social, financial and natural capital in the study area.

4.2 Characteristics of the studied households

4.2.1 Occupation

The types of occupation of the respondents as displayed in **Table 4:1** shows that for the majority of respondents, the major source of income was from farming. Other than in the lowland zone where one respondent reported to depend on non-farm income sources, in the midland and highland zones all respondents depended on farming as their main source of income.

Table 4:1 Occupation of respondents in studied households as summarised from survey results across the lowland, midland and highland zones

Occupation	Count/Percentage	Zones			Total
		Lowland	Midland	Highland	
Farmer	Count	23	35	47	105
	% within zone	95.8%	100.0%	100.0%	99.1%
Non Farming	Count	1	0	0	1
	% within zone	4.2%	0.0%	0.0%	0.9%
Total	Count	24	35	47	106
	% within zone	100.0%	100.0%	100.0%	100.0%

4.2.2 Education level

Previous research has indicated that household heads with no primary level of education are prone to be affected by extreme weather events (Opiyo, et al., , 2014). Figure 4:1 displays the education level of household head as analysed from household survey in the three different zones. What stands out in this table is that in all three zones, more than 80 percent of respondents had at least a primary level of education. Just one quarter of all respondents in the three agro-ecological zones had received a secondary education while no respondent had received a tertiary level of education except one in the highland zone. The percentage of respondents who have secondary and tertiary education is small and does not mirror the region's educational provision as there is relatively better access to education in the Kilimanjaro compared to other region in Tanzania (Tacoli, 2001). The majority of people in this region educated to secondary and tertiary level are not resident in their home villages due to several reasons which will be dealt with later in the section 4.4.4 about migration.

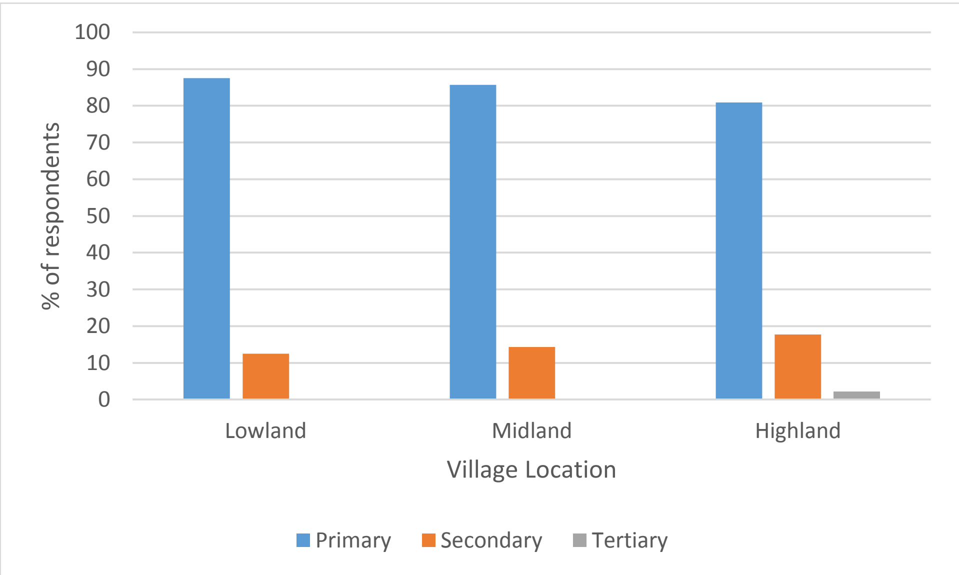

Figure 4:1 Education level of respondents in studied households as summarised from the household surveys from the Lowland, Midland and Highland zones

4.2.3 Marital status of respondents

Previous work has suggested that households which are headed by divorced or widowed heads have the potential to be impacted by climate variability and extreme weather events (Opiyo, et al., 2014). As displayed in Figure 4:2, all zones had respondents with different types of marital status (married, single, widow) except the highland zone where there were no respondents who were single. The majority of respondents in all three zones were married and few were widows and single.

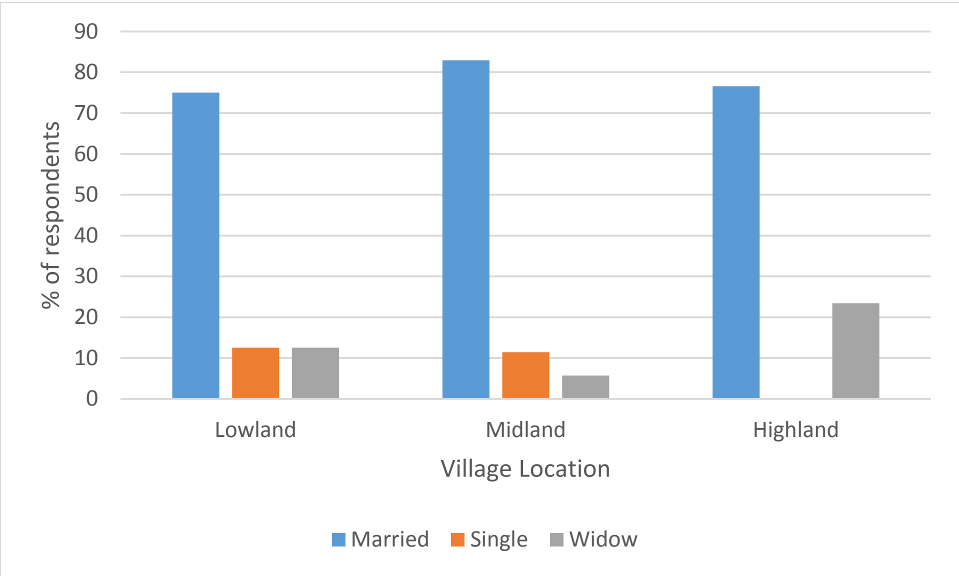

Figure 4:2 Marital status of respondents from the studied households as summarised from the household surveys from the lowland, midland and highland zones.

4.2.4 Age of respondents

Figure 4:3 shows the age groups of people involved in the household head survey in the zones. The majority of respondents in the highland zone were above 56 years of age while in the midland and lowland zones the majority were between 46 and 55 years of age. Few respondents from the highland zone were between 25-45 years, and the midland area had equal number of respondents with 56+ years and 25-45 years. The lowland zone had slightly more respondents in the 25-45 year compared to those above 56 years. The age distribution of respondents involved in this study should not be taken as a typical age distribution of the population in this region because as in many developing countries, the number of people decreases with an age increase from the age group of 15 years (Regional socio-economic profile, 2014).

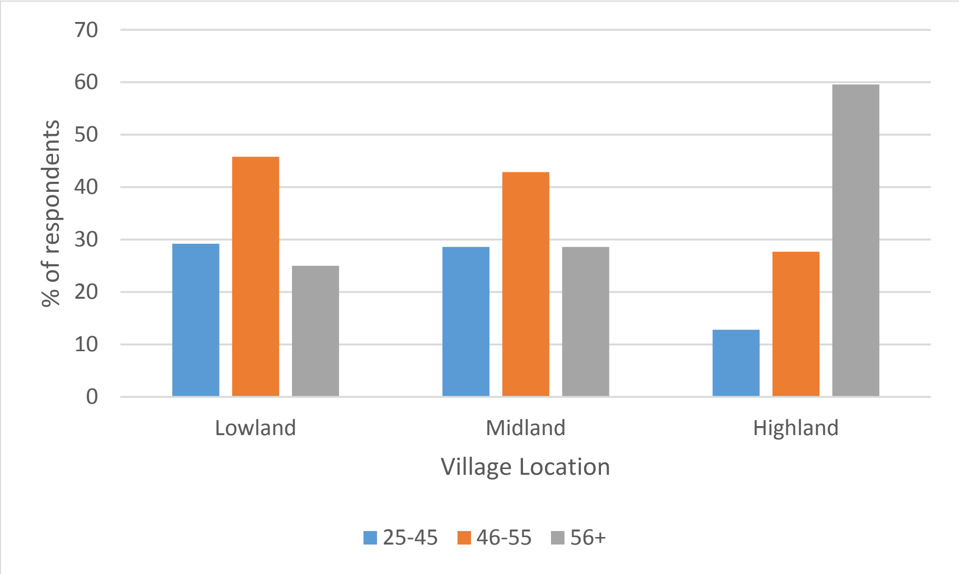

Figure 4:3 The age of household head respondents from the lowland, midland and highland zones

4.2.5 Households with people more than 15 years of age

To understand the amount of labour force available in the household, the study inquired about the number of people in the household over 15 years of age. The results in Figure 4:4 indicate that except in the midland zone, the majority of households had between one and two people in addition to the household head at home above 15 years of age. The majority of household head respondents in the midland zone reported to have three to four people in addition to the household head, at home with more than 15 years. This means that more than 50 percent of respondents in the highland and lowland zone reported to live with only their husband and wife as the only adults in the household. Only a few households had between five to seven members over 15 at home, which were recorded only in the midland

and highland zones. Although the survey did not ask about the total household size because I wanted to understand the labour force, the regional socio-economic profile (2014) shows that the Kilimanjaro region had an average household size of 4.3 in 2012 which is the lowest in the country compared to a national average household size of 4.8 in the same year.

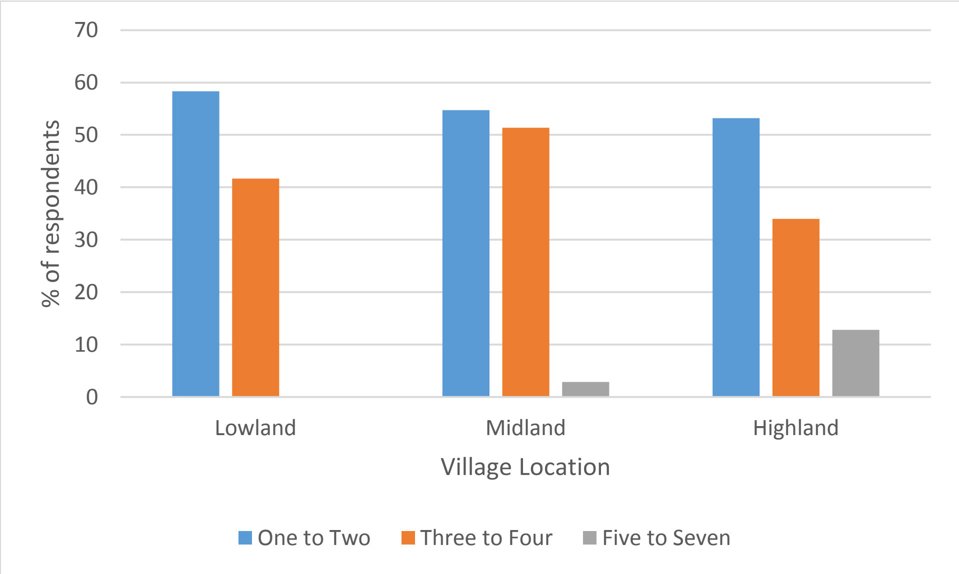

Figure 4:4 Number of people above 15 years of age at home

4.2.6 Farm location

Table 4:2 shows the location of the household head respondents' farms in the three zones. There was some variation across the zones as to where respondents own their farms. While the majority of respondents from the lowland and midland zones owned farms in the lowland and midland zones respectively, the majority of respondents from the highland zone owned farms both in the highland and lowland zones. This is because settlement in this region started in the highland zone, but as population increased and the need for larger farm sizes increased, the early generation of people in the highland zone were given extra land in the lowland zone by traditional leaders, in addition in later years to some highland farmers buying land in the lowlands zone (Soini, 2005). Few respondents from the lowland and midland zones own farms in other zones. This implies that if rainfall variability is experienced in the lowland zone for example, it is likely people in the highland zone will also be affected because some of their farms being located in the lowland zone. However, having farms in two agro-ecological zones could also increase the resilience of farmers to climate variability preferentially felt in one agro-ecological zone.

Table 4:2 Location of the household head respondents' farms as summarised from household survey across the lowland, midland and highland zones

Farm location	Count/Percentage	Zones			Total
		Lowland	Midland	Highland	
Lowland	Count	23	2	1	26
	% within zone	95.8%	5.7%	2.1%	24.5%
Midland	Count	0	28	0	28
	% within zone	0.0%	80.0%	0.0%	26.4%
Highland	Count	0	1	17	18
	% within zone	0.0%	2.9%	36.2%	17.0%
Midland and lowland	Count	1	4	0	5
	% within zone	4.2%	11.4%	0.0%	4.7%
Highland and lowland	Count	0	0	29	29
	% within zone	0.0%	0.0%	61.7%	27.4%
Total	Count	24	35	47	106
	% within zone	100.0%	100.0%	100.0%	100.0%

4.3 Perception of Climate Change

This section explores the small-holder farmer's perceptions of climate change drawing on data from the focus groups in the three agro-ecological zones. To determine the participants' perception of the existence of climate variability, the focus group participants were asked to describe the rainfall patterns and how this has changed over time.

4.3.1 Description of rainfall patterns of a 'normal' year

Figure 4:5 displays the description of rainfall patterns of what was seen as a normal year as described by respondents from the three agro-ecological zones. As agreed in all the focus group discussions, what stands out in this figure is that, in all three zones, a normal year has two rain seasons, a long and a short rain season. However, although the number of months with short rains is almost the same across the three zones, there was temporal variation across three zones in long rain season rainfall in the long rain season which were three months, four months, four months and two weeks in Lowland, Midland and Highland respectively. Therefore, the highland zone has the least number of dry months compared to the other zones.

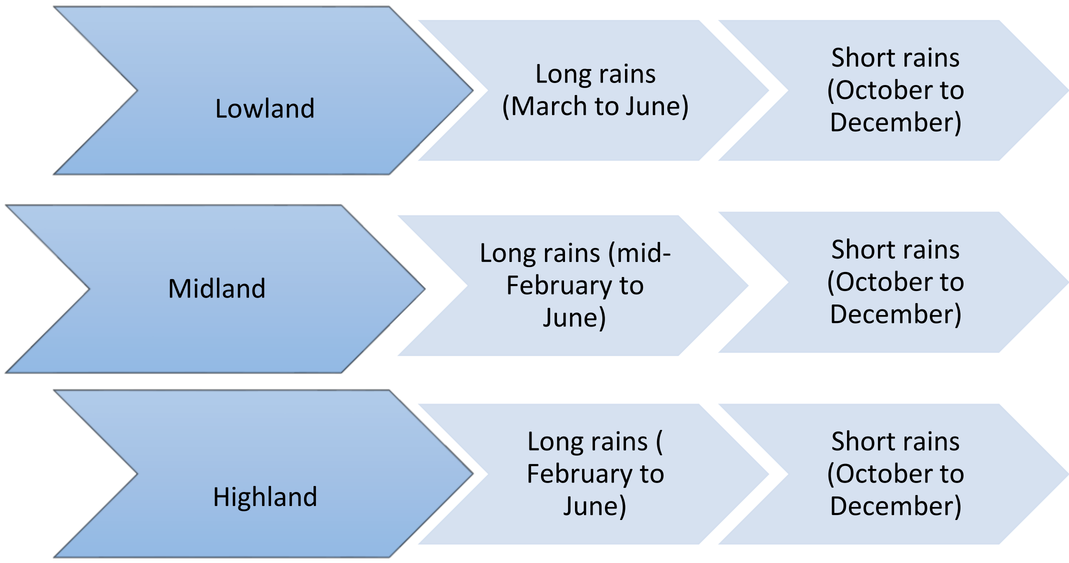

Figure 4:5 Description of rainfall in what is seen as a normal year as perceived by respondents in focus group discussions across the three agro-ecological zones.

4.3.2 Perception of climate change

Farmers understand the patterns of the weather in their region and use this knowledge to guide decisions regarding farming activities (Nidumolu et al., 2015). Focus group respondents reported changes from what they perceived as normal rainfall patterns in all three zones. Farmers perceived changes in both the long and short rain seasons.

4.3.2.1 Perceived changes in short rain patterns

In all the focus group discussion, the short rains were perceived to have change but there were differences in the ways these rains were perceived to have changed and the magnitude of the changes across the three zones. All the focus group participants agreed that, rainfall in the lowland and midland zones had become infrequent or there was no rain at all in the short rain season. The farmers in the highland zone also had an interest in the rainfall patterns in these two zones because some highland zone households also have farms in the lowland and midland zones. All focus group respondents perceived that the short rains do not arrive every year as they used to and in some years it does not rain at all in the short rain season. The infrequent and irregular short rain pattern was perceived to start in the 1970s and 1980s, s reported:

'…. but now even short rain season is not available… the problem started around 1970s and 1980s. Before that, the short rains were good enough and capable of providing enough water for crops growth to maturity.' (Focus group discussion, Lowland).

Compared to the lowland and midland zones, respondents from the highland zone perceived changes in the distribution of the short rains rather than a complete absence of short rains. To them it is not common to have no short rains, but they perceive a difference in the number of rainy days during the short rain season compared to the past. These changes were reported to have started in the 1980s, with the situation worsening over the last ten years, as reported:

' …. problems with rains started around 1980s. But for the past ten years the problem has increased because the number of rainy days and its distribution has decreased. The problem has increased from the past ten years… it is very challenging here because if short rain is not good here (Highland), it affects the coffee flowering, so the following season there will be no good coffee harvest' (Men focus group discussion, Highland).

This implies that, short rains have changed in all three zones. However, the greater impact is perceived in the midland and lowland zones which can now see an absence of rain during what was known as the short rain season.

4.3.2.2 Perceived changes in the long rains

In all the focus group discussions except for some people in the male focus group in the midland zone, the current rainfall variability in the long rain season was described as new, and unpredictable, shrinking, and of changed in temporal distribution. Some participants in the male focus group in the midland zone perceived the existing long rain patterns as a normal pattern.

The number of the rainy days in the long rain season were perceived to be fewer than in the past. In the lowland zone it was perceived that, compared to the past when it used to rain for three months, currently it sometimes rains for only a month. The respondents from the highland and midland zones reported shrinking long rains season which negatively affects people's livelihoods as rain cannot support crop growth to maturity:

'….it doesn't rain like past. For example, in the past ten years we have been experiencing decreasing rainfall. We used to see rainfall starts few days before or during Easter holiday, but currently it has changed. Sometimes the rain starts in March and end in May.' (Men focus group discussion, Midland)

The rains were also reported to be unpredictable. It was reported in focus groups in all three zones that, currently it is difficult to tell when the rains will start, and the decision of when to plant crops is difficult for farmers to make compared to the past when they knew the right time for planting crops as there was a known pattern of weather systems in the area. One farmers made the analogy to gambling when it came to the process of selecting and deciding planting dates. Getting the right time to plant is currently beyond the traditional knowledge systems embodied by these farmers. An excerpt describing the unpredictability of the long rains is given below:

*'…. I just want to say that; the rainfall depends on God's grace. For example, in the past ten years, it has been difficult to know exactly when to plant maize seeds. I can recall, in my childhood, there was a specific time in the season our parents used to make sure seeds must be in the ground (planted). It was from 5th March onward. And it won't take long before it starts raining. It will rain consecutively in such away maize will be getting enough rainfall until they grow to maturity. But from the past ten years it is like tossing the dice, people plant seeds but they are not sure when it will rain. But currently we plant and pray, if you are lucky you may guess the right time' (*Men focus group discussion, Highland).

This implies that, the past trend of rainfall has changed in such a way that farmers are unable to use their traditional knowledge to understand the onset of the rainfall, thus making it difficult for them to decide the right time for farming activities because of the increased weather variability.

Another change observed in the long rain season is the way rainfall is distributed throughout the season. In all three zones, the distribution of the rainfall was one of the biggest challenges observed in existing weather patterns. In addition to changes in the number of rainy days, and the timing of the onset of the rainfall, respondents described how even when it starts raining and farmers decide to plant their seeds or seedlings, the way rainfall is distributed is not the same as in the past. Farmers perceived that in the past, when it started raining, it would rain consecutively with few dry spells that could affect plant growth in the lowland and midland zones, or with no dry spells at all especially in the highland zone. The changes in rainfall distribution was the most complex issue which farmers in all focus groups had concerns about, as one farmer explained:

'…. in the past you will find in March it is heavily raining in this zone (Highland) and when it gets to May and June, it is a heavy storm in such a way people cannot go anywhere. But now you will find in May you might get two to three weeks with no rainfall during the long rain season. It doesn't rain consecutively as it used to do in the past. And for the Lowland where we grow most of cereal crops, it may rain for a week then it stops for two weeks, then it may rain again for three days or week and then stop again, in fact the way the rainfall is distributed thought the season in most cases is the problem' (Men focus group discussion, Highland).

This implies the perceived presence of dry spells during the long rains season where they were perceived not to exist before.

A few respondents in the focus groups particularly in the midland zone had the opinion that the observed weather patterns now are just part of the weather systems that have always been experienced and that people have been living with these changes. To them, the observed variability is not something new although there may be an increased level of variability, as explained:

' …. I am not very old, currently (2017) I have 74 years, although I admit there is increase level of climate variability, but I can say rainfall variability started long time ago. I can recall, in 1969 long rain season started 26 April, I can remember this as it was my wedding day. but the harvest was normal, we did not experience food shortage……. the rainfall has been changing sometimes in every ten years as we used to experience heavy storms in ten years but the next ten years' rainfalls wouldn't be enough. There was also a period of high temperature which forced people to sleep outside as coping mechanism' (Men Focus group discussion Midland).

The results from the household survey as shown in Figure 4:6 show that more than 60 percent of respondents in all three zones perceived rainfall variability was increasing. While no respondents from the lowland zone perceived decreasing rainfall variability, a quarter of respondents in total from the highland and midland zones perceived decreasing trends in rainfall variability over the past 30 years. Less than two percent in total of respondents from the midland and lowland zones perceived no changes while no respondent from the highland zone reported no changes in rainfall variability. What this results tells is that the majority of, but not all, respondents perceive increased levels of climate variability.

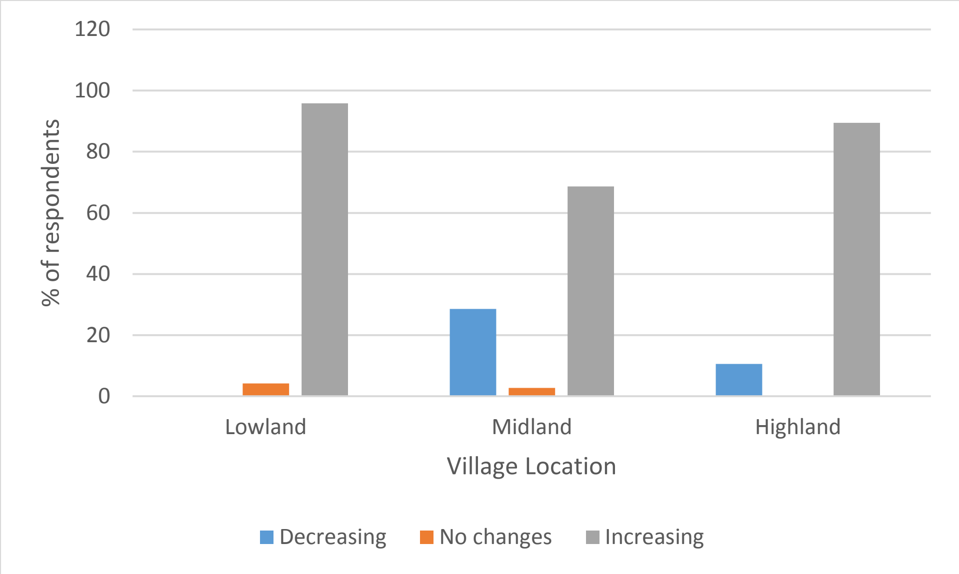

Figure 4:6 The trend of rainfall variability as perceived by household head survey respondents from the highland, midland and lowland zones.

4.3.3 Perceptions of likely future variability in rainfall

The farmers from the focus groups and household surveys were asked to predict the trend of rainfall variability in the next 10 to 20 years. Results show variation between the responses from the focus group discussions from different zones and from the household surveys. The results from the focus group discussions indicated that both focus groups from the highland zone were very uncertain about how the future will unfold, and both focus groups in the midland zone perceived rainfall to be so unpredictable it was hard to tell what will happen, while respondents from the lowland zone reported that if serious measures to address the problem are not taken, the area is at risk of turning into a desert Table 4:3.

Table 4:3 Summary of focus group results on the future variability of rainfall

Condition/Zone	Lowland	Midland	Highland
Unknown			(shaded)
Unpredictable		(shaded)	
Desertification	(shaded)		

Below are some excerpts from the respondents

'…. we cannot really understand how conditions will be in the next 10 and 20 years. We are not sure of what will happen.' (Women focus group discussion, Highland)

'…. it is unpredictable.' (Women focus group discussion, Midland)

'…. if the efforts will not be taken the area may turn into a desert and water can disappear.' (Focus group, Lowland)

The results from the household survey Table 4:4 show that there are differences in the perception of the trend of rainfall variability over the next 10 to 20 years for respondents from all three zones. As opposed to focus group participants, especially in the midland and highland zones who showed uncertainties in considering future climate, most of the respondents in the midland and lowland zones (58.3 and 54.3 percent respectively) perceived that it is very likely for rainfall variability to occur in the next 10 to 20 years while the majority of respondents in the highland zone (53.2 percent) perceived the opposite, as they hope that conditions will improve due to their tree planting. However, in my opinion, although planting could increase water resources (due to condensation from the atmosphere) other measures to reduce emission of greenhouse gases also are needed.

Table 4:4 Household heads' perceptions of the future climate variability for respondents from the lowland, midland and highland zones

Future variability	Count/Percentage	Zones			Total
		Lowland	Midland	Highland	
Unlikely	Count	2	11	25	38
	% within zone	8.3%	31.4%	53.2%	35.8%
Somewhat	Count	8	5	7	20
	% within zone	33.3%	14.3%	14.9%	18.9%
Very Likely	Count	14	19	15	48
	% within zone	58.3%	54.3%	31.9%	45.3%
Total	Count	24	35	47	106
	% within zone	100.0%	100.0%	100.0%	100.0%

4.4 Impacts of climate change on livelihood assets

The data about the impact of climate variability on livelihood assets was collected by household heads survey, focus group discussions and key informant interview. The household head survey used the post-disaster assessment tool kit by the Food and Agricultural Organisation of the United Nations (FAO) and International Labour Organisation (ILO) (2007) in order to assess the impacts of climate change impacts on livelihood assets. Since this tool was modified to avoid assuming the presence of climate change in the study area, an additional question about the significant impact of climate variability on livelihoods was asked. The perceived impact of climate variability is broadly characterised based on the capital assets on which the households depend. Based on the respondents' perceptions, the impacts are presented below in four categories namely, human, financial, natural and social capital. There was no significant impact on household physical assets like motor bikes, bicycles, cars, farm implements or other assets of the like owned by household. This section starts by presenting results from the household heads survey, then includes results from the focus group discussion. The section finishes with data drawn from the key informant interviews.

4.4.1 Impact on financial capital

The study inquired about households' sources of income and whether this has changed over time in order to find out if respondents have changed their income sources as a result of climate change. The results show that no farmers have changed their income sources. However, results relating to the perception of climate change impacts on their livelihood assets show that the majority of the survey respondents from the highland and midland zone reported that climate variability had reduced their household income, associated with crop failure or low yield. The same observation was made in all the focus groups discussion across the three zones, as exemplified by the except below:

'We participate in farming activities as a means of getting income …. the production is not enough, and the income has decreased' (Women focus group discussion, Highland)

The majority of survey respondents from the lowland zone perceived that the main impact of climate change relating to financial capital related to increased production costs, mainly coming from the need to purchase seeds, and associated costs of re-doing activities if there were delays in the rain it was irregular. The same theme of increased costs came up in all focus group discussions across the three zones as exemplified by the below excerpt:

'…. sometimes we have to replant even two or three times because we don't understand these rains. You may plant crops or seeds when you see rainfall has started or the time that we usually plant seeds has arrived but the rain may delay or it may rain for a day and stop. The seeds decay and we decide to plant again, after replanting we may or may not get a

harvest depending on how it will rain. So this rainfall makes us incur extra costs to buy seeds, fertilizer and pay labour costs as we repeat farming activities which might contribute to low/no profit at the time we sell crops.' (Men focus group discussion, Midland)

Other respondents perceived the financial impact of climate change to be the high costs of buying food because of the need to buy food which would normally come from the farm, and the increased food price when the harvests are low. The same theme appeared in all the focus group discussions across the three zones when discussing the impact of climate variability to their livelihoods as explained in the excerpt below:

'Our main source of food is our farms, even though sometimes we may buy other food which we do not produce such as rice or sugar, we depend on farming to get money to buy those foods. So when we do not produce enough we are required to buy food which was initially not in our budget because we expect to have some from our farms. To make things worse, when there is not enough harvest the food price goes up thus requiring more money to buy food at the time when money is not available' (Men focus group discussion, Highland).

As shown in Figure 4:7 a few survey respondents across all three zones considered the main impact was for them to abandon their farm, particularly for areas with no access to irrigation. Some farmers described how they have been pushed by climate variability to stop farming in their own farms because they perceived that if the rain was not enough, they would not have the means to provide alternative water sources to rescue their crops. The same theme was raised by focus group participants in the lowland zone but not in the midland or highland zones. The excerpt below illustrates this point from a lowland farmer;

'In the places where there is no access to irrigation some people have left their farms for many years without cultivating any crop because they perceive it to be riskier to invest. If they were able to use their farms they will have contributed to their livelihoods development' (Focus group discussion, Lowland)

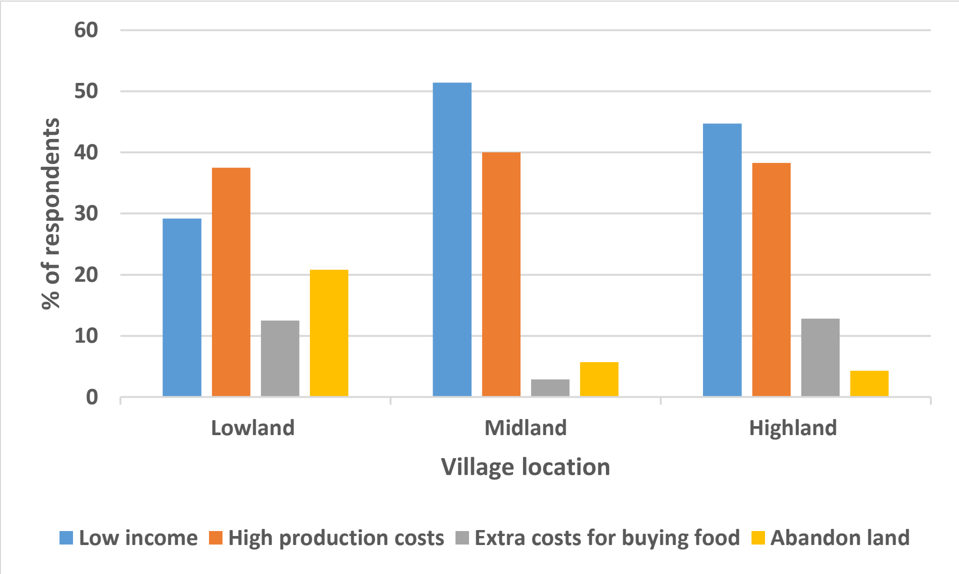

Figure 4:7 The household survey results from the three agro-ecological zones on the main impact of climate variability on financial assets

Another theme which was common from the focus group discussions across all zones but did not appear in the survey related to the decline of business because of reduction of people purchasing power to goods and services. The difficult environment for doing business is evident through the excerpt below:

'…. even doing business is being difficult because people have got no money,' (Men focus group discussion, Midland)

4.4.2 Impact on natural capital

The impact of climate change on natural capital was expressed in terms of a reduction of water in streams and rivers. The household survey asked respondents about the trends in the amount of water available in their streams and rivers and the potential causes for any trends. The results show that respondents associated rainfall variability with a changing availability of water resource Figure 4:8. The majority of respondents across all three zones who had access to streams and rivers reported decreasing amounts of water (lowland 91.7%, midland 42.9% and highland 87.2%). It is important to clarify that in the midland zone, although the percentage of people who perceived decreasing water volume is less than 50%, this figure represents the majority of respondents with access to water, as most of the respondents had no access to irrigation (coded as not applicable).

Very few respondents considered that the amount of water in rivers or streams was increasing or normal. The reason which was mentioned by all respondents with access to water for irrigation for the reduction in water volume was decreasing rainfall. Although potential rainfall decrease may indeed have contributed to water shortages, there may also be other reasons, not mentioned by respondents in the survey or focus groups, which might have contributed to a reduction in water volume in the area, such as an increase in the number of people using irrigation practices and land use change.

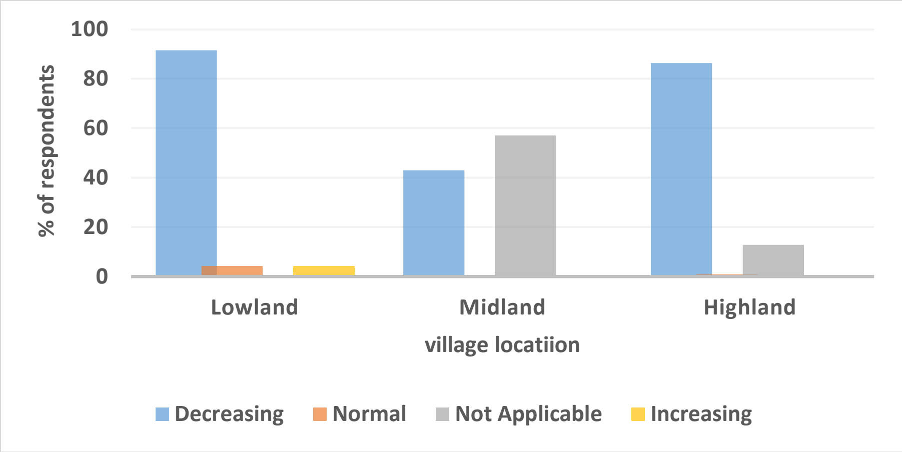

Figure 4:8 Reported trends in the amount of water in rivers and streams from household head surveys across the three agro-ecological zones

The implication of a reduction of water volume in rivers and streams to the household's ability to make a living shows that for the majority of respondents with access to water for irrigation in all three zones the perceived main impact was a reduction in the number of hours allocated for irrigation Figure 4:9. A small number of survey respondents in all zones mentioned how a reduction in water volume had happened led to a reduction in farm size. Other impacts in the midland and highland zones included wilting crops and a need to stop horticulture (growing vegetables). These impacts were felt more by female headed households, and those with older people as they could not deal with challenges that comes with struggles to ensure water reach their farms. A few respondents had experienced no perceived impact.

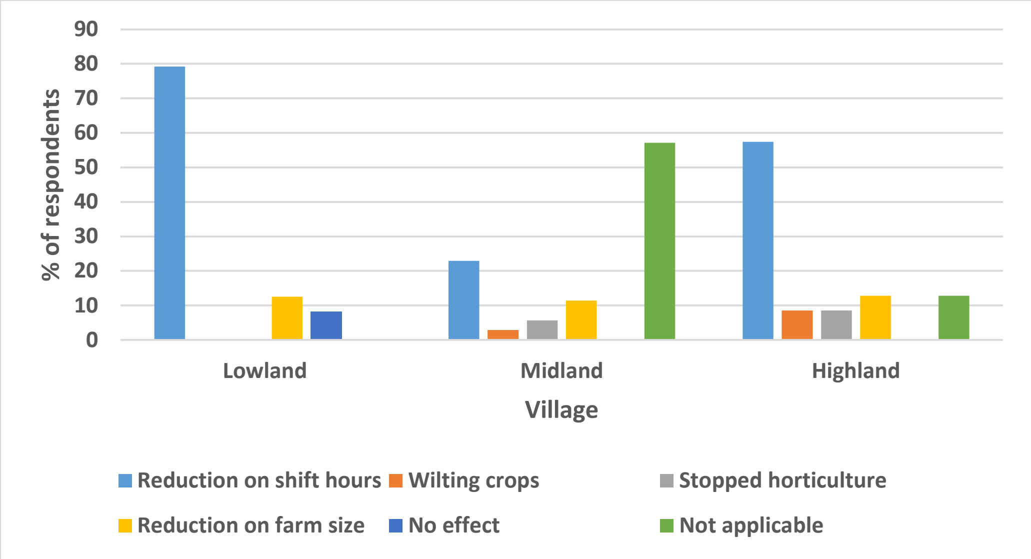

Figure 4:9 The survey results about the main impact of reduction of water in surface water sources as perceived by respondent across three agro-ecological zones

4.4.3 The impact on social capital

The impact of climate change on social capital was examined through an assessment of any trends in support between households, perceived reasons for any changes, and an understanding of the current major sources of support in case of problems related to livelihoods in the family.

Respondents were asked about their overall sources of support if there is problem in the household. It was observed that there were differences in the major source of support across the three zones. As displayed in Figure 4:6, major sources of support for respondents in the lowland zone included their children, followed by informal financial institutions such as village community banks; in the midland zone major sources of support included relatives, followed by neighbours; while in the highland zone, as with the lowland zone, major sources of support were from their children, followed by informal financial institutions. The use of formal financial institutions, community and friends were not common sources of support in all three zones. Note that, this question was analysed using multiple response as respondents mentioned more than one source of support.

Table 4:5 The overall sources of household support in the lowland, midland and highland zones as reported in the household survey

Zone/Problem		Children	Clan members	Informal finance	Formal finance	Neighbor	Village and religious	Relatives	Friends
Lowland	Count	15	6	11	2	1	2	1	0
	Percent	62.5%	25.0%	45.8%	8.3%	4.2%	8.3%	4.2%	0.0%
Midland	Count	6	4	12	1	15	3	18	4
	Percent	17.6%	11.8%	35.3%	2.9	44.1%	8.8%	52.9%	11.8%
Highland	Count	21	9	14	3	9	1	12	2
	Percent	44.7%	19.1%	29.8%	6.4%	19.1%	2.1%	25.5%	4.3%

The respondents in the household survey were asked to describe the trend of social capital in the form of support between households. As displayed in Figure 4:10 it was revealed that, more than three quarters of household head survey respondents in all three zones reported decreasing support between households. Very few respondents in all three zones considered support between households to be increasing or static.

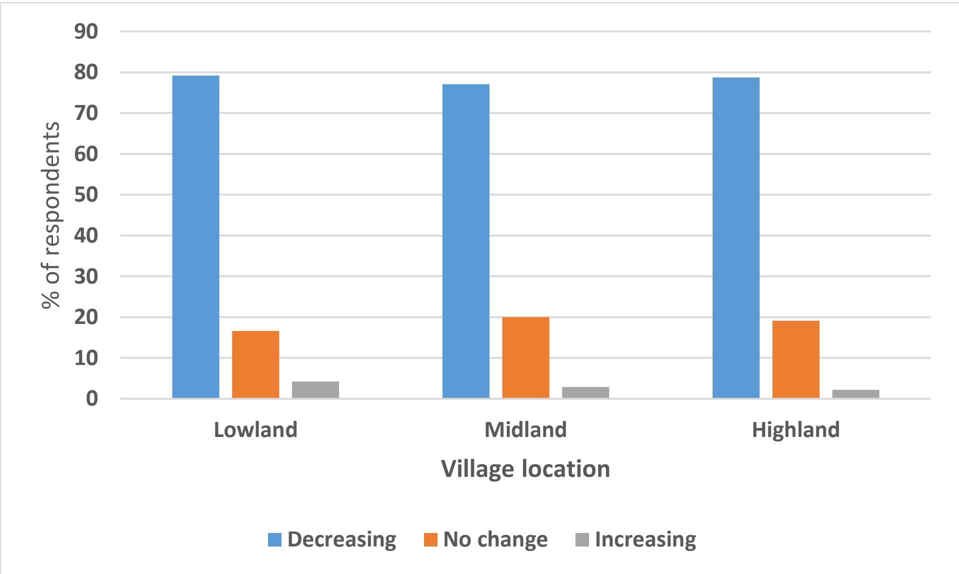

Figure 4:10 The trend of support between households across the three agro-ecological

There are several different reasons that were given for the reduction of support between households. The results show that Figure 4:11 more than half of respondents in all three zones perceived that they did not have enough from what they produced to be able to give it away to other households. A small percent of respondents in all three zones mentioned that the value had increased of most of the things which may previously have been given away for free, so people would sell these things for income, and that there was less love between households than previously.

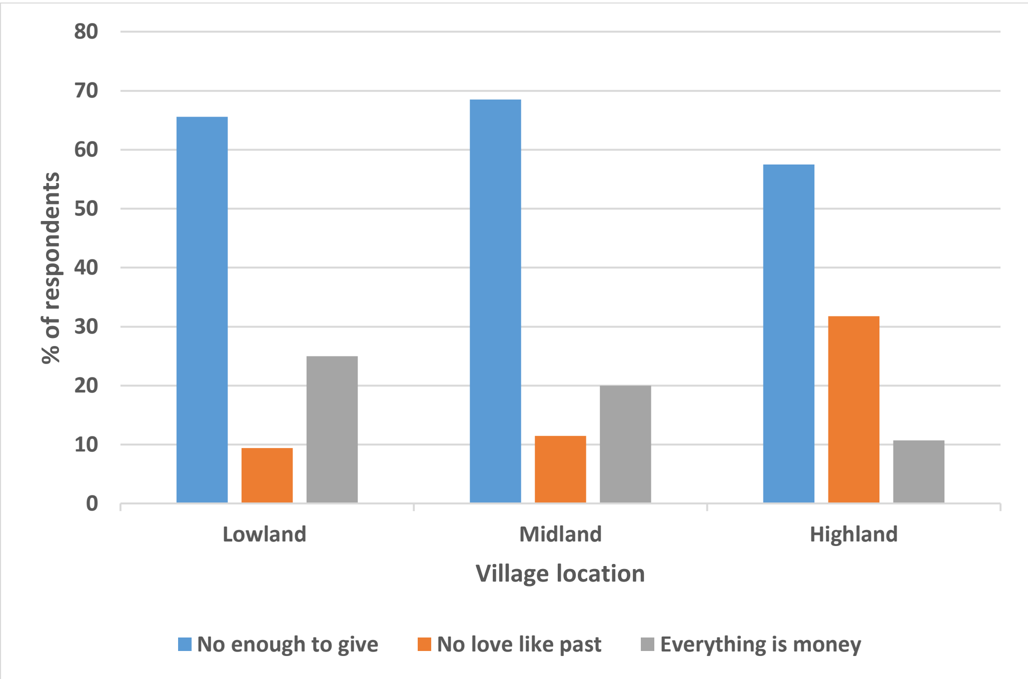

Figure 4:11The main reasons given in household head surveys for decreasing household support across the three agro-ecological zones.

Respondents were asked about the impact of the reduction in support between households to the ability of the household to make their living. It was observed that majority of respondents from the highland zone reported a positive impact due to the promotion of household independence by encouraging saving, while in the midland and lowland zones nearly half of respondents reported that life was more difficult, as well as an increase in independence; and small proportion of respondents in each zones reported to increased life costs Figure 4:12.

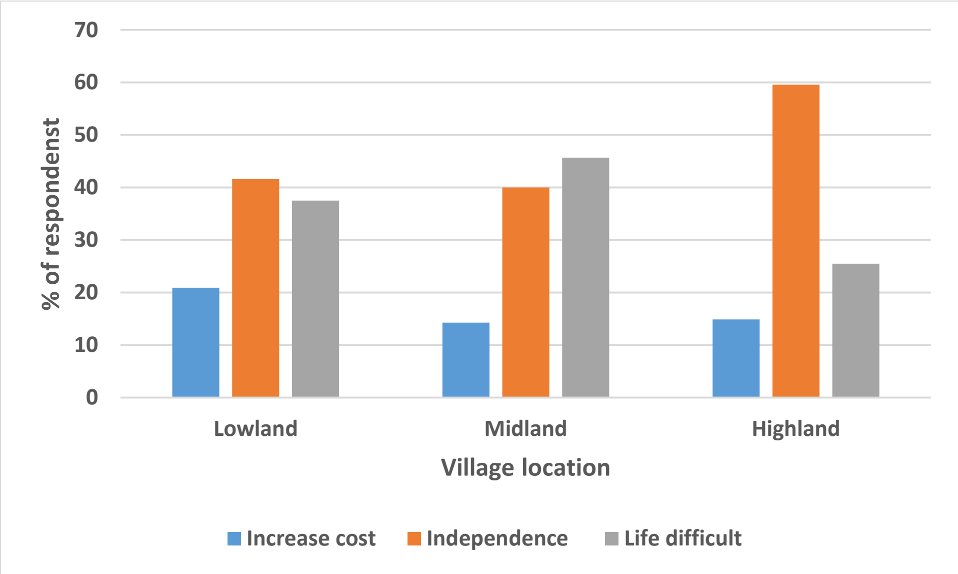

Figure 4:12 The major impact of reduced social capital (through reduced between-household support) to people's livelihoods in the three agro-ecological zones as reported in the household survey

4.4.4 Impact of climate change on human capital

The climate change impacts on human capital manifested in several ways as observed in the household survey and focus group discussions. The impacts related to how climate change led to a reduction of human labour through migration, and how the prevalence of malaria affected human capital.

4.4.4.1 The role of migration

The household head survey inquired whether there was a member of the household who had migrated to a different region for more than six months. The results show that the highest percentage of the respondents who had experienced outward migration from their household were from the highland zone, followed by the midland zone and the lowland zone.

This means for at last every two households in the study area, at least one had experienced outward migration Figure 4:13.

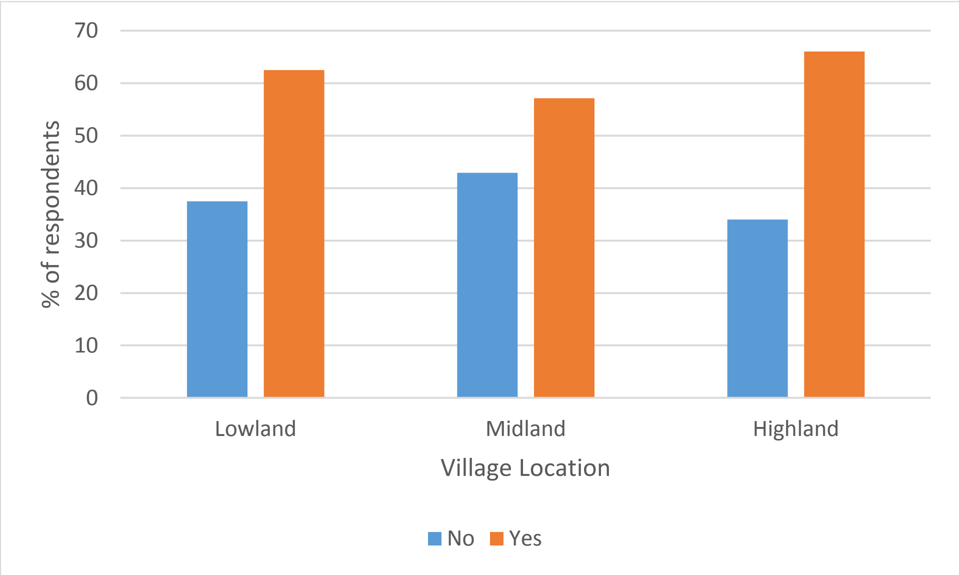

Figure 4:13 Experience of outward migration from households in studied households across the highland, midland and lowland zones

There are many reasons which have contributed to people moving from the study areas. As displayed Figure 4:14, more than a quarter of households that had experienced outward migration reported that members of the family had moved away to find jobs due to the limited job opportunities in off farm income job in the area. The second most common reason for outward migration from the lowland and midland zones was due to failed farming. This category described situations where household members had been happy to stay and farm, but had decided to move away after trying farming for several years and failing, until they decided to try something else elsewhere. Education was given as a reason to describe migrants who are away from the household because they are studying away from home. Even though this may be seen initially as a temporary measure the lack of secondary and tertiary educated household heads suggests that it is unlikely that those currently away for education purposes are likely to return to take part in the household and small-holder farming activities on a more permanent basis. Only a few respondents mentioned members of the household migrating because of marriage or business purposes. Not applicable was a code for households which had no migrants.

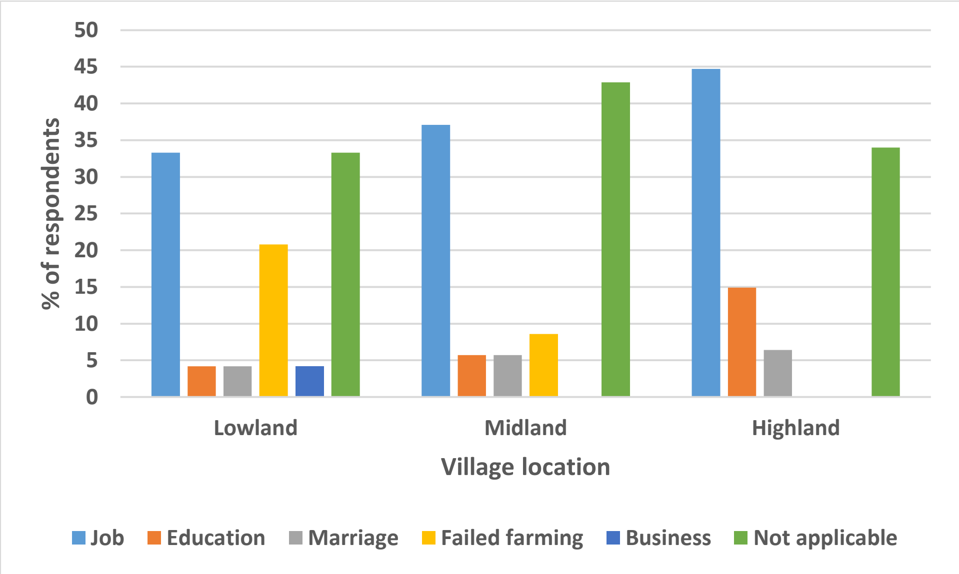

Figure 4:14 The main reasons given for household members moving away as reported in the household survey from the three agro-ecological zones

Respondents were asked how the absence of a member of their household who migrated away for more than six months a year affected their livelihoods. It was observed that there were mixed opinions across three zones. Apart from the household which had no migrants (coded not applicable) out of those household with migrants, the majority of respondents in the highland and midland zones considered migration to have a positive impact as they benefit from remittances, while in the lowland zone equal number of respondents perceived migrants to contribute by sending back remittances but equal amount perceived migration to contribute to labour shortages in the farm. While there were no respondents from the highland zone who perceived migration to reduce family income, a proportion of respondents in the midland and lowland zones believed this was the case Figure 4:15.

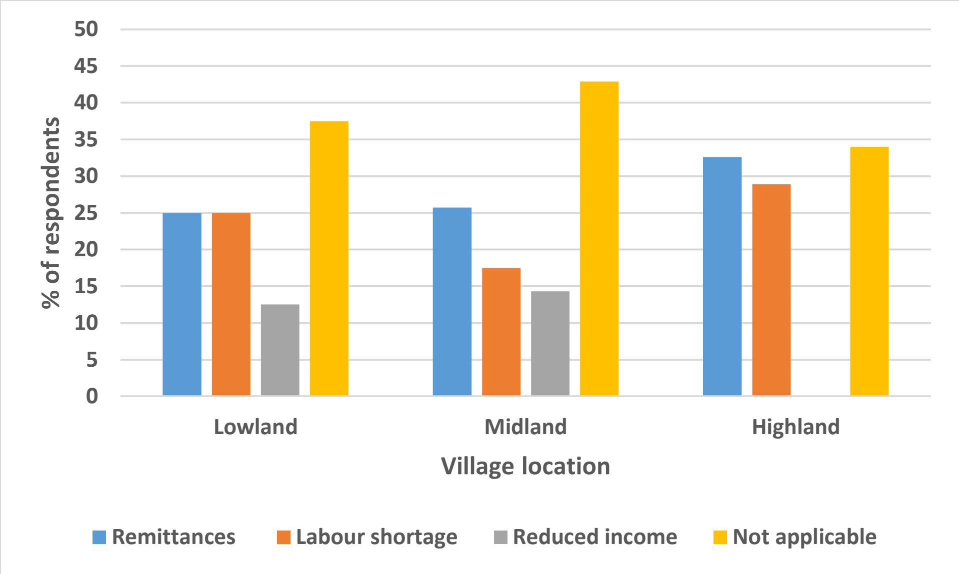

Figure 4:15 The main impact of human migration to the respondent's livelihoods across all three agro-ecological zones as reported in the household survey

4.4.4.2 The prevalence of malaria and its impact on livelihoods

Because of an increase in both maximum and minimum temperature across the region as displayed in Figure 4:16, the majority of respondents from all three zones stated that there is a problem of malaria in the study areas. The question about malaria disease was specifically asked as (Kulkarni *et al.*, 2016) had already reported the problem in the study area so I wanted to understand farmers' perception about the problem and how it affect their livelihood. The largest percentage of respondents to see malaria as a problem were recorded in the midland zone, followed by the lowland zone and then the highland zone. Very few respondents across all three zones reported to have no experience with malaria in the study area.

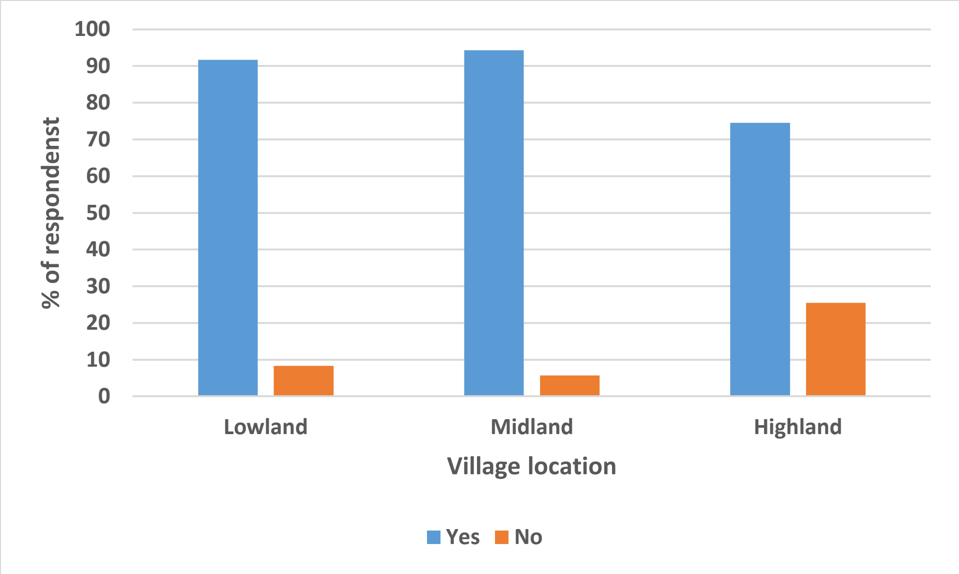

Figure 4:16 The percentage of respondents from the household head survey who were affected by the presence of malaria in the study area

The focus group participants in all three zones agreed that, there has been an increase of malaria in their area seen to be as a result of increased temperatures, even in places such as the highland zone where the temperature used to be too low to allow the survival of mosquitos which spread malaria:

'…. Currently we are facing the problem of malaria disease because of increased temperature as it (the disease) didn't exist before in this area (Highland)…. it was the disease for people in Lowland or those living in Dar es Salaam (area with relatively high temperature). It used to be very cold here for mosquitoes to survive. (Men focus group Highland).

Respondents were asked to explain how presence of malaria affected their livelihoods. The results indicate that Figure 4:17 the majority of respondents in the lowland and midland zones reported that the presence of malaria lowers production because they those who are sick with malaria cannot take part in production activities, and in the highland zone a greater proportion of respondents complained that the disease contributed to reduced income as they needed to spend money on medication instead of investing in the farm. Not applicable was coded for respondents who did not reported the presence of malaria in their location.

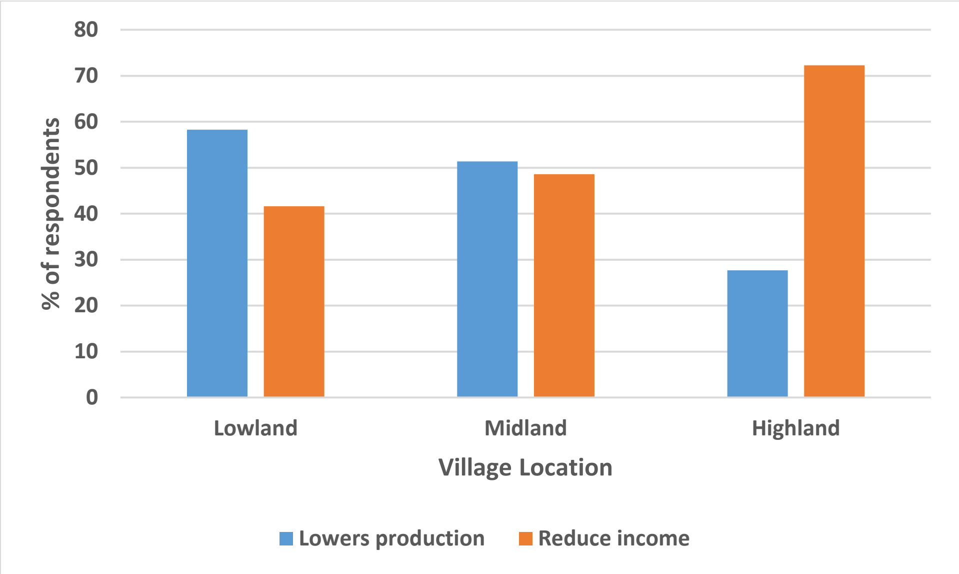

Figure 4:17 The effect of malaria on household head survey respondents' livelihoods across the three agro-ecological zones

4.5 The results from key informants on the impact of rainfall variability in the study area.

Interviews with key informants were carried out as part of the data collection for this study. As part of the interviews key informants were asked about their views on the impact of climate change on small-holder farmers in the study area, and about the impact of climate change on their own roles.

4.5.1 Perceived impacts of climate change on small-holder farmers

The key informants were asked whether impact of climate change to small-holder farmers actually being seen in this area and reported climate change to affect small-holder farmers in different ways. Similar to the responses from the household head survey and focus groups these responses can be categorised into financial, human and natural capital impacts, there was impacts related to social capital. The impacts of climate change on small-holder farmers mentioned by key informants included income shortage, increased production costs, increased malaria, increased pests and disease, reduction of water volumes, and potential for increased temperatures that could threaten the suitability of the area for *coffea arabica* production. The *Coffea arabica* is produces in areas with optimum temperature ranges between 18-21^{o}C, and can tolerate a maximum of mean annual temperature up to about 24^{o}C (Scott, 2015).

All key informants reported that, climate change contributed to small-holder farmers' failure to produce enough crops to be able to sell surplus for income to be spent on other life expenses. As exemplified by the excerpt below:

'…. Farming is almost everything to farmers. Because of rainfall variability farmers don't produce enough. If there is no good harvest, they won't get money for medication, clothing, and even paying school fees.' (Community development officer).

In all key informant interviews the respondents perceived climate variability to intensify agriculture lack of appeal particularly to youth caused by persistent failure in crop production. The interviewees emphasized that there was a common belief especially amongst the youth in rural areas, that a career in farming does not give good returns, and that given the recent increase of failure in farming activities amplified by climate variability, many of the younger generation are now less interested in farming activities.

'…. as some people perceive you cannot live successful life if you are a farmer, the climate variability makes youth think investing in agriculture is not worth doing.' (MVIWATA)

All key informants also believed that increased rainfall variability in the study area may contribute to a lack of access to food for the people in the study area. They argued that, as a result of climate variability which affects the amount and distribution of rainfall, and other impacts such as pests and disease, the amount of crops harvested decrease. Since farmers mostly produce their own food, low crop production automatically creates food insecurity. As one key informant reports:

'For farmers' harvests are affected because of amount, distribution or increase pests and disease the shortage of crops harvested lead to food shortage. Although it is not common for people in this area to face serious hunger, but the amount and quality of food consumed when there is less or no harvest is different from when there is harvest. When rain is enough there is plenty food and even green vegetables are plenty in many households. But if rain is not enough, even vegetables are difficult to access' (District Agriculture extension officer).

All key informants identified issues associated with increased malaria as a result of an increased temperature. As reported by community development officer;

'…. In some places especially in Highland, it was difficult for mosquito to survive because of cold weather, but now people are complaining about malaria disease because of increased temperature.'

The climate change is also associated with increase pests and disease in the study area. These diseases were reported to crops like tomatoes, banana, beans and maize. Some of the disease were reported to have no cure or treatment and when the crops were affected they are so contagious is such away if the disease begin today, the following day would be spread to all farms and even if the crop was ready for harvest.

Also, climate change may potentially change the climate of the agro-ecological zones across the study area and endanger the suitability of the area for coffee Arabica cultivation. This concern was raised by a representative from the Coffee Research Institute:

'*As you may be aware, in this area we grow coffee Arabica, which do well in cold and mountainous areas. However, if the temperature increase will persist, the area will be unsuitable for coffee Arabica and make farmers investment in this species futile'*

4.5.2 Impact of climate change on the key informants' role

Key informants perceived climate change to affect their own roles in a number of different ways. The role of these stakeholder is presented in section 3.6.1. The village agriculture extension officer reported that farmers doubted the advice they were been given especially relating to the time to plant seeds. Because of increased climate variability, the officer encourages farmers to prepare their farms early and plant as soon as the early rains arrive. However, because of the increased climate variability, the approach does not work all the time thus making farmers question the advice given:

'Climate change puts farmers trust in me to the test, because we need farmers to cope with existing variability by getting their farms ready as soon as possible so they can plant crops with the first rains. However, if the rains come and farmers plant their crops, and then the rains stop for while in such a way that the seeds or maize decay or wilt, farmers complain and ask me how did I predict this? This is very challenging because the strategy does not work sometimes.' (Village Agriculture Extension Officer)

Climate change also affected key informants' roles through affecting planned programmes of work and data quality in coffee experiment plots managed by the Tanzania Coffee Research Institute in the Kilimanjaro region. Climate change was reported to negatively affect the quality of the data collected from farm experiment plots, and the plans of work due to rainfall variability and unpredictable invasions of pests and diseases. As reported by the key informer from the Tanzania Coffee Research Institute:

'…. it affects us because as a research institute we usually have plans broken into five years. For example, you will find we have planned this year we want to undertake a certain amount of research. The emergence of pests and diseases as a result of climate change is unpredictable, they can emerge any time. So sometimes we shift our focus from our schedule and address the emerging problem. Also we have our experimental plots in different places, which are rain fed, so the quality of data is also affected.'

Furthermore, climate change affects some of the key informants' roles by reducing the capacity of farmers to adopt the innovations encouraged. For example, climate change contributes to low financial capacity of farmers to employ encouraged practices such as the use of agriculture inputs which they cannot buy if they do not have surplus crops. Or the climate-driven reduction of water flows in surface water sources limits farmers' capacity to plant improved coffee species because farmers complain they need a lot water which currently is not easily accessible. As reported by Tanzania Coffee Research Institute:

'*The climate change affects our role because it diminishes farmers' capacity to implement advice we provide to improve agriculture productivity. For example, the use of disease resistant coffee can help farmers cope with coffee berry disease and leaf rust disease, and can be harvested relatively earlier than the traditional ones. However, they need to be watered more regularly than the latter, so farmers complain about water shortage contributed by climate change'* (Tanzania Coffee Research Institute).

4.6 Summary

This chapter set out to explore indicators of climate change in the Kilimanjaro region, and how it affects the livelihood assets and capacity of small-holder farmers to make their living. Farmers and key informants perceive the existence of climate variability and uncertainty in all three zones. Rainfall was perceived to have changed both in the long and short rain seasons across the three zones, characterised by shrinking of the rain seasons, increased variability in the onset and distribution of the rainfall. This is also supported by Otte *et al*. (2017) in their study of the Kilimanjaro region, particularly in the lowland zone where they observed that climate change has increased seasonal rainfall fluctuation, with a quite large intra-seasonal variability and significant decline of long rains.

Most rural people in Sub-Saharan Africa depend on farming to ensure food security and income (Afifi *et al*., 2014) so changes in rainfall pattern have impacts on farmers' lives as crops produced by farmers serve both as a source of food and income for meeting necessary life cost such as building a house, educating children and medical treatment costs.

This study shows that climate variability affects farmers' livelihood assets across areas of financial, human, natural and social capital. Farmers' financial assets in all three zones were perceived to decline because of low crop production. Repeating farming activities was used as a coping mechanism to climate variability, as was buying food which would normally be produced on the farm, and renting farm land with access to irrigation.

Instead of investing in their capital assets, farmers are forced by circumstances to use the same income to re-buy seeds after crop failures, to repay labour to re-do planting and other necessary crop management practices after crop failures. Other studies in the Kilimanjaro region have estimated that climate change has claimed more than three quarters of farmers' income due to declining crop yield (Afifi et al., 2014). The impacts of climate change on financial capital are reported to multiply many fold where farmers' inputs are out-sourced. As Hertel and Rosch (2010, p.16) state:

'In the absence of commodity price changes, adverse impacts on productivity due to climate change will reduce farm earnings. These losses are likely to be magnified if farmer-owned inputs are not the only factors of production. For example, if farm-owned inputs account for half of total costs and the prices of purchased inputs are exogenous to agriculture, then, in the absence of a commodity price rise, a one percent decline in agricultural productivity will result in a two percent decline in farm income'.

Hertel and Rosch's (2010) observations are relevant to farmers in the Kilimanjaro region because sometimes they outsource labour, inputs such as fertilizers and seeds, and even transport to and from farm.

Reduction in available water sources due to climate change has an impact on people's way of making a living. Water from streams and rivers is used for farming purposes through irrigation. Partly, because of climate variability, water flows in surface water sources was perceived to be low in all three zones by the majority of respondents. The farmers' perceptions in this study of reduced water availability is supported by empirical modelling of river flows in the area. Clement *et al.* (2016) modelled water flow in the Sigi catchment river (located in Pangani basin where most rivers in Kilimanjaro are also found), and found that lower river volumes could be accounted for by land use change and climate change. Other studies of farmer perceptions with similar results to this study have been reported from the Southern Highlands in Tanzania (Kangalawe, 2017). As a result of water scarcity, hours available in irrigation shifts and farm size were reduced, and some farmers stopped horticulture practices to cope with the reduced water availability especially female headed and elderly households. Horticulture provides a source of vegetables to the household and an extra source of income when any surplus is sold (Misana *et al*., 2003) and therefore stopping horticulture has several knock-on impacts.

In addition to changes in rainfall amount and distribution, climate change is felt through increased temperature. This was perceived by farmers and key informants to affect human capital through increasing the incidence of malaria. The prevalence of malaria in the highland zone is reported in other studies, and is projected to increase because of temperature rises (Kulkarni *et al.*, 2016). This is quite a new disease for people in the highland zone (Soini, 2005; Pachauri *et al.*, 2014). Farmers in the study area perceived the prevalence of malaria to affect their livelihoods through reduction of family labour and reduction of household income through that spent on medication.

Climate variability has also produced a new group of migrants in the study area. Although the Kilimanjaro region is reported to have the highest amount of outward migration in search of green pasture (Kilimanjaro region socio-economic profile, 2014). There is new a group of people moving away from rural areas because of a persistent failure in farming amplified by increased climate variability. Some households with successful migrants send back remittances while others do not and their migration away from households affects the amount of labour available in the household.

Human capital is also affected by climate change through limiting research development in coffee experimental plots, as coffee is the major cash crop in the region. The disturbance in coffee experiment is categorised under human capital because it deals with knowledge creation. This may have an impact on the development of new coffee species and management practices that can increase productivity and resilience of the crops against changes in environment and diseases. Farmers loss of farming motivation is also a problem brought up by key informants and farmers, which can reduce the number of people participating in farming and therefore affect the amount of food production in the region and country as whole.

Climate variability is also perceived to have contributed to a reduction of social capital in the study area through reduction of support between households during difficult times. Although it is difficult to associate these changes specifically to increased climate variability, it can be argued that climate change has contributed to some degree. Farmers have depended on variety of sources of support when they need help, which include children, relatives, friends, neighbours and informal financial institutions. However, such support especially that involving household to household support was reported to have decreased.

4.7 Conclusion

This chapter set out to outline the perceived climate change trends and livelihood impacts of small-holder farmers, drawing on data from small-holder farmers themselves and several key informants who have links into the lives of the farmers in different ways. The chapter outlines perceived trends in temperature and rainfall in the Kilimanjaro region across three agro-ecological zones, and the impact of these climatic trends on small-holder farmer livelihood assets and the ability for farmers to make a living. The results indicate that climate change is perceived to have affected people's livelihood assets across areas of human, financial, natural and social capital. The climate change impacts on these assets affects the capacity of farmers in this area to construct their livelihood which may throw many farmers into greater poverty and reduce their capacity to meet their basic needs.

5 Household farm production practices and their impacts on environmental resources

5.1 Introduction

This chapter aims to explore the farm production practices small-holder farmers use and the impact of these practices on the natural capital of soil and water, which is used as proxy for environmental conditions (Turner *et al.*, 2003; Paavola, 2008) across the three agro-ecological zones. In this section I will present practices or strategies perceived by farmers to affect the quality and efficient use of environmental resources such as soil and water and therefore contribute to livelihood vulnerability to climate change. It should be noted that throughout, the measure of environmental conditions is through the perceptions of the small-holder farmers rather than through direct measurements of the conditions themselves.

The nature of the small-holder farmers that this project focuses on makes it appropriate to base a measure of environmental conditions and the impact of different management practices on their perceptions. Firstly, the farmers in question have a low level of economic development and therefore do not necessarily use modern measurement techniques to determine the soil characteristics. Secondly, research has established that the traditional knowledge capacity embedded in these farmers can accurately identify soil conditions (Kangalawe, 2012: Karltun, *et al.,* 2013:Ofgeha, 2017). Furthermore, it is important for me to study farmers' perception of environmental conditions because this is the significant factor in deciding on the options for soil management (Kangalawe, 2012; Ofgeha, 2017), which is an important condition in reducing livelihood vulnerability to climate variability. Mostly farmers in these settings use indicators such as soil erosion and land productivity as a proxy for good soil condition (Ofgeha, 2017).

This chapter begins by presenting different strategies employed by the small-holder farmers studied that affect soil conditions followed by strategies for water management and water-use efficiency, drawing on the household surveys and focus group discussion from all three agro-ecological zones. Thereafter, farmers' perceptions on agricultural land management and reasons for their perceptions of selected adaptation measures is presented. The chapter then explores the different adaptation measures promoted by key informants.

5.2 Practices affecting land and soil conditions

This subsection starts by presenting data from farmers' focus group discussions followed by data from the household survey results. Recall, results in the focus group is based on analysis of trend in soil fertility, water volume in surface water sources and amount trees in the farm. So the results in focus group presents changes in farm production practices defined as approaches enhancing or limiting soil and water management (Sivakumar and Motha, 2008). The survey results present soil management practices that are actually in use by farmers in the study area.

5.2.1 Farm production practices and their impact on soil condition

The focus groups explored changes in farm production practices and their perceived impact on soil fertility. These are summarised in Table 5:1. These practices increase livelihood vulnerability by having negative impacts on the soil and reduce the soil capacity to increase agricultural production. The discussed practices that negatively affect the soil condition include removing crop residue, mono-cropping, deforestation, and excessive and inappropriate use of chemical fertilizers. I will explain each practice in detail as follows.

In the focus group discussions participants reported that the majority of farmers especially with farms in the Lowland and Midland zones remove crop residues after harvest hence exposing the soil to agents of erosion and decreasing soil organic matter. This is contrary to what it is said past generations used to practice, and occurs because of the pressure of livestock feeds and free grazing animals. As one respondent in the highland focus group put it*:*

'In the past, our grandparents used to leave crop residues in the lowland farms, and because of that, the soil was very fertile. But currently cattle are grazed in our farms immediately after harvest, and we usually also move the straws to upland to feed cattle which causes soil erosion and reduces soil fertility.' (Men focus group, Highland).

Retaining crop residues could potentially have significant benefits to the soil and nutrient cycling, but may still leave an issue relating to livestock feeding.

Table 5:1 Summary of different soil-related livelihood management strategies and their outcomes as perceived by small-holder farmers as discussed in focus group discussions in the three agro-ecological zones.

Strategy/Zone	Highland		Midland		Lowland
	Men	Women	Men	Women	
Removing crop residues	Removing crop residue reduce cause erosion and reduce soil fertility	Removing crop residue reduce cause erosion and reduce soil fertility	Removing crop residue reduce cause erosion and reduce soil fertility	Removing crop residue reduce cause erosion and reduce soil fertility	Removing crop residue reduce cause erosion and reduce soil fertility
Mono-cropping	Mono-cropping reduces soil fertility	Mono-cropping reduces soil fertility	. Mono-cropping degrades soils	Mono-cropping degrades soils	Mono-cropping degrades soils
Excessive use of chemical fertilizers	Excessive chemical fertilizers degrade the soils. Soil were more fertile when organic fertilizer was used	Chemical fertilizers degrade the soils.	Excessive use of chemical fertilizers degrade the soils .	Soils were more fertile than now because of the use of organic fertilizers. Chemical fertilizers degrade the soils	Soils were more fertile than now because of the use of organic fertilizers. Chemicals fertilizers degrade the soils
Deforestation	Trees on the farm increase soil fertility and provide shade., Cutting trees affect the soil.	Trees on the farm increase soil fertility, and provide income. Cutting trees degrades soils and degrades other economic benefits	Trees on the farm increase soil fertility and provide shade. Trees cutting affects soil fertility and soil moisture.	Trees on the farm increase fertility and provide shade. Tree cutting places pressures on livelihoods	-

In all of the focus group discussions, participants reported most farmers, especially those with farms in the Lowland and Midland zones practiced maize mono-cropping (Figure 5:1) which contributes to the degradation of the soils, in comparison to intercropping as was practised by past generations. The priority of maize over beans is stem from the desire for income as maize is currently not only a food crop by a cash crop. The focus groups discussed how the use of intercropping increases soil fertility especially when combined with leguminous crops, prevent nutrient mining and provides resilience in case one crop fails. For example:

'In the past it was very common to mix maize with leguminous crops, but currently you will find some people are growing single crop regularly without changing or mixing with leguminous crops like past. For example, when they harvest maize, they do not rest the farm or mix with beans instead the next season will plant maize again which results in soil degradation' (Women focus group discussion, Midland).

Growing a single crop regularly affects the soil quality because different crops have different soil nutrient requirements and take nutrients from different depths, so growing same crop regularly takes preferentially removes certain nutrients from the soil which may later affect soil quality and farm productivity (Brankatschk and Finkbeiner, 2015).

Figure 5:1 An example of a maize mono-cropping observed in the lowland zone (source: author).

Cutting down trees without planting a new one was discussed in all the focus groups in the Highland and Midland zones, as negatively affecting soil quality and other socio-economic benefits from trees. Because of the desire for additional income and wanting additional growing room for horticulture, most farmers were reported to irresponsibly cut trees from their farms. Trees on the farms were mostly planted by the past generation and were reported to improve soil fertility, provide shade which conserved soil moisture, as well as having other benefits such as providing food and fibre. For example:

'There were many trees in the farms especially on the farm boundaries which helped to provide shade and increase soil fertility. However, recently people have been excessively cutting trees sometimes without consideration of young trees or fruits for the purpose of getting income and giving room for horticulture. Although it is challenging to us, the rules established by regional commissioner have forced people to stop cutting trees' (Men focus group, Highland).

I argue that the indiscriminate cutting of trees increase livelihood vulnerability not just by affecting environmental conditions but also jeopardising the additional socio-economic benefits associated with trees which are significant for livelihood adaptation to climate variability. On the other hand, through research that can develop appropriate tree species and distance to vegetables to reduce shade, there is potential of combining trees with horticulture.

Excessive and inappropriate use of chemical fertilizers was reported in all focus group discussions and was seen as negatively affecting soil quality. The use of inorganic fertilizers was most prevalent by farmers located in the Midland and Lowland zones and Highland farmers with farms located in Midland or Lowland where cereal crops are produced. The use of inorganic fertilizers in these zones was perceived to contribute to soil degradation. In comparison the use of manure and other organic fertilizers were reported to improve soil fertility compared to the use of chemical fertilizers. The use of chemical fertilizers is complicated by farmers' inability to undertake the soil tests to know the soil's requirements so they can use types and amounts of fertilizer appropriate to their soil's demands. As one farmer reports:

'….in the past, our grandparents were prepared for farming. If for example, they are planting banana trees, they will put animal dung and banana tree leaves in a pit and leave them to rot, after a while, they use it in their farms. When they plant banana in that way, the banana harvest was very good…. But recently people have expanded their farms and so it is difficult to transport or get enough manure for big farms. Instead, chemical fertilizer has been highly used and increased crop yield. Amid, people are complaining about several things including soil degradation, or that if you do not apply some, you cannot get any harvest' (Women focus group, midland).

5.2.2 Household survey results on the farm production practices used by household to improve soil fertility

This subsection presents results from the household surveys which asked farmers to identify practices they use to improve soil condition. The results shows that in the Lowland zone (Figure 5:2) the majority of respondents reported to use manure and chemical fertilizers. Other strategies which were mentioned included intercropping, mulching, fallowing[5] and crop rotation. No respondents mentioned the use of terraces[6] probably because most of the land in the lowland zone is flat. This data was analysed using multiple response because households were able to identify more than one strategy. The results from the household survey tally with those reported in the focus group discussions, with few farmers using intercropping or crop rotation, with more emphasis placed on the use of chemical fertilizers.

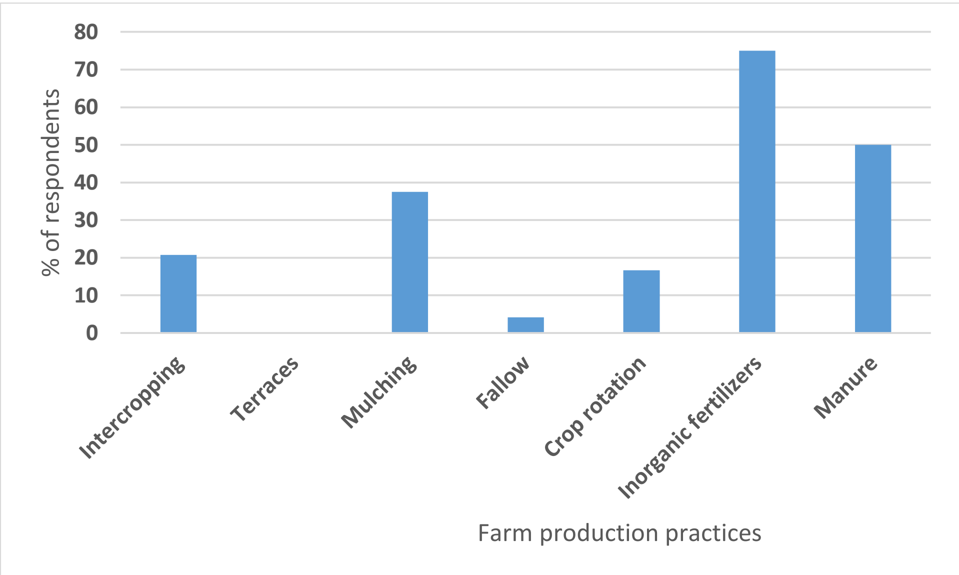

Figure 5:2 Household survey results of soil management strategies used by farmers in the lowland zone. Percentages are the percentage of farmers reporting to use that particular strategy out of the total of Lowland household surveys conducted.

[5] Not planting crops on the farm for a period of time in order to improve soil quality
[6] Narrow strips of land build in step- like structures to grow crops on sloped areas

Responses from the Midland zone survey (Figure 5:3) show that the majority of respondents mentioned the use of both organic and inorganic fertilizers, and few mentioned the use of others strategies such as intercropping, mulching, and crop rotation. There were no respondents who mentioned the use of fallowing. Compared to the Lowland zone there is a slightly higher number of respondents reported to use manure in their farms because respondents reported that most of them have cattle in their homestead so they mostly use manure for farms located in the Midland zone and chemical fertilizers in the Lowland zone farms. The fact that only a small percentage of respondents mentioned the use of intercropping, mulching or crop rotation tallies with results from the focus groups where people are prioritizing removing crop residues and mono-cropping, and the use of chemical fertilizers particularly in farms located in the lowland zone. No respondents reported the use of fallowing in the midland zone, potentially because of pressures over land area.

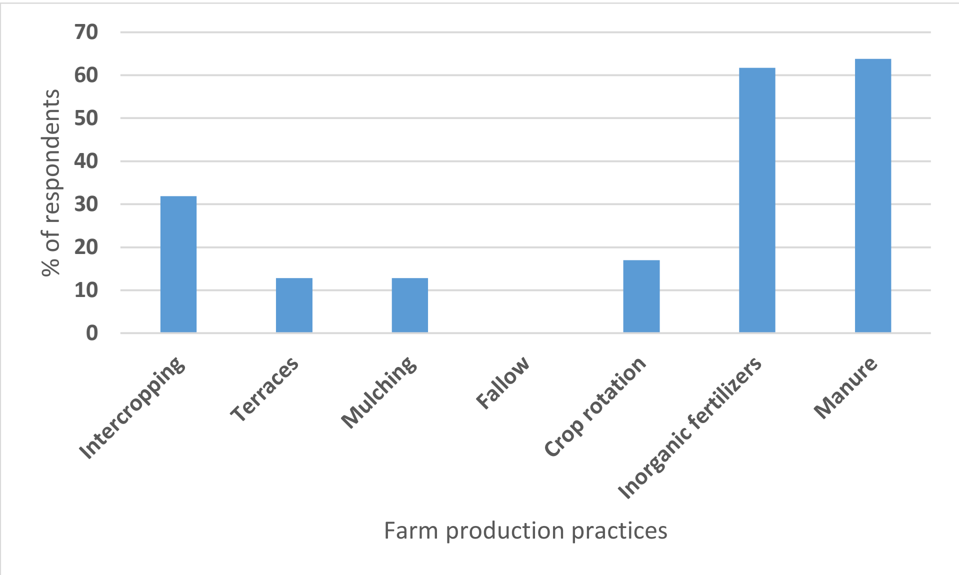

Figure 5:3 Household survey results from the Midland zone, showing the percentage of households out of the study population for that zone, using each of practice

The majority of the respondents from the Highland zone (Figure 5:4) mentioned the use of manure as a fertilizer particularly in farms located in the Highland zone and inorganic fertilizers for farms located in the Lowland zone to improve the soil conditions. Few respondents mentioned other strategies such as intercropping, terraces (Figure 5:5), mulching, and crop rotation. There were no respondents who mentioned the use of fallow periods in the Highland zone potentially because of land shortages. Compared to the other zones, a slightly higher percentage of respondents from this zone reported the use of terraces because of the steeper topography of the area.

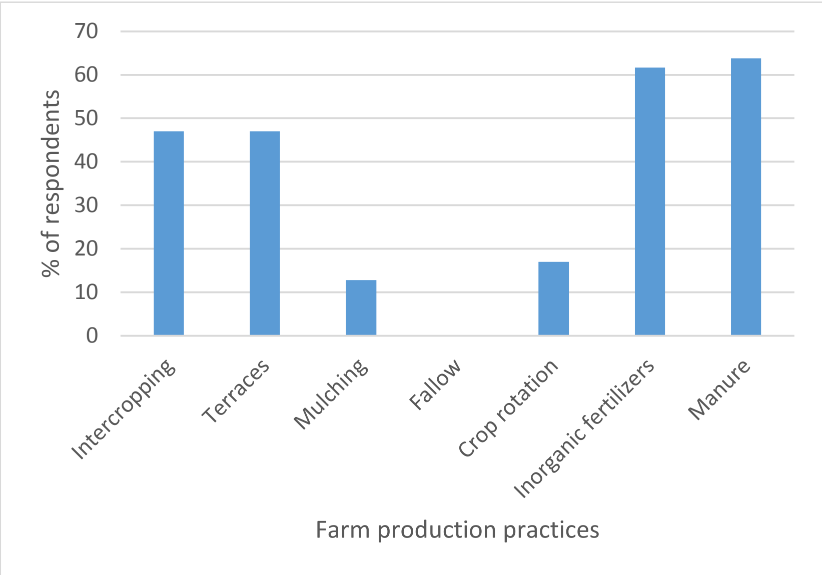

Figure 5:4 Household survey results from the Highland zone, showing the percentage of households adopting each soil management practice in this zone.

Figure 5:5 The use of terracing to control soil erosion in areas with steep slopes as observed in the Highland zone (source: author).

To identify whether farmers were using agroforestry strategies, and whether the number of trees on farms had changed, in the survey respondents were asked whether they had trees on their farm and any changes in the number of trees. The majority of respondents across all three agro-ecological zones reported the presence of trees on their farms and only a few respondents in all zones reported to have no trees on their farms (Figure 5.6). These trees were reported to provide benefits like fruits, shades especially in coffee farms, firewood, and improve soil fertility. Economic benefits such as income from selling timber was reported to be limited because of regional government restriction to cutting trees unless one has a permit. And to get the permit, it was reported to be difficult unless the tree is too old to present hazard in case it falls, or there is the need for building a house where the tree is located.

However, more than 40 percent of respondents in the Highland and Midland zones reported a decrease in the amount of trees on their farms (Figure 5:7), while 42 percent of respondents in the Lowland zone reported no change in the number of trees. It is important to clarify that, although respondents from the Lowland zone reported to have trees on their farm, evidence from field observation (Figure 5:8) shows that, it might be two or three trees in a one-hectare farm. In contrast, in the Highland and Midland zones, there are relatively more trees because they practice agroforestry (Figure 5:9).

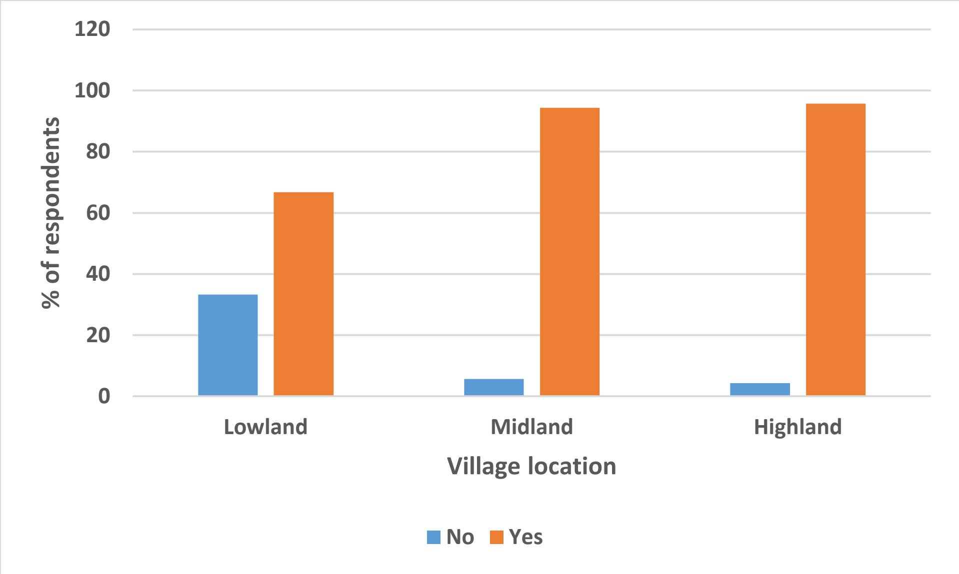

Figure 5:6 Household survey results on the presence of trees on the respondents' farms across the three agro-ecological zones

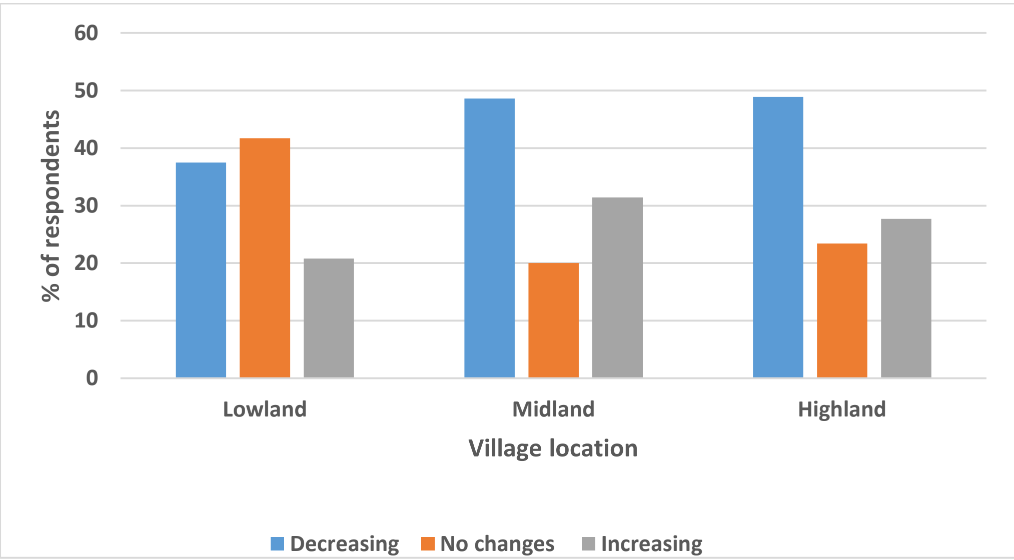

Figure 5:7 Household survey results on the trend in the amount of trees on the respondents' farms across the three agro-ecological zones.

Figure 5:8 The image showing the nature of the farms in the lowland zone. The number of trees in the farms in this zone is small (source: author).

Figure 5:9 Image showing the trees integrated in banana and coffee farms as observed in the highland zone (source: author)

Before going to the next subsections, I will first reflect on some important points from this subsection. The results show that, the focus groups participants in all three zones are critical of several seemingly negative farm production practices and understand implications of them, yet clearly do them anyway. These practices are removing crop residues, mono-cropping, excessive use of inorganic fertilizers and deforestations. Farmers use these practices as response to different stressors such as demands for livestock feed and free grazing livestock, desire for income to compensate low income from coffee, and excessive use of chemical fertilizers because of incapacity to transfer manure to farms located far from households and lack of capacity to undertake soil test. Although this chapter has highlighted some factors influencing farmers use of practices that increase livelihood vulnerability by improper management of soil resource, the detailed social factors contributing to livelihood vulnerability is presented in Chapter Six.

5.3 Practices affecting water resources and water-use efficiency

This sub-section presents practices affecting water resource and water use efficiency as reported in the study area. The result on this section will focus more on the results from focus group discussion as there was no much information about practices affecting water resources and water use efficiency in the survey in highland and midland. In all focus group discussions in all three zones, practices that had negative impacts on water resources were due to activities in the water catchment areas. Water-use efficiency in all three zones was affected by low use of water efficiency irrigation methods, growing high water demand crops.

Irrigation is an essential strategy that can help to address soil moisture deficit and insufficient or variable rainfall. In all focus groups across the three agro-ecological zones, participants recalled the history of irrigation in the study area, which began a long-time ago through construction of traditional furrows which take water from the Highlands and distribute it to different places in the region. Having water available for irrigation ensures food security as well as allowing households to grow crops outside of the rain seasons. However, human activities like cutting trees, and grazing livestock in water sources dry streams because they make the land bare (Figure 5:10). Clement *et al.* (2016: 153) describe the impacts of bare lands on water systems: 'Bare lands have strong effects by promoting rapid surface runoff, reducing water concentration time and reducing percolation. In turn, it increases surface runoff causes the variation in infiltration into the ground, soil moisture contents and groundwater storage which reduces base flow and water yield components of the catchment'. Focus group participant from my study reported:

'…. our granddads were very creative, they created walls to collect water in the streams and dug furrows to distribute water to different places for domestic and irrigation purposes. Due to the presence of water for irrigation, there are plausible strategies to work against famine in this region. In the past people did not cut trees and feed livestock close to water sources. Trees were plenty and water was plenty too. But as time went on, people started cutting trees and farming near water sources which lead to reduction of water volume' (Men focus group discussion, Midland).

Figure 5:10 One of the streams providing water for irrigation in Lowland with few trees around it because of deforestation to give room for agriculture activities (source: author).

Regardless of the perceived decrease in water volume, in all three zones farmers in the focus group discussions reported increased growing of high water demand crops particularly during the dry season using irrigation. In all three zones, farmers grew vegetables in some places especially the midland and highland zones to replace coffee crops which needed less water compared to vegetables. One focus group discussant reports:

'The amount of water is low and now people are putting efforts in growing different types of vegetables in sometimes former coffee farms which did not require regular irrigation like vegetables. Although horticulture provides income, the amount of water does not match the demands of the population that grow vegetables and in some places conflicts between farmers have been reported. Water levels are very low especially during the dry season where most vegetable growing are concentrated' (Men focus group discussion, Highland).

Some crop species which are grown during the rainy season were reported in the survey and focus group discussion in all three agro-ecological zones to increase livelihood vulnerability to climate variability. Farmers reported the incompatibility of some traditional crop species with the shortened growing season being experienced. They reported some farmers to grow traditional maize seeds which were reported to be relatively resistant to diseases but take sometimes six months to mature, making them inappropriate for present rainfall trends. As one focus group participant reported:

'…. Some farmers plant traditional maize. These maize are relatively resistant to diseases but take sometimes up to six months to mature. If you plant these maize now, and it happen the rainfall is not good, you will just harvest maize straws and no maize. The rainfall in the past is not like the present.'

In the household survey, I asked farmers in each zone to identify the type of maize seeds used in their farms in order to the understand the extent to which early maturing maize is used. As displayed in Figure 5:11 the results indicate that the majority of the respondents in the Midland and Highland zones use early maturing hybrid types, and half of respondents in the Lowland use early maturing hybrid type and recycle them for a while before buying new seeds. While there were no respondents in the midland who recycle non hybrid maize, a quarter in the Lowland and 10 percent in Highland respectively reported to do so. These results show that most of the respondents in the midland and highland zones purchase early maturing hybrid maize every farm season, and the majority of respondents from the lowland zone also use hybrid maize but they do not do the same every growing season. They buy some during the dry season where irrigation is used, and reuse the same seeds during the rainy season to lower the loss from crop failure because of uncertainties in rainfall distribution and volumes.

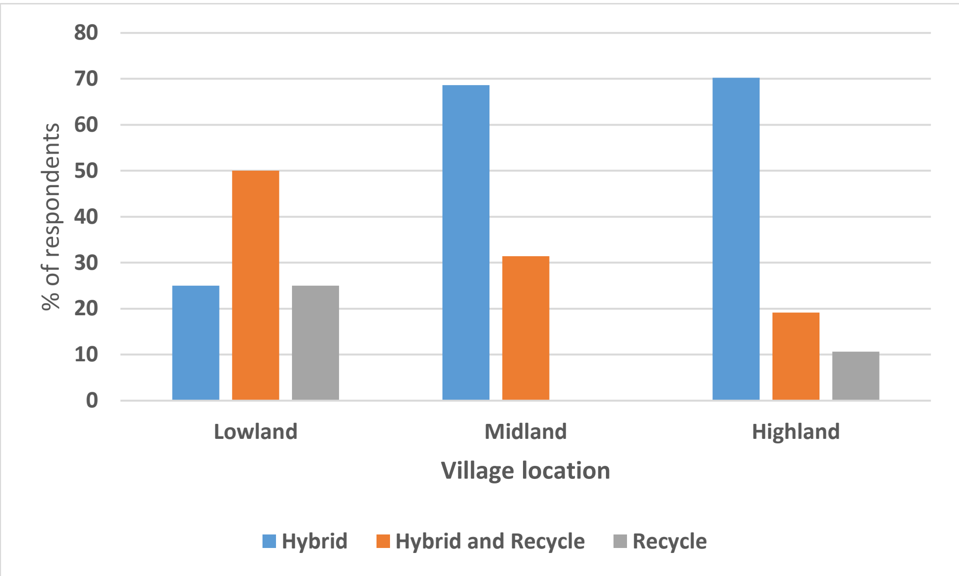

Figure 5:11 Types of maize seeds used by small-holder farmers as reported in the household surveys across the three agro-ecological zones. Recycle means reuse of the seeds.

The use of drought resistant crops is among the strategies that can help grow crops where there is limited water availability (Tambo and Abdoulaye, 2013: Antwi-Agyei,et al., 2014: Coulibaly *et al.*, 2015). However, a low rate of planting drought resistant crops was reported in all three zones. While farmers were discussing changes in the types of crops produced in all three zones in the study area, few people were reported to grow drought resistant crops such as millet and cassava across all three zones. Farmers were aware that these crops can resist drought but they were not ready to adopt them because they are not used to them in the way that they are used to maize, and they were not sure of the market, as one focus group respondent reports:

'*Small population in this area also plant millet and cassava, but majority do not. If we plant these crops where shall we sell? It is easier to get a market for maize than cassava and millet because many people use them. After all, if you make food from millet kids refuse it even before testing, the millet colour is not appealing'* (Women focus group discussion, Highland).

However, there are strategies for improving water use efficiency which have been practised by some and agreed in the discussion in some zones as having the potential of helping households adapt to climate variability. These strategies include sunken beds and spate irrigation.

Literature has reported that the establishment of irrigation schemes should be employed together with improved irrigation methods (Wall and Smit, 2005). Water-saving agricultural practices are vital in dealing with growing requirements, water shortages, and increasing water demands for agriculture. The aim of water efficient irrigation methods is to enable more crops per drop of water (Lankford, 2006; Van Halsema, and Vincent, 2012). Some farmers reported in the lowland zone the use of sunken beds to reduce the amount and time for irrigation. Sunken beds are made through altering the land surface to make a series of shallow valley like structure to facilitate irrigation (Singh, *et al.,* 2010). This was practiced more in the lowland zone compared to highland and midland zones Figure 5:12. In the lowland zone, focus group participants reported that there was strict reinforcement of the utilization of the sunken beds as efficient irrigation methods. One focus group participant emphasized:

Figure 5:12 The image showing the sunken beds created to irrigate beans as observed in the highland zone (source: author).

'…. we use good irrigation practices so that all water users can get access to irrigation. In the past, few people used to practice efficient irrigation methods. With climate change, farmers are coping by growing crops in farms with access to irrigation. So we use sunken beds which can help irrigate one hectare in one hour or two to cope with an increase demand for irrigation. In the past one person was capable of irrigating for 5 to 6 hours. If a person has not

created beds in their farm, no irrigation shift is allocated to him/her' (Focus group discussion, Lowland).

In the household survey, the use of sunken beds was mentioned by 70 percent of respondents from the lowland zone, but it did not come up in the surveys in the midland and highland zones when farmers were asked to discuss the strategies they use for soil management and the efficient use of water. Compared to the midland and highland zones, there is a strict rule enforcing the use of sunken beds in the lowland zone because probably these beds are more suitable in flat, dry areas (Singh, et al., 2010) which do not typify the highland and midland zones, except in few places, or because more effort to adopt efficient irrigation methods is placed in the lowland zone because they are more vulnerable to rainfall variability as they receive less rainfall compared to the other zones.

Farmers in the focus group discussions, particularly in the lowland zone talked about the use of drought-resistant crops (Figure 5:13). These crops were reported to resist drought meaning that families that use them can be assured of food even when rainfall is scarce. However, only a few people were reported to grow them. A focus group participant emphasized while discussing trends of crop production in the study area that:

'…. we didn't grow millet and sunflower in the past. Some people do now but majority do not. These crops do not need much water so you can be assured of a harvest even when the rain is not that much' (Focus group discussion, Lowland).

Figure 5:13 This millet crop (a more drought resistant crop) was being kept outside to dry after harvest as observed in the lowland zone (source: author).

Before I present the results about farmers' perception about the ability of selected practices to contribute to climate change adaptation I will briefly summarise the key points to be taken away about practices affecting water management and water use efficiency. The results show that, farmers are aware of the practices that increase livelihood vulnerability through inefficient use of available water sources; including surface water sources and rainfall. Existing surface water sources provide alternative water sources to be used both to supplement rainfall deficit or growing crops outside the rain season. However, some farmers cut trees and feed livestock near water sources and contribute to reduction of amount of water in this sources. The types of crops grown by some farmers also increase vulnerability as they are not compatible with amount of water in surface water sources and the amount of rainfall. The type of irrigation used contribute to water lose. Chapter Six will explore in detail some of the social factors that face farmers in this area and reduce capacity to employ practices that can improve water use efficiency.

5.4 Perceptions of selected adaptation strategies

The respondents in the household survey were asked about their perceptions of and reasons for their consideration of the use of some selected strategies (use of early maturing maize, drought-resistant crops-millets and cassava, traditional crops and planting trees) promoted by key informants in the study area to ensure household food security, income, adaptation to climate change.

5.4.1 Farmers perceptions on the use of trees in adapting to climate variability

Planting trees can provide both adaptation and mitigation to climate variability and change. Since the study was focused more on adaptation, the respondents were asked about their perception on the use of trees to adapt to climate variability and change.

shows the perception of farmers from the household survey of using trees to adapt to climate change across the three agro-ecological zones. The majority of farmers in all three zones perceive trees as very useful to cope with climate change. A quarter of respondents from all zones had doubt, and 3.8 percent had ultimately no hope in the role of trees for adaptation to climate variability and change.

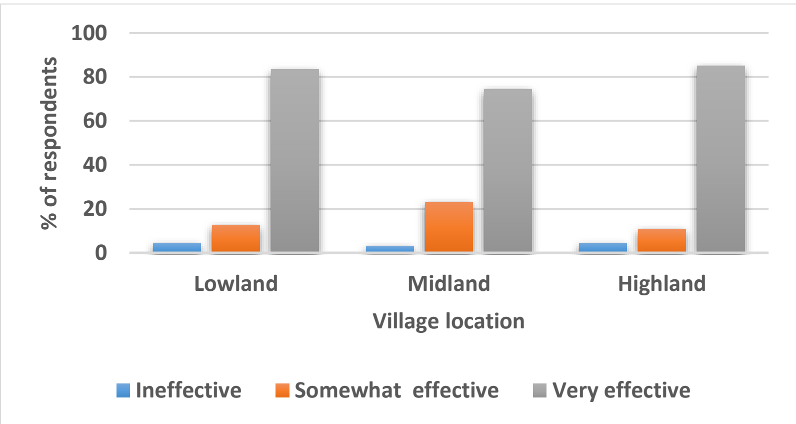

Figure 5:14 Farmers' perceptions as presented in percentages on the use of trees in the farm to adapt to climate change as reported from the household surveys.

Figure 5:15 shows the reasons provided by respondents in the survey for their perception on the use of trees in the three agro-ecological zones. The results show that respondents perceive trees are good because they provide both environmental and social-economic benefits and small proportion reported trees to be incompatible with their current farming practices and environment because the crops they grow do not need shade and their environment is dry so trees could not survive. This implies that although the majority of respondents believe that trees can be useful for adapting to climate change by provision of environmental and socio-economic benefits, small proportion of respondents in all three zones had negative comments related to the appropriateness of trees as part of climate adaptation strategies.

Figure 5:15 Farmers' reasons for their perceptions on the use of trees on their farms as a climate change adaptation strategy across three agro-ecological zones as reported in the household surveys.

The socio-economic and environmental benefits that trees are said to provide demonstrate their appropriateness for climate change adaption. Although farmers also gave some reasons for why trees may not be effective or appropriate on their farms, these perceptions are at odds with some of the literature and raise further questions.

Research has established the benefits of having trees on farms that do not need shade and how trees can be managed in relatively dry areas. For example, in the dry lands of the Shinyanga region in Tanzania, a wide range of agroforestry technologies ranging from planting of woodlots, fodder banks and the use of nitrogen-fixing trees were employed as part of land rehabilitation activities following decline in livestock and crop productivity making it one of the most successful land rehabilitation projects in Tanzania (Kyule, *et al.,* 2015). In addition, research has established that it is possible to grow maize as part of an agroforestry system in small-holder famers farms in southern parts of Africa (Garrity et al., 2010). Figure 5:16 shows how farmers integrated faidhebia trees in their maize , which contributed to soil fertility and improved crop yield. This highlights the need for researchers in collaboration with farmers to understand crop species that can be compatible with environmental characteristics within vegetables and maize farms, but also that farmers may be prejudiced against particular strategies without a full understanding of the strategy.

Figure 5:16 Faidherbia fertilizer trees in a maize conservation agricultural production system. Trees are 9 years' old. Source: Adapted from Garrity et al., (2010)

5.4.2 Farmers' perceptions of the use of early maturing maize to adapt to climate variability

Figure 5:17 shows farmers' perceptions of the use of early maturing maize to cope with climate change across the three zones. The results show that the majority of respondents in all three zones believe that early maturing maize can be effective in coping with climate change. A sum of 25 percent in all three zones reported that early maturing maize was 'somewhat' effective. There was no respondent in midland who reported early maturing maize to be ineffective, those who reported so in highland and lowland make a total of almost six percent. This result shows that although the majority believe that early maturing maize can help adapt to the changing climate, there are still some who do not have faith in these varieties. A lack of trust in the ability of early maturing maize to adapt to climate variability and change may have negative implications to their adoption.

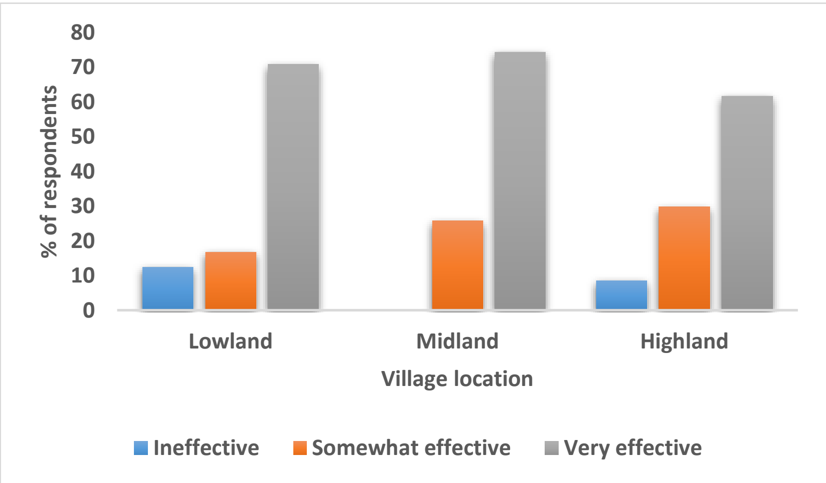

Figure 5:17 Farmers perception on the use of early maturing maize to adapt to climate change across three agro-ecological zones as reported from the household surveys.

The reasons for the farmer's perceptions on the effectiveness of early maturing maize are summarised in Figure 5:18 and indicate that the majority of farmers in the lowland zone said they were effective because they mature early and can be harvested as early as 45 days. The majority of respondents from the highland zone said that the early maturing maize was effective because of the nature of rainfall which is increasingly shrinking, and equal proportion of the respondents in the midland zone ascribed the effectiveness of early maturing maize to both the nature of the changing rainfall and their ability to mature early. However, a total of 29 percent of respondents perceived early maturing maize to have limitations such as a lack of capacity to survive increasing climate variability, and the vulnerability of the seeds to diseases.

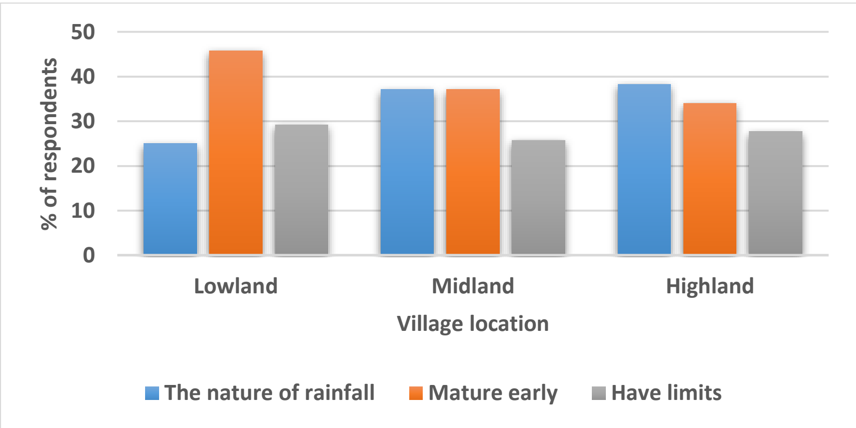

Figure 5:18 Reasons for the farmers perception on the use of early maturing maize as a climate change adaptation strategy across three agro-ecological zones as reported in the household surveys.

5.4.3 Farmers' perceptions of the use of drought resistant crops (millet and cassava) to adapt to climate variability

Figure 5:19 shows farmers' perceptions on the use of millet and cassava to adapt to climate variability. The results show that the majority of farmers in the midland and lowland zones perceived that cassava and millet are 'somewhat' useful while in the highland zone they are considered to be ineffective.

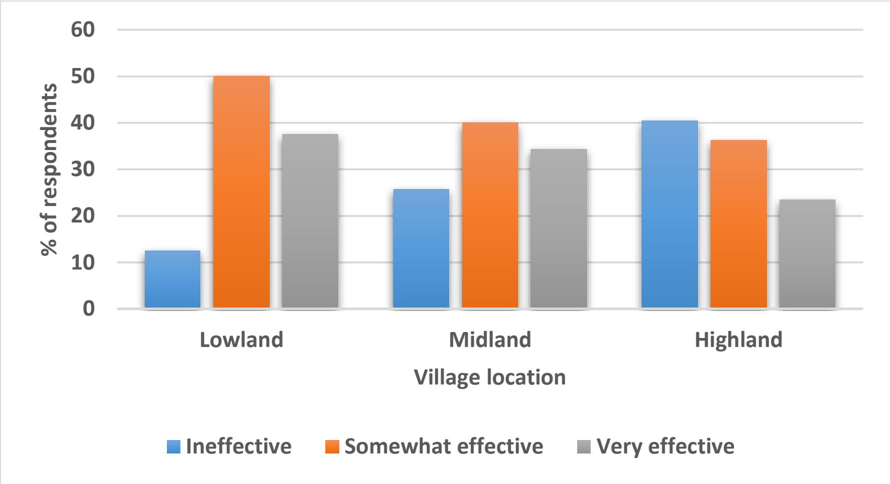

Figure 5:19 Farmers' perceptions of the effectiveness of the use of millets and cassava as a climate variability adaptation strategy from across the three agro-ecological zones as reported in the household surveys.

Figure 5:20 shows farmers' reasons for their perception of millet and cassava for coping with climate change. An equal percentage of farmers in the lowland zone considered them to be not traditional, as well as able to resist drought. The majority of respondents from the midland zone reported that these crops were not part of their traditions, and the majority of respondents from the highland zone reported other reasons, including that cassava kills[7], cassava takes a long time (6months) to mature, and that they lack a good market. This result implies that less than half of all respondents had positive opinions (such as able to resist drought, or use as an alternative food) regarding the use of millet and cassava for climate change adaptations. While more than half of respondents in all three zones perceived them

[7] There is belief for most of the people from Highland and Midland, cassava grown in cold and high altitude areas like Kilimanjaro are generally poisonous. However, it has been established that cassava carries cyanide which is potentially poisonous to human (Mshumbusi, 2018) and there are likelihoods of increasing poisonous with altitude (Oluwole et al., 2007) for the context of this study area, there is need to research cassava species farmers complain about and contextual factors to be able to refute or accept the farmers' claim.

to be not part of their culture and so people they are not used to them, or that they lacked a good market, take a long time to mature. In addition, farmers from the highland and midland zones perceived cassava to be toxic. These results imply that there are several different reasons that limit the adoption of millet and cassava as a climate variability adaptation strategy in this area.

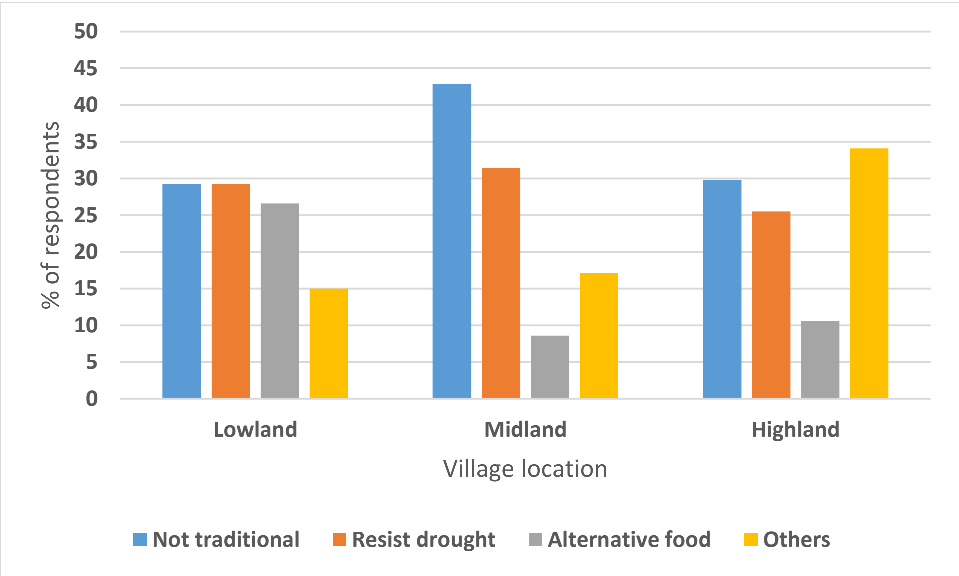

Figure 5:20 Reasons on the respondents' perception on the use of millets and cassava as presented in three agro-ecological zones

5.5 The role of key informants in helping farmers' livelihoods adapt to climate change

This section presents results from key informants asked about what they do to help small-holder farmers' livelihoods adapt to climate change in order to understand the extent to which farmers are part of a two-way dialogue. It is important to clarify the relationship between key informants to the farmers; the key informants decide what to promote to farmers who then decide what to do themselves. Having clarified the relationship between the two, below are the adaptation measures promoted by key informants in the study area.

There are a variety of strategies that key informants promote to help farmers adapt to climate change Table 5:2. The strategies discussed were mostly confined to the key informants' area of influence and therefore differed between interviewees, and some were similar to the strategies discussed by the farmers themselves. The results from the key informants' interviews shed light on what agricultural practices they encourage farmers to use to adapt to climate variability. The subsection also looks at the practices encouraged to understand the reasons for why there are some variations in the practices of livelihood adaptation across the three zones as presented in the household surveys and focus group discussions.

It shows that there are wide range of soils and water conservation measures encouraged by most key informants. The slight difference between the practices mentioned by Village Agriculture Extension Officer and District Agriculture Officer is to encourage farmers to grow disease resistant coffee. This is because the later oversee the entire district which part of it grow coffee but the earlier work in the lowland where coffee is not produced. Destocking was mentioned by MVIWATA, Village and District Extension Officer, where they encourage livestock keepers with large amount cattle particularly with no enough farm area to graze to reduce the number of livestock. Community Development Officer links farmers with innovators with adaptation technologies.

Table 5:2 Summary of the practices or strategies that key informants use to help small-holder farmers in the study area adapt to climate change as reported by key informants interviewed from the Kilimanjaro region.

Key informant	Role	What they encourage
MVIWATA Kilimanjaro	Capacity building to small-holder farmers	Agroforestry, leaving crops residue,destocking, early maturing maize, irrigation,conservation of water catchments, planting drought resistant crops, and use of organic fertilizers.
TaCRI	The institution research technological innovation and provide advice to improve productivity and quality of coffee in Tanzania	Agroforestry, organic fertilizer, mulching, disease resistant coffee species.

Village Agriculture Extension Officer	The officers provide farmers with agricultural knowledge and skills to improve their farming practices and eventually productivity.	Destocking, leaving crop residue, organic fertilizers, drought resistant crops, early maturing maize, irrigation, efficient irrigation methods, conserving water catchment area.
District Agriculture Extension Officer	The district agriculture extension officer oversees agriculture extension officers working directly with farmers in the village or ward level.	Destocking, leaving crop residue, organic fertilizers, drought resistant crops, early maturing maize, irrigation, efficient irrigation methods, conserving water catchment area and coffee resistant coffee.
Community Development Officer	Linking farmers with other departments or stakeholders working with the community.	Linking farmers with technological and innovation developers eg. TaCRI, improved maize seeds developers.

The key informants draw attention to the importance of geographical context; as the different agro-ecological zones exhibit different climatic and crop production activities. This implies that the Kilimanjaro region is not homogenous so each agricultural practice is not necessarily applicable throughout the region. For example, agroforestry is perceived by the District Agriculture Extension Officer as incompatible with cereal and vegetable cultivation taking place mostly in the lowland zone because the crops do not flourish under shade as would be produced in an agroforestry system. As he said:

'…. we encourage them to plant trees in the area the crops grown need shade like upland and midland to get multiple benefits like timber, fruits and to conserve the small available soil moisture.'

This statement probably explains why agroforestry was not identified as a resilience building strategy in the focus groups in the lowland region although some farmers reported to have trees in their farms in the survey which might be not necessarily for agroforestry purpose. The lowland zone farmers have fewer trees in their farms (I personally observed this in the field - a one-hectare farm could have just one or two trees) due to the crops grown being mostly cereals, and horticulture being perceived as not requiring shade and so not being applicable for agroforestry. Base on observation by (Garrity *et al.*, 2010: Kyule, *et al.*, 2015) as explained in subsection 5.41, I would suggest that although these crops do not require shade, it doesn't rule out the use of agroforestry in relation to these crops, and that there is further room for consideration of how agroforestry can be used by small-holder farmers as part of maize production.

Small-holder farmers from the lowland zone were strongly encouraged by the Village Agriculture Extension Officer to use efficient irrigation methods. The use of sunken beds which were common in the lowland zone. The focus on irrigation efficiency by the Village Extension Officer may partly explain why respondents from the lowland region in their focus group discussion placed such emphasis on irrigation efficiency methods, because they have been taught and enforced to use them because they are significant to their livelihood resilience. Another explanation could be that, farmers may also just do it anyway, and as I haven't interviewed the midland and highland extension officers we don't know what the equivalent suggestions would be in the other zones.

In some cases, responses from key informants highlighted strategies which can enhance the resilience of livelihoods but were not mentioned by focus group participants in some zones. For example, the use of drought-resistant crops was encouraged especially for all farmers with farms located in the lowland zone. Some farmers from the midland and highland zones who also had farms in the lowland zone and those who reside in the lowland zone were encouraged by village and district agriculture extension officer and MVIWATAN to grow these crops as they can survive moisture stress. As the MVIWATA representative said:

'…. we encourage farmers to grow crops that can survive under limited rainfall especially millets and cassava in lowland areas as they can withstand drought season and irregular rains'.

This implies that, although the majority of farmers do not grow drought resistant crops as reported in the focus group discussion, it does not necessarily mean they do not know about them. It may mean that there are other barriers to adopting drought resistant crops as a climate change adaptation strategy. The results about farmers' perception about use of these such as millet and cassava (section 5.4.3) to adapt to climate change may partly explain why there is low adoption of these crops. For example, the strategy may not meet their interests in terms of food or potential for income generation.

There are some climate change adaptation strategies identified by key informants that did not come up in the focus group discussions with the famers themselves. for example, the use of disease-resistant coffee species was identified by the representative from Tanzania Coffee Research Institute as an important strategy for adapting to climate change because it can withstand coffee berry and leaf rust diseases but was not mentioned by farmers. This may be because the focus group discussion was dominated by issues around cereal production because almost all farmers grow cereals but not all of them grow coffee. However, where some farmers still grow coffee on their farms, I argue that they should consider disease resistant coffee species due to increased incidences of crops pests and diseases brought by climate variability and change as reported by key informants.

The Community Development Officer reported that they helped farmers through linking farmers with stakeholders with technologies for adapting to climate change as well as linking them to Non-Governmental Organisation and other stakeholders with projects related to small-holder farmers such as TaCRI, maize seeds developers' and the innovators of energy efficient cookers. Additional support is being put in place by the government. For example, the government has ordered 10 percent of district revenue from taxes, levies and fees from local governments to be used to provide loans to women and youth in the districts each (women and youth groups) getting 5 percent. This fund support women and youth groups project[8] and later they pay it back for other people to borrow. However, generally the Community Development Officer reported that the amount is not enough compared to the demand for such loans.

5.6 Summary

This chapter set out to explore agricultural practices of small-holder farmers and the influence on environmental resources particularly soil and water. Turner *et al.*'s (2003) vulnerability framework stresses that the conditions of these resources partly determine the potential of the farmers to be impacted by climate change. The quality of the environmental resources (land/soils and water including the volume and efficient use of them) determine the capacity of these resources to contribute to agricultural production (Ofgeha, 2017) in the face of climate change.

From this study area, land/soil management practices that some farmers use increase livelihood vulnerability by reducing the soil fertility include removing crop residue, mono-cropping, deforestation, and excessive and inappropriate use of chemical fertilizers. These practices go against agricultural practices that can reduce the climate change impacts on soils as well as reduce agricultural productivity in the long run (Clair, and Lynch, 2010).

[8] The district calls for proposals from women and youth groups and the best business idea is funded. The number of projects that are financed depend on the available amount of revenue raised in the particular year.

The results further show that some farmers increase their livelihood vulnerability by performing human activities such as feeding livestock and cutting down trees near water sources. Also there is limited use of efficient irrigation methods, and growing high water demand crops, low uptake of drought resistant crops, and use of traditional maize which cannot withstand shrinking rainfall levels also increase livelihood vulnerability to climate change. Farmers in this area increase vulnerability to climate change by selecting inappropriate crop varieties to grow, inadequately managing water from rainfall and other sources, and inappropriate practices that affect water sources (Bot and Benites, 2005).

A variety of agricultural practices are encouraged by key informants and these agricultural practices have a significant role in enhancing farmers' adaptation to climate change. However, some key informants should develop a broader understanding of the appropriate adaptation strategies in different contexts.

5.7 Conclusion

This chapter has explored small-holder farmers' agricultural practices which increase livelihood vulnerability to climate change. Some farmers in this areas increase their livelihood vulnerability by employing agricultural practices that reduce soil organic matter and inappropriate use of fertilizer. Also some farmers in this area increase vulnerability to climate change by selecting inappropriate crop varieties to grow, inadequate management of water from rainfall and other sources, and inappropriate practices that affect water sources. Farmers are aware of the impacts these practices present to their livelihood but they do them anyway partly because of existing social factors which will be explored in the next chapter (Chapter Six).

6 Livelihood strategies and social structures increasing livelihood vulnerability to climate change

6.1 Introduction

This chapter presents a range of social factors or human conditions that contribute to livelihood vulnerability to climate change. The social factors are discussed across livelihood strategies to understand factors limiting development in this subsector and therefore how they contribute to livelihood vulnerability to climate change (Paavola, 2008). The chapter also explores household social structures that govern crop and household income use and their contribution to livelihood vulnerability to climate change. The chapter is organised by first briefly describing each livelihood option before I present social factors contributing to each subsector's vulnerability to climate change. Livelihood strategies in this area include crop production, livestock keeping and diversification to a range of off-farm income earning activities. The chapter starts by exploring crop production and how it is organised over the year in the three zones and social factors limiting the development in this subsector. The chapter is followed by description of the livestock subsector and off-farm income sources and underlying social factors contributing to vulnerability in each livelihood strategy. Then the chapter will explore household social structures that govern crop and household income use and their contribution to livelihood vulnerability to climate change. The last part of the chapter will present key informants' discussions relating to the constraints that face small-holder farmers' livelihoods.

6.2 The crop subsector and its constraints

6.2.1 Crops produced

Crop production is a dominant livelihood strategy in the study area. There are several crops which are grown in the study area, of both annual and permanent variety, particularly in Midland and Highland. Figure 6:1 summarise how crop production is organised over the year

Crops	February	March	April	May	June	July	August	September	October	November	December
highland and midland zones respondents											
Maize (lowland/midland farm)	Preparing the farm	Planting	1st Weeding		2nd weeding		Harvesting				
Beans (lowland/midland farm			Planting	Weeding		Harvesting					
Maize and beans (highland/midland farm)					Farm preparation		Planting		Weeding		Harvesting
Horticulture(highland /midland farm)	Spraying	Harvesting							Farm preparation		Planting
Lowland zone respondents											
Maize					Farm preparation	Planting		1st weeding	2nd weeding		Harvesting
Beans					Planting		Weeding	Harvesting			
Rice							Farm preparation	Planting	Weeding	Harvesting	

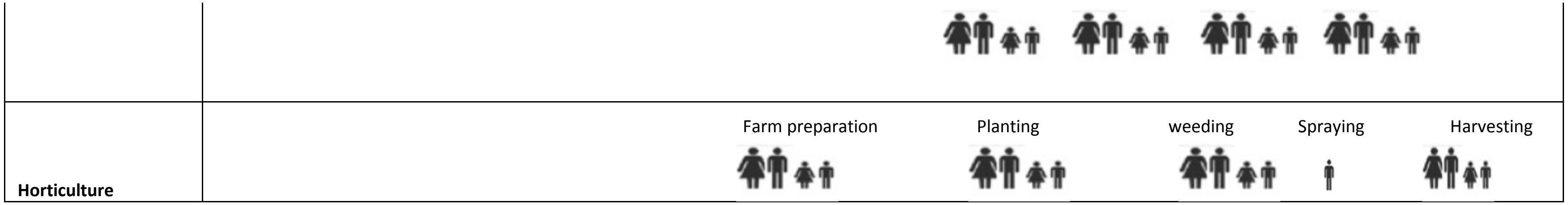

Figure 6:1 The summary from the focus group discussions in the three zones showing the crops grown, the time of year and the people involved in performing selected farming activities

Key;

Symbol	Meaning
	Farther
	Mother
	Children

as reported by focus group participants in three zones. As reported in Chapter Four, some farmers in highland and midland also have farms located in other zones. Respondents from highland and midland reported that in addition to permanent crops (bananas and coffee) grown by some farmers in the highland and midland zones which, they also grow cereals in the farms located in midland and lowland. They begin farm preparation from February for planting maize which is harvested in August. After first maize weeding, some farmers who prefer to intercrop maize with beans plant beans at this time and harvested in from August. While farmers are waiting for crops grown in midland and lowland to dry (in the farm) they begin farm preparation for farms located in highland for highland farmers and midland for midland to plant cereals in these zones Figure 6:2 . As reported from one of the FGD in the highland zone:

'…. currently (July), while waiting for crops to dry, we are working in the upland to weed the farm. At the same time, we collect manure close to the banana trees and cover the manure with the soil. After that, we plant maize and beans in open spaces on the farm which will grow using the available soil moisture from long rain season until the short rains arrive in October' (Women focus group, Highland)

Other crops which are grown by few farmers in these two zones are cocoyam Figure 6:3 and climbing yams. For farmers interested in growing vegetables, they usually do it in farm located in highland and midland and with access to irrigation. They begin farm preparation around October when they have harvested crops grown in lowland or midland. This production system allows households to have at least two harvest a year contributing to household income and food security.

Figure 6:2 Highland zone farm with maize and beans integrated in the banana farm as observed during field work, late August, 2017 (Source: author).

Figure 6:3 Cocoyam planted in the banana farm as observed in the midland zone (Source: author).

In the lowland zone, the crop production over the year is complex involving growing crops in dry region areas *(barakavu - areas without irrigation access)* as well as wet region areas (*baramaji- areas with access to irrigation).* Most of the areas with access to irrigation have got clay soils which causes water logging in the long rain season making most farmers in this area rest their farms or grow rice in some parts. Farming in the dry region takes place during the long rain season where maize and beans are mostly grown. However, a few farmers grow cowpeas and sunflowers in the dry region instead of maize because they perceive them as slightly drought resistant. During the dry season and short rain season, maize, beans, rice and horticulture are grown in the wet region using raised beds to irrigate maize, beans and vegetables to avoid water logging Figure 6:4 One member of the focus group discussion in the lowland zone explain how they organised the farming activities over the year:

'We plant rice in August which will be harvested by February then from March we will plant maize or vegetables for areas with access to spate irrigation. We then rest the rice farm during the rainy season or a few individuals who can afford the cost of managing maize and rice grow both crops in this period. During the short rain season, part of the area with access to irrigation is grown either maize, beans, vegetables as well as rice. These crops are harvested before the beginning of the long rain season. But if the rains are enough the areas with clay soils are grown with rice only, because other crops do not survive water logging'. (Focus group discussion, lowland zone).

Figure 6:4 Beans growing and an irrigation channel in the lowland zone as observed during fieldwork in August (dry season) using raised bed for irrigation in the clay soil (Source: author).

6.2.2 Problems facing crop subsector

These subsection presents result from household survey and focus group discussion about the major challenges that limit development in crop subsector. The results from the survey show that Figure 6:5 lack of capital was mentioned by the majority of respondents from the highland and midland zones, and was mentioned by almost a quarter of respondents from the lowland zone. The challenge of a lack of capital was also mentioned in all focus groups in the three zones (Figure 6:5) especially in relation to the ability to access agricultural inputs. The use of agricultural inputs is important in adapting to climate variability and change, particularly the use of fertilizer and pesticides (IPCC, 2014) and improved maize seed. As reported:

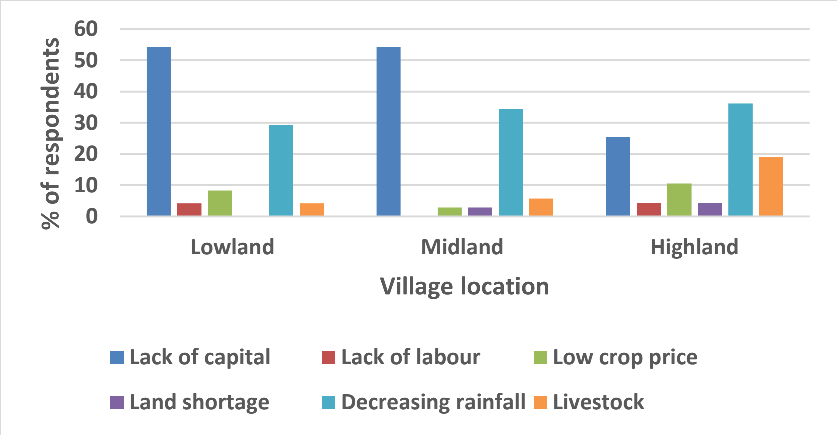

Figure 6:5 Problems associated with crops as reported in the household survey implemented in the three agro-ecological zones (source: author).

'The use of improved seeds, fertilizers and insecticides is important in order to speed up the plant growth and get more yield. But we smallholder farmers have got not enough income to buy all required inputs. We know we have to use planting fertilizers, booster, and destroy pests and disease which might affect plant in order to harvest something. But the price of the input doesn't equal to our income. We may buy fertilizer to use in our farm but because of price we cannot use the appropriate ratio required' (Women focus group, midland zone).

Table 6:1 Summary of the problems facing crop production as reported in focus group discussions in the highland, midland and lowland zones.

Problem/Zone	Highland			Midland		Lowland
	Men	women		Men	Women	Men and women
Price of agricultural inputs	High price of inputs	Doesn't relate to farmers income		High price of inputs	High price of inputs	High price of inputs
Decreasing rainfall	Sometimes even early maturing maize doesn't survive	Sometimes even early maturing maize doesn't survive		Limits the growth of early maturing maize	Limits the growth of early maturing maize	Sometimes even early maturing maize doesn't survive

Lack of enough alternative water sources	Lack of water harvesting facilities and water loss in existing water infrastructure	Lack of water harvesting facilities and water loss in existing water infrastructure		Lack of water harvesting facilities and water loss in existing water infrastructure	Lack of water harvesting facilities and water loss in existing water infrastructure	Lack of bore holes and affordable sources of energy for water pumping and water loss in existing water infrastructure
Livestock keepers	Limits choice of adaptation options	Limits choice of adaptation options		Limit choice of adaptation options	Limit choice of adaptation options	Limit choice of adaptation option
Lack of reliable and profitable market	High price fluctuation and dishonesty in the market	High price fluctuation and dishonesty in the market		High price fluctuation and dishonesty in the market	Dishonesty in crop market	Dishonesty in crop market, price fluctuation
Population increase and land scarcity	Population is bigger than available land can support	Population is bigger than available land can support		Population is bigger than available land can support	Land shortage	Land shortage
Fake inputs	Not effective	Not effective		Not effective	Not effective	Not effective
Lack of ability to test soils for required inputs	Lack of knowledge and money to test soils	Lack of knowledge and money to test soils		Inability to identify soil nutrient requirements	Lack of knowledge and money to test soils	Lack of knowledge and money to test soils
Policy and directives	Export ban	No price guides and export ban		No price guides and export ban	No price guides	Export ban, no price guides
The biggest challenge	Lack of enough water for irrigation	Water for irrigation		Lack of enough water for irrigation	Lack of water	Lack of enough water for irrigation

Decreasing rainfall was the second most mentioned constraint that was mentioned in the survey in all three agro-ecological zones. The reason why this is an issue for consideration is explained by participants in all three focus groups: 1) that there is lack of enough alternative water sources which can be used to supplement rainfall shortage; 2) that even existing adaptation measures were being affected by decreasing rainfall.

The decreasing rainfall was reported to affect some of the current adaptation options to climate change. Participants in the men's focus group discussions especially in the highland and midland zones were concerned about the effect of decreasing rainfall on early maturing maize that was being used to adapt to climate change. The participants complained about the high rainfall variability which sometimes even early maturing maize could not survive, as one participant reports:

'*The use of early maturing maize helps us to get some harvest when the number of rainy days' decrease. But sometimes it rains in a weird way such that, even maize that can be harvested after 45 days cannot survive. It may rain for two weeks, then disappear and come when all seeds have died because of water deficit. After replanting, may be it may rain again for just a month, what maize type can be harvested in just 30 days?'* (Men's focus group discussion, highland zone).

Participants in all the focus group discussions reported that rainfall variability is complicated by the inability to effectively make use of available sources such existing rainwater and groundwater resources, as well as a lack of efficient and affordable energy for pumping water to supply water in areas with no access to irrigation infrastructure. Respondents from three zones emphasized the use of alternative water sources based on the available opportunities in each zone. The midland and highland zone focus group participants emphasized rainwater harvesting through the construction of earth dams to harvest available rainwater. The midland and highland zones receive a relatively high amount of water even under current climate variability compared to the lowland zone. Respondents in all zones perceived that opportunities such as horticulture and irrigation during the dry season and in dry spells in the rain season would be possible through rainwater harvesting if there was infrastructure to store water from the rain seasons. As reported:

'during the rainy season a huge amount of water flows to the ocean, and we do not have a mechanism to keep it for future irrigation. When you look at lowland where we complain about lack of harvest because of rainfall variability, if we had dams, they would help keep rainwater' (Men's focus group discussion, midland zone).

Water lost from the irrigation canals was also identified to contribute to water shortages and the need to line canals with concrete in traditional irrigation system in all three zones were proposed to reduce seepage. As reported:

'…. The government should improve our traditional canals because much water is lost which could be used for irrigation. We also need help with more boreholes and affordable energy to pump water because not every farm has access to existing water structure. If we get wind vane and tanks that can help pump water to areas which have no access to irrigation, everybody will get enough harvest' (Lowland zone focus group discussion).

Previous research has established that, water conveyance in unlined earthen canal loses large amounts of water through seepage and evaporation (Turpie et al., 2005; Komakech et al., 2012). In the Pangani water basin in the Kilimanjaro region traditional furrows are estimated to have an overall efficiency of less than 15% (Turpie, et al., 2005), which is very small compared to the high irrigation demand brought about by increase climate variability.

The impact of livestock was mentioned as a limit to some adaptation strategies in household surveys in all three zones. The issue of livestock raises the important point of the role of the social structures in terms of where people live in relation to their farm which determines the challenges they face and potential solutions. Livestock keeping (by others) was mentioned as a constraint on planting trees and other drought resistant crops that take a relatively long time to mature (such as cassava), making crop production of farmers particular from the highland zone vulnerable to climate change. Livestock keepers were accused of free grazing animal in other people's farms immediately after harvest. This made some farmers consider taking away crop residues instead of leaving them in the farm as a mulch. As reported;

We have huge problem with livestock keepers particularly in lowland. They make it difficult for us to manage our farm the way we want. For example, experts encourage drought resistant crop such as cassava because they can resist drought. But this crop cannot grow well in highland and if we plant them in lowland, it is difficult for us to manage because they take up to six months to mature. Because we do not live in lowland it will be difficult for us to invest our time for such long period to guard cassava against livestock and theft. We cannot even leave crop residue in the farm and find them in the next day. We can't even plant trees because livestock will not allow them to grow and we can't do anything to stop them. So cassava is the best options for people living in lowland but not us because at least they live close to their farms' (Men focus group discussion, Highland).

Low crop price was also mentioned as a challenge in the household surveys in all three zones. The focus group participants in all three zones agreed that crop price is too low compared to the investment made in terms of time and money because of high price fluctuations. It is difficult for most farmers to sell at a high price because most of their crops are sold a short time after harvest because of a lack of income to meet other life costs. As reported:

'There is huge price fluctuation which sometimes it is even difficult to understand the pattern. For some crops like maize and beans immediately after harvest the price is normally low if the harvest were good, later the price may rise but most people may have sold their crops because of family commitments. Crop like vegetable is difficult to keep, so when you harvest and the market is bad you can't keep them as they are perishable. This fluctuation is difficult for farmers to deal with it and get benefits' (Focus group, Lowland).

A small number of respondents of the household survey from the lowland and highland zones mentioned other problems such as fake inputs and land shortage. Although these problems were not mentioned in the midland household survey, they came up in the discussion in all focus group in all three zones.

Land shortage was perceived to contribute to poor and declining productivity of agricultural land. Land scarcity was reported to encourage continuous farming on the same plot of land and contribute to soil depletion. The problem of land shortage is caused by three related factors: 1) population increase; 2) fragmentation of land through inheritance; and 3) land use change. The land use change happens through conversion of former cropland into settlement area, reducing the crop production area. As reported in mens' focus group discussion in the midland zone:

'Another problem is land scarcity in this area. We have to agree that the number of people in this area is not proportional to the available land. Due to population increase and land inheritance in this area where parents divide their land to their male children in every generation has led to land fragmentation which has no longer economic value. The former farm land has been replaced by settlement as each generation inherit plot of land.'

Fake agricultural inputs were reported in all focus group discussion in the highland, midland and lowland zones. Participants from all three zones complained about the existence of fake maize seeds and agrochemicals. Participants complained that when fake seeds are planted money and time invested in buying, planting and weeding and adding fertilizers do not produce the desired return. As reported in the women's focus group in the midland zone:

'…. you may buy seeds and plant, but you may wait for it to grow for several days without success. the same to insecticides…. the same problem applies to some agrochemicals, because you spray with no effect'

Although it is likely that there are fake inputs available in the markets, the problem may be more complicated than that, making it difficult to conclude whether seeds or agrochemicals are fake. For example, sometimes farmers may under dose or use the wrong insecticides which are not meant for the problem trying to be tackled. This problem is explored further in section 6.5 drawing on the interview with the MVIWATA key informant.

Two problems that were given attention in all focus groups in all three zone were the lack of soil testing and the role of policies. Although these issues did not come up in the household surveys, it is important to mention them because of the importance attributed to them in the focus groups discussions.

The need for soil testing surfaced mainly in response to discussion around farmers' application of fertilizer without a knowledge of the demand on soil nutrients. Farmers in all three zones were worried about the action of just applying fertilizer on their farms without knowing that what they are doing is worthwhile. In the men's focus group in, the highland zone participants thought:

'.... we do not know the requirements of our soil, we just apply fertilizers. We need help on the soil test otherwise we cannot get the most out of fertilizers and bad enough we may cause more soil degradation by increasing certain chemical to the soils.'

Policies were also considered as a source of challenge in the focus groups. Government at the national level was seen as being responsible for creating livelihood vulnerability to changing climate through the policies put in place. Effective policies were considered by focus group participants as a fundamental element for prosperous livelihoods. However, concerns were expressed by focus group participants in all three zones about the nature of government policies, as well as the lack of policy enforcement. Several aspects were identified in the discussions of how the government affects the livelihoods of small-holder farmers.

The government assumes the role of the main regulator of water use for catchment water resources. Water that has been used for small-scale irrigation and livestock needs by midland zone farmers has been appropriated by the government for transfer to Moshi city for domestic use[9] . This has had significant consequence for the livelihoods of small-holder farmers in this area. As reported in the midland zone:

'.... we owned canals for many years and invested a lot time and labor in the construction and maintenance of irrigation canals which we used to practice irrigation but the government took the stream to provide water for people in urban areas without giving us a substitute.'

Although it is important for urban dwellers to have access to domestic water, it is important for the government to consider how important the stream is for the livelihoods of small-

[9] 'The water policy and act gives priority to registered domestic water uses and cities and only states that the other uses will be allocated taking into consideration the economic and social values' (Komakech, et al.,2012,p.716).

holder farmers by providing alternative water sources such as digging boreholes or building dams for water storage which could provide a substitute. Therefore, policy interventions of this nature marginalize some farmers from access to irrigation.

A related problem was reported in the lowland zone where some farmers have been asked to abandon their farm because it is within 60 meters of a water source to protect water sources.

'…. I do not understand this government, my dad bought the land, and we have been using it for a long time. Now they are telling us no human activities in this area, where shall I produce food? This is the only land I have.'

Participants in all focus groups also complained that the government has given directives that crops must be measured using scales and not any other instrument, in order to prevent cheating, but despite the directive it has not been implemented.

'Unfortunately, measurements used like the use of plastic Sadolin (containers famous for paints packaging) cheats farmers because buyers soak the Sadolin container into kerosene to expand. As a result, a sack which can be filled with normal 30 Sadolin, when buyers use theirs will be reduced to only 25. So every day the business people create means to destroy farmers. But why can't government deal with these people? They instructed the use of scales but they are not forcing these business people to implement this' (Women's focus group discussion, midland zone).

Another complaint associated with government directives was frequent bans on exporting crops. The government was reported to frequently ban maize exports to neighbouring countries to ensure food security within the country. However, farmers are unhappy with this because they perceive it to be unfair to them. As reported:

'The government frequently makes it unlawful to sell maize to the near countries especially when it happens most places did not get enough rainfall that caused crop failure. But when we were borrowing money to buy input and pray to God that we get enough rainfall and get good price for our crops the government was not there. Now that people come and they want to buy and give us a good price the government says no. Why can't government buy then and give us the money we want?' (Focus group, lowland zone).

Focus group participant in all three zone were asked to identify the most difficult problem out of the problems identified in the discussion and in all three zone, they reported if they are asked to pick only one problem to be addressed to help them adapt to climate variability and change, then it would be in relation to access to alternative water sources.

6.3 Livestock keeping

Farmers in the focus group discussions in all three zones reported mixing crop and livestock farming as an important form of diversification for increasing livelihood resilience. Participants in the focus group described the types of animals kept in the study area, such as cattle, goats and poultry and how important each is for the security of their livelihoods. Apart from nutrient cycling between animals and crop systems, these animals can save families from adversity, especially where there is stress including stress from weather-related shocks. As reported

'…. keeping animals, as well as crop production, provides many benefits to us. The more diverse you are, the more you protect your most important livelihood assets. For example,

10*chicken protects goat, and goat protect the cow, cow protects land and land protect the house. That is why it is not common for people in this area to sell land.'* (Women focus group, Highland)

This means that, some families with more diverse livelihood sources are more likely to protect (not to lose it may be by being forced by circumstances to sell it to address problem facing household) their most valuable assets such as land in case of shocks. In difficult time such as periods of crop failure, there are many options that a household with livestock can choose from such as selling the chickens, goat or cow before needing to consider selling land.

Farmers in the focus group in all three zones agreed that, the benefits of crop-livestock diversification cannot be optimized if farmers do not select appropriate livestock species that can provide the most economic benefits. Respondents have learned from their own experience and that of others, and education provided to farmers by government and NGOs that, improved cattle species have more economic benefits than the traditional cows. As reported in the focus group discussion while discussing the trends in the type of livestock and their implication to adaptation to climate change and increasing resilience, one respondent said:

'…. in the recent years as a result of education to farmers, from government and NGOs, we have changed from traditional cows to improved cattle species with more meat and milk…. in the past, our parents used to keep traditional cows (with a node at their back). These cows produced very little milk - only two liters, even the body size was small so when sold, not much money was obtained.'

[10] Before they sale goat to manage emergent risk, they sale available poultry first.

The household survey shows that Figure 6:6 the majority of respondents from the highland and midland zones keep more valuable cattle breeds that produce more milk, and less than a quarter of respondents reported that they did not keep the improved cattle species. Not applicable was coded for household that do not keep livestock at all. The main message from these results is that more than half of respondents from the lowland zone do not keep livestock, and 25.8 and 19.2 percent of respondents from the midland and highland zones respectively do not keep any type of livestock. This means that they miss an opportunity to benefit from an extra income source, food (particularly milk), and nutrients from animal manure for their crop production. In addition, they are potentially more at risk of falling into crisis especially at this time of increased climate variability because they have more limited risk management strategies in the case of shocks including weather related shocks (Ellis, 2000).

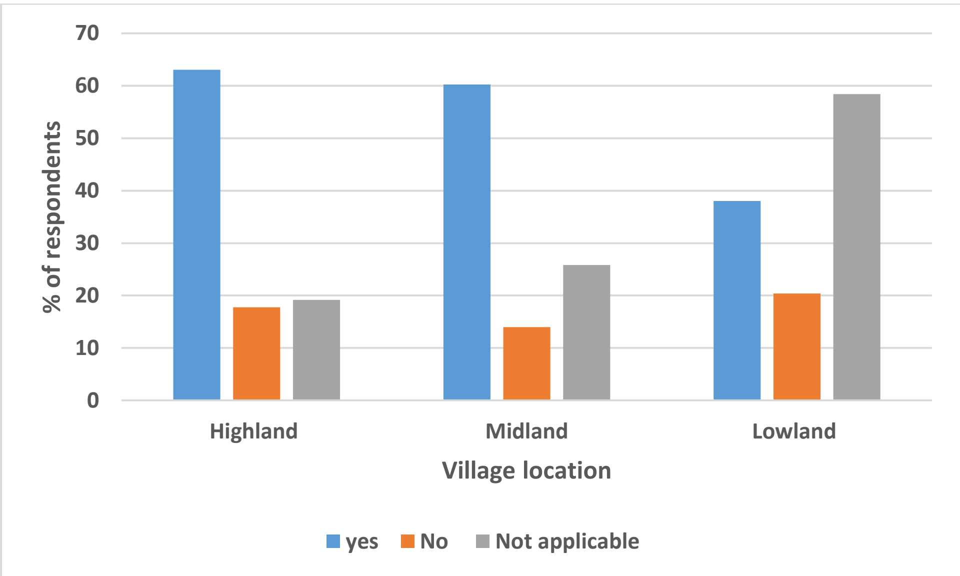

Figure 6:6 The percentages of household who keep improved cattle (yes) or traditional cattle(no), and those with no livestock (not applicable) as reported in the household surveys from all three zones

However, the adoption of improved cattle breeds does come with challenges such as the requirement for relatively high amount of feeds including supplements which households have to supply making it more expensive to keep these improved cattle breeds than the traditional species which were free grazed.

6.3.1 Problems associated with livestock

This chapter presents difficulties that are associated with livestock drawing from data in the household survey. The problems in this sector did not came up in the discussion with focus group participants. The intention is to understand these challenges so that policy measures can be put in place address to help the livestock sector contribute to livelihood development. Figure 6:7 presents quantitatively the problems facing livelihoods associated with the livestock subsector for farmers in the lowland, midland and highland zones. Lack of sufficient fodder and lack of money to buy feed were the greatest drawbacks for most farmers in the midland and highland zones. Farmers complained about the demand for more fodder particularly when there is insufficient rainfall reducing accessibility to fodder because of drought. Farmers also talked about the high cost of nutrients that cattle need in order to produce more milk. When the supply of fodder is insufficient, even prices for fodder goes up making it more difficult because of financial constraints. In the lowland zone the majority of respondents complained about animal diseases making it expensive for them to treat animals because of low capital. Other problems which were mentioned included expensive medicines in the highland and lowland zones and lack of veterinary services in the midland and highland zones.

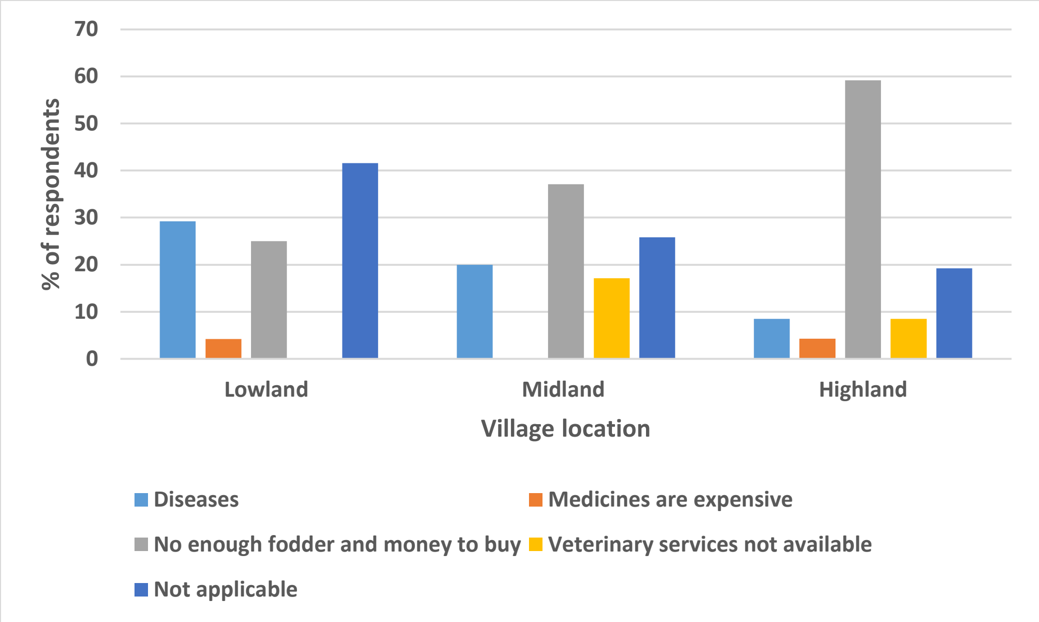

Figure 6:7 Percentage of households reporting different problems facing the livestock subsector as reported in the three agro-ecological zones in household survey. Not applicable refers to households with no livestock.

6.3.2 Off-farm income activities

6.3.2.1 Types of off-farm income activities

The respondents of the household survey identified several different types of off-farm income sources which I categorized into two main types: paid job; and small business. The results show that Figure 6:8 more than 45 percent of respondents in all three zones reported did not practice off-farm income activities. Those who practised off-farm income activities, mostly practiced small businesses such as local running of milling machinery, carpentry, local shops, food vendors, tailoring, transportation by having motorbikes, minibuses and pickups, buying selling agricultural products and clothes. Most of the people reporting to take part in small enterprises were women particularly through buying and selling crop products. Twenty percent of respondents in the midland and lowland zones, and 15 percent of respondents in the highland zone reported getting additional income from paid jobs such as driving (including motorbikes), teaching, and casual jobs like selling labour for other farms. These results imply that significant numbers of respondents do not take part in off-farm income activities, and those who do are dependent on small business activities. Having no off-farm income activities is riskier to livelihoods because of increased risk of crop production and livestock keeping to the impacts of climate change because of too much dependency on natural resources. On the other hand, as some of the respondents depends on selling crops as an off-farm activity this off-farm activity is equally as vulnerable to climate change.

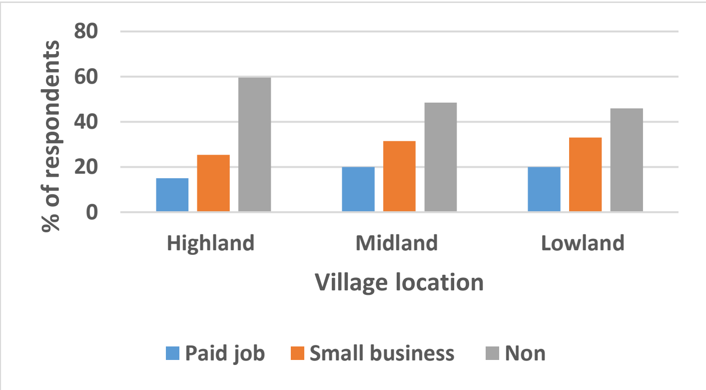

Figure 6:8 Types of off farm income activities as reported in the household surveys across the three zones.

6.3.2.2 Problems facing off-farm income activities

Figure 6:9 shows the range of problems limiting livelihood development through the off-farm income activities subsector. The most significant problems reported in the highland and midland zones was lack of customers for the different business activities, mentioned by 19 and 31 percent of respondents respectively. The respondents complained about the low purchasing power of people in their villages, meaning that the return from their business is very small. A lack of capital to improve their business was mentioned by the majority of the respondents from the lowland zone. Other problems mentioned in all three zones relate to irregular pricing and tax and the lack of good infrastructure in the highland zone. All of these challenges affect the ability of farmers to make the most out of off-farm income activities limiting their potential as effective adaptation strategies to climate variability and change.

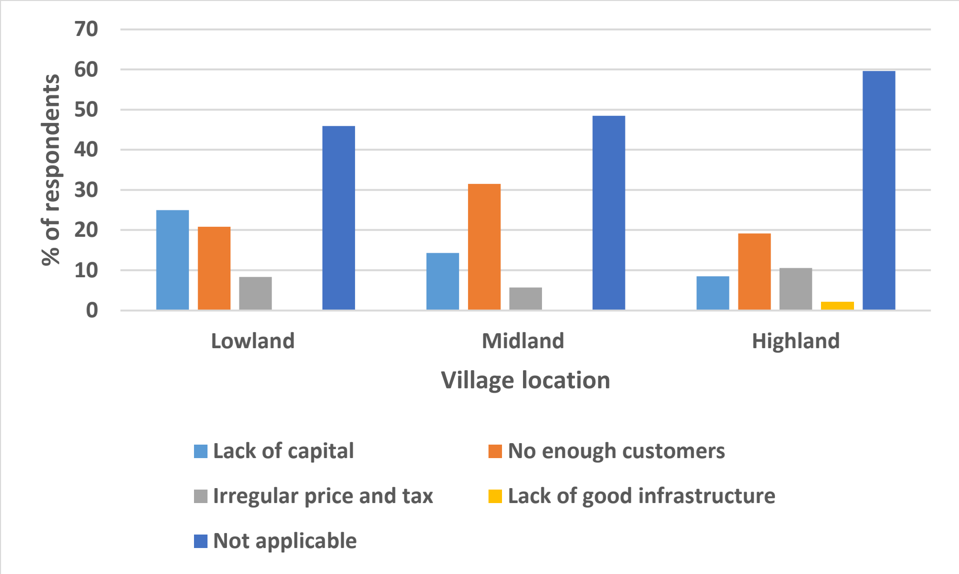

Figure 6:9 Percentage of respondents reporting problems facing off-farm income activities across the three agro-ecological zones as reported from the household survey. Not applicable refers to the households where no off-farm activities are carried out.

6.4 Social strategies governing household income and crop produce utilisation

This section explores the social structures and in-home strategies that govern the ways that household resources are used and they contribute to livelihood vulnerability to climate change. These aspects are important for consideration because they help to ensure livelihood outcomes such as improved well-being and food security within the household are attained (Kiewisch, 2015). These structures and strategies as identified in the focus group increasing livelihood vulnerability have been themed into the following areas Table 6:2: Lack of synchronisation of family planning and production activities; ii) division of ownership and household obligation. These strategies are discussed in detail below.

Table 6:2 Summary of the social structures and strategies that affect household resource utilisation and their outcomes as discussed in focus group discussions in the highland, midland and lowland zones.

Strategy/Zone	Highland		Midland		Lowland
	Men	Women	Men	Women	
Synchronizing production and reproduction	Timing of child birth and breeding of cattle ensures family labour and household food security	-	Timing of child birth and breeding of cattle ensures family labor and household food security	-	-
Division of ownership and household obligations	Division of ownership and household obligations promotes inefficient use of resources	Division of ownership and household obligations promotes inefficient use of resources	Division of ownership and household obligations promotes inefficient use of resources	Division of ownership and household obligations promotes inefficient use of resources	Division of ownership and responsibilities does not have negative effect on household livelihood resilience

Synchronizing family planning with farm practices and production was reported to be a way to contribute to food security in the past. In the men's focus group discussion particularly in the midland and highland zones, respondents reported lessons from their parents that helped to avoid labour and food shortages, and spending money to buy foods especially when a new baby is expected in the family. As reported:

'…. in the past year's weddings were conducted in December for a baby to arrive in September, so women should provide support in the farm, at the same time there should be a cattle giving birth one month before the arrival of the baby so that mother and child could get milk' (Men's focus group discussion, midland zone).

The past generation used to consider the most appropriate times for reproduction and production to enable labour and resources to be available when necessary to support livelihood development and prevent adversity in the family.

The respondents warned that the current generation has lost the wisdom of timing for reproduction and end up struggling to ensure food security especially when a new baby arrives in the family. As reported:

’…. our granddads were very clever. Not like the current generation who sometimes suffer a lot to get income and food to feed the mother and new baby because they do their wedding and have a baby at any time of the year. The Chagga (the dominant tribe in Kilimanjaro region) traditions required that before mum gets pregnant, you start with a cow (ensure cow is pregnant) a month before. So that childbirth would take place at the time of plenty food mostly a few months after harvest.’ (Men focus group discussion, highland)

This practice was not mentioned in the women’s focus groups in the highland and midland zones probably because of the following reasons. 1) May be this teaching was provided to male children only. 2) May be it is because they did not remember to mention it, or 3) they did not feel comfortable mentioning it. The farmers in the lowland zone are not the Chagga tribe which have been mentioned to synchronise reproduction with household production activities, which may be one reason why this strategy was not mentioned. Alternatively, as the lowland zone focus group was conducted with both men and women, it may be that participants were not comfortable discussing these (and other issues) in a mixed gender discussion.

Research has established that ownership and distribution of family crop produce and financial responsibilities increases livelihood vulnerability to shocks (Kiewisch, 2015). In all three focus groups, it was agreed that mostly households have a tradition of dividing crops between the mother and father and each had a different obligation in the family. The mother was responsible for food crops and ensuring food was available at home and the father was responsible for cash crops and supplementing what the mother has produced for food. Onn top of that the father was responsible for covering medical expenses, paying tuition fees for children and other household development activities such as building a house.

There were differences in the implication of these divisions between the highland, midland, and lowland zones. The results from the highland and midland zone focus groups confirm that access to money increases the decision-making power within the household but that the decisions were not necessarily beneficial to the well-being of the people in the household. As reported;

'…. we have food crops and cash crops. In the case of cash crops, coffee was owned by the father. The children and women participate in the coffee value chain as well. Banana trees, both parents worked together, but control on the use was on mum. Maize, both parents worked together, but control was on dad; but beans were solely mother crops in terms of working over them and even the use was defined by mother. Cattle were taken care of by all parents but milk was for mum but the cow was for dad. In the past, it was a shame (lost honour and respect) for a father to hold onto beans and milk as a source of income. The man controlled the economy in the past… in the past dad used to tell mum, she neither came with a cow nor the coffee to his family, this made dad sell coffee and put money in his pocket sometimes ignoring his family … people lived that way in those time as it was a custom. But currently, economy is controlled by women, because there is no money in the coffee like in the past, and women are doing business which give them income sometimes more than men. It is not common for women to have income and leave their children suffering, but division will not help us anymore. Now everything need to be on the table for both parents to plan how the household resources should be used' (Men focus group, Highland).

This implies that, since resources such as coffee farms and cattle were the fathers', that the mother married into, she had no power to influence how the income can be utilised although she might have provided labour in the production process. This division of resources and poor decision making was described as a more common practice in the past, respondents argued that there are still families who do the same in the study area. Where some household heads, mostly men, misused family income because they acted as it belonged to them and not the women or household in general. The participants in the focus group discussion in the lowland zone agreed that there was division in ownership and responsibilities within the household, but they emphasised that it did not negatively affect the household. The difference between the discussion of these issues between the lowland zone and the midland and highland zone, may again be a result of the mixed gender focus group in the lowland zone.

6.5 Key informants' results on interviews on the problems facing small-holder farmers' livelihood adaptation to climate variability

The key informants were asked to identify the main problems that affect small-holder farmers' livelihood adaptation to climate variability. Some of the responses identified by farmers were similar to key informants' observations while there were also other issues raised only by key informants.

The problems identified by the key informants included lack of capital, poor irrigation infrastructure, poor policy, land issues, lack of reliable markets for agricultural produce, lack of information and inadequate agriculture extension staff and facilities Table 6:3. These challenges are explained in detail below;

Availability of limited capital to invest in livelihoods was a raised as a challenge by the village and district agriculture extension officers, coffee research institute, and MVIWATA. The village agriculture extension officer perceived farmers to have low capital making them unable to purchase required agriculture inputs such as fertilizers, seeds and pesticides, while the district agriculture extension officer and MVIWATA perceived that having low capital availability meant farmers cannot afford to invest in water efficient irrigation technologies. The key informant from the Tanzania coffee research institute, perceived that the low capital of farmers meant some cannot afford to buy disease resistant coffee seedlings.

These results demonstrate that there are many areas where capital is needed to contribute to small-holder farmer's livelihoods. Capital is needed to buy agricultural inputs, as well as buying technologies that can support livelihood adaptation to climate change and variability. Since farmers cannot adequately invest in those areas, it is difficult for their livelihoods to be resilient against climate variability and projected climate change.

Table 6:3 Summary of the problems reported by key informants that limit the capacity of small-holder farmers ability for livelihood adaptation to climate change

Problem Source	Village Ag. Ext. Officer	Community Development Officer	Coffee Research	MVIWATA	District Ag. Ext. Officer
Low capital	Doesn't meet the input demand	Poor repayment of informal financial institutions	Farmers inability to buy seeds	Low repayment in informal financial institutions	Low capital limits use of water efficient technologies like drip irrigation
Poor irrigation infrastructure	Causes too much dependency on rainfall	-	-	Water wastage in traditional irrigation systems	Water wastage in irrigation infrastructure
Poor policy	Poor farmers can't afford even subsidized inputs	-	-	Agriculture subsidies, no soil test, export ban, contradiction between policies	Unfair inputs policy, no soil test
Land issues	-	Small plots of land have no viable economic benefits	-	Small farm size limits adaptation options	Renting land discourages land investment

No reliable market	-	Crash of coffee market	-	No reliable market for agricultural produce	-
Lack of Information				Not enough information on use of agrochemicals	Farmers inability to appropriately use agrochemicals
Inadequate extension staff and facilities	No facilities to help extension farmers reach farmers	-	-	Not enough extension officers	Not enough extension officers and facilities, like means of transport and fuels
Low adoption of innovation	Low adoption of drought resistant crops	-	Low adoption of improved coffee species	-	-

Poor irrigation infrastructure was also identified as a limit to adaptation potential by three key informants. The village agriculture extension officer perceived livelihoods to be vulnerable because of too much dependency on rainfall as a source of water because of inadequate access to irrigation infrastructure. While the MVIWATA representative and district agriculture extension officer stress the problem in terms of water wastage in the available irrigation infrastructure as the farmers lack access to concrete to line the irrigation canals and prevent water loss. These problems should not be necessarily considered in isolation, as in some places water infrastructure needs to be improved, and in other places there is no access to irrigation at all.

Problems related to policies and government institutions were identified by three key informant's -the village and district agriculture extension officers and the MVIWATA representative. The weakness of National Agricultural Input Voucher Scheme (NAIVS) was mentioned by three informants. Other policy weakness which were raised by the MVIWATA representative were related to fake inputs, export bans, and contradictions between policies. These areas are all discussed further below.

One of the weaknesses of agriculture subsidy policy that was highlighted was the applicability of the policy to the majority of intended recipients and a lack of ensuring that the small-holder farmers are getting the most out of the policy objectives. The NAIVS provides farmers with improved seeds and fertilizers for selected crops, maize being one of them with subsidized price. However, key informants reported the weakness of the NAIVS in two areas. The first is the inability of the poor farmers to benefits from the policy as the amount they have to pay is still expensive to them thus raising the fairness issues. The second weakness discussed is that the government provides fertilizer subsidies without first understanding the soil demands. As reported, by the district extension officer:

'…. farmers are supposed to contribute on the inputs price which very few can raise such amount…on the other hand, the policy says, farmers should be provided with seeds and fertilizers but the government has not done the soil test to understand what are the requirements of the soils'.

Interviewees also highlighted how the problems of fake inputs could be seen as rooted in poor government institutions. The government has established bodies, policies and laws[11]

[11] The Fertilizer Act (2009) provides for the regulation and control of the quality of fertilizer and The Tropical Pesticides Research Institute Act (1979) regulates research on pesticides to ensure their quality.

that ensure genuine agricultural inputs are available in the market, but these institutions have failed to deliver the required services. As reported by the MVIWATA representative:

'…. The government has established several bodies to deal with agricultural inputs. the Tanzania Fertilizer Regulatory Authority (TFRA) and the Tropical Pesticides Research Institute (TPRI). Sometimes you find chemicals in the market which have not been approved by TPRI. When we call the TPRI to talk about these matters in the seminar, they usually say Tanzania is bigger than their capacity. So they cannot control everywhere.'

This observation by key informants supports complaints made by farmers in the focus groups and survey about existence of fake inputs in the market, and that the root cause of the problem is partly lack of enough resources in the institutions responsible for their regulation and control.

Inconsistency between policies can affect farmers' livelihoods and can lead to losses. When one policy is encouraging something and another one discouraging it, this puts farmers in a dilemma, and severe livelihood failure can occur. As reported by the MVIWATA interviewee:

'…. there is contradiction between land policy which gives people access to land to perform human activities while in water policy human activities within 60 meters from the water source are illegal.'

This implies that there are two policies in operation that contradict each other thus causing a negative impact to farmers' livelihood. These comments explain the root cause of farmers' complaints about the appropriation of land that is within 60 meters from water sources, where they have been asked to slowly start moving away from these areas because of the need to conserve water sources.

Some directives provided by the government affect livelihoods by causing loss to farmers. This is the case for the orders that restrict selling crops outside of the country regardless of the presence of profitable markets elsewhere, meaning that farmers are forced to sell their crops in the local market regardless of the low market price of produce. As the MVIWATA interviewee states:

'…. in most cases after harvest, the government pose an export ban, while they are not capable of purchasing those crops from farmers. They claim that farmers would sell all crops and later complain about hunger.'

The decision by the government, apparently seen as a strategy to help farmers to ensure food security, is reported to create more problems for farmers.

Problems related to land were mentioned by three key informants, and each looked at the problem from a different angle. The community development officer perceived the problem to be the size of land owned by the farmers in these areas which is too small to bring enough production to meet a household's needs:

'*In this area the population is not proportional to the available land. So farms are so small in such a way that even when production is good, the output will not be enough to cover the household's needs. Let's take an example of a family with a half a hectare, what will he do* *with the output to cover food, medication, education and other life costs? The land size limits what people can do to increase their livelihood productivity.'*

On the other hand, the MVIWATA representative perceived that land size is the problem as limits the use of land management strategies such as fallowing:

'Farmers depend on land to grow crops which are the main ways they get their income. Since land is small, they cannot even rest the farm which causes soil exhaustion because of overuse. Farmers keep growing on the same land every year which may end with soil degradation'.

For the district extension officer, the land-related problems were related to people with no land entitlement, which affects decision making and land-management practices on land which is rented*:*

'There are some people who do not own their land because of land scarcity in this area. These groups of people survive by hiring a piece of land from other people. Since the land isn't theirs, they tend not to invest in land management strategies particularly whose benefits are not instantly accrued such as planting trees and use of manure. These affect the overall sustainability of the land and their resultant productivity.'

The issues raised by key informants show how land tenure and size of available land constrains adaptation and affects livelihood outcomes. A small farm size will not be enough to produce crops for a relatively large family and provide for their needs. Small land size also limits the utilization of some land management practices such as fallowing because of a lack of alternative land, potentially leading to long term soil degradation. It is possible to use other options like hiring land elsewhere to be able to rest the farm for a few season but this problem is complicated by low capital availability to invest.

Another area of challenges highlighted by the key informants were problems related to markets. These problems were articulated by two key informants - the community development officer and MVIWATA representative. According to the community development officer, a major problem has been the crash of the coffee price (he did not mention when it happened) in the global market. Coffee was the major cash crop in the Kilimanjaro region and the primary source of cash for most households in the region whose primary market was the world market. When the market crashed, caused by the increase in supply from other places in the world, livelihoods of the small-holder farmers in the region were in danger because they could not get enough income to invest in the farm and also invest in their general well-being. Since then, the production of coffee has declined because of the lack of finance to invest in the farm, while also no longer providing the income needed to support farmers' livelihoods. These issues were reported by the community development officer when explaining challenges facing livelihoods development:

'…. regardless of the various crops grown to replace coffee, still farmers have not recovered from the impact of the failure of the coffee market. Transforming to other crops for some is not possible, and others have gone for horticulture, but still they have not got income like the one from coffee…. so generally livelihoods have been impacted in so many different ways, even covering education expenses for children is now difficult.'

Another problem relating to small-holder farmer livelihoods identified by key informants is the lack of information available to farmers. The MVIWATA representative and District agriculture officer who both identified this as a problem identified farmers' lack of knowledge about the appropriate use agriculture inputs. These key informants were concerned that farmers do not have enough information about the appropriate use of agrochemicals, and fertilizers which had implications to the effectiveness of the input used. As reported by district agriculture extension officer:

'*There is also the problem where farmers decide on the dosage of the chemical by looking at the colour or smell instead of reading the appropriate measurement that has to be used which affects the intended results because the dosage may be either high or low. There is the same problem with use of organic fertilizers.'*

What this signifies is that although farmers complain about fake inputs, it is likely that it is combination of issues that affect the outcomes of the use of agrochemicals.

Several key informants (the village and agriculture extension officer and MVIWATA representative) identified problems affecting small-holder farmer livelihoods associated with inadequate extension staff and facilities. The key informants complained that agriculture extension officers are only available to a few villages, and even when they are available, they lack the means of transport to visit farmers and provide advice in context as even public transport in the villages cannot be accessed everywhere. The agriculture extension officer interviewed claimed that:

'…. the agriculture extension officers have great role to play in providing timely information to farmers regarding farming activities. But the problem is that there are not enough extension officers and even when available they lack means of transport to access farmers. So you may find there is an extension officer in the village but because she is not mobile, their impact will be very minimal as they will rely mainly on learning through farmer's groups, but cannot follow

up to see actually what is happening in the field and even when farmers want them in their farm they can't go because of lack of transport.'

Also during the discussion with key informants' complained about farmers' reluctance to adopt innovation in farming practices was widespread. For example, although the key informants promoted several strategies to help improve farmers' livelihoods, especially in adapting to the climate variability being experienced, there was complaints about low adoption of innovation. Key informants reported advising farmers on the types of seeds to plant (eg. early maturing maize) and how they can use it (buy seeds every season and no reuse), type of crops to plant (eg. drought resistant crops), and farm management practices that can help cope with climate variability and change, but with little uptake from farmers. For example, farmers are advised to use early maturing maize, but it is said that the farmers are not ready to invest in their farm by buying seeds every season, there is therefore a disconnect between what the key informants see as useful strategies and sometimes the farmers' own views and experience.

Greater understanding is needed of the reasons for farmers' actions or inactions. For example, farmers refusing to buy maize every growing season and perceiving it as high investment that will not bring them any profit, does not necessarily represent reluctance to adapt. It may be because the farmers do not generate the profit that can allow them to buy seeds every growing season or they do not have enough capital to cover those expenses.

Also farmers were reported by key informants as being reluctant to plant drought-resistant crops such as cassava and millet as farmers think they are inappropriate. As reported by the Village Agriculture Extension Officer:

'….in this area people are used to maize. They do not believe that they can substitute maize with millet. Although they see that maize production is highly affected by climate change, they do not want to grow millet. They perceive millet is for people from Dodoma and Singida region (arid and semi-arid part of Tanzania). While they see it does not rain like the time of our granddads.'

However, the village agriculture extension officer's observation is based on just one issue based around the crop as a food source, but I argue that this ignores other issues such as access to markets as farmers do not only practice livelihood strategies for the sake of food, but also income. Farmers reluctance to grow millet is not just because of food, based on observation from farmers themselves, the crop (millet) do not have large market like maize which farmers stick to produce regardless of uncertainties in rainfall.

The Tanzania coffee research institute (TACRI) has developed technologies to cope with diseases of coffee plants, as well as to manage soil water and nutrients through crop patterns that will reduce competition on resources. However, the key informant from TACRI finds that farmers' adoption of these technologies is not encouraging:

TACRI: '…. farmer's reluctance on the adoption of innovations such as coffee varieties resistant to diseases especially coffee leaf rust and coffee berry disease, growing in clear pattern between trees, banana and coffee is also a problem.'

Although key informants' observation about farmers' reluctance to adopt innovations in the face of climate change or other pressures seem critical of the farmers, I argue that there may be many factors, not considered by the key informants, that may hinder farmers' adoption of innovations. If farmers lack resources such as knowledge, or financial resources, or if the innovation does not meet farmers' socio-economic interests, it will be very difficult for them to adopt and implement the proposed innovations of the key informants or the organizations that they represent.

Another problem that contribute to vulnerability is low level of farmers' participation in decision making. Analysis of results from all key informants when asked during the interview how they decide on how to support farmers to adapt climate variability shows that, the level of farmers' participation as used by all key informants in public sector is not enough. It was observed that, farmers were likely to take part in problem diagnosis but not necessarily on the ways the problem could be addressed. So the challenge of this approach is that although the right problems may be addressed, the solutions are not built from the ground level and may not take into account all of the relevant circumstances of the farmers' livelihoods. Thus making the decisions to become too far removed from the 'on the ground' understanding

6.6 Summary

This chapter has set out to present the social factors that may contribute to livelihood vulnerability to climate change. The results show that there are several social factors that may contribute to livelihood vulnerability to climate change. The social factors were categorised into two main parts: firstly, problems that limit livelihood development in three livelihood options i) crop production, ii) livestock keeping and iii) off-farm income activities, and secondly social structures that guide household income use and crop produce use.

As this study focused on small-holder farmers, crop production was the dominant livelihood option and was practiced by all focus group and household survey respondents in all three zones. Many different crops are grown, increasing the potential from crops for food and income in the household. In the highland and midland zones, apart from permanent crops (banana and coffee) grown by some people, farmers also grow vegetables, beans and maize on their farms. Some farmers in the highland zone also own farms in the lowland zone where most cereal crops, maize and beans are grown.

For the respondents from the lowland zone, farming rotates between the dry region for rain-fed agriculture and wet region for irrigation farming. In the dry region, cereals are cultivated and in wet region rice farming takes place during the long rain season, and maize, beans and horticulture during the dry season and during long and short rain season if there is not enough rainfall.

If we look at the number of respondents reported in the household reporting to take part in other livelihood options eg. livestock keeping and off-farm income activities, we learn that all of the respondents took part in crop production, but some combined it with livestock keeping and/or off-farm income activities, hence diversifying their livelihoods. In regard to livestock keeping, the lowland zone had the least percentage of respondents who took part in livestock keeping. Off-farm income activities were not performed by more than 45 percent of respondents in all three zones. This means that farmers with no off-farm income activities either depend only on crop production or may depend on crops and livestock keeping. Where there are no off-farm income activities, this places their livelihoods at a greater risk to weather-related shocks because they have less income sources which do not depend on natural resources. Similarly, farmers who perform off-farm income sources based on selling agricultural crops may also be vulnerable to climate change.

The results focusing on social factors that contribute to livelihood vulnerability to climate change highlight a number of categories where there are immediate problems for farmers' livelihood, these include lack of capital, low crop price, livestock discouraging some adaptation strategies, and land shortage. In addition, the results from the key informants and focus group discussion shows that there are social structures within the study community that exacerbate problems facing farmers making farmers' livelihoods vulnerable to climate change. For example, the failure of market institutions thorough the crash of coffee markets affected farmers' livelihoods. Farmers coping strategies to the problem of the collapse of the coffee market was to use other crops such as cereals and vegetables as cash crops. Unfortunately, the market institution in the study area does not meet farmers' expectations of getting a profitable price from these agricultural products. There is lack of reliable and profitable market, and the existing markets are characterised by high price fluctuations and government restrictions. All these reduce the amount of profit that famers would accrue from livelihood options and future investment into livelihood and household wellbeing.

The use of agricultural inputs in the study area is also a problem. Not all farmers have access to them, some are fake and they are not used appropriately by some farmers. These problems are partly associated with poor government institutions such as policies and organisations that are related to small-holder farmers' livelihood. The The NAIVS lack fairness as the poorest farmers cannot afford to buy inputs. The government institutions responsible to ensure only genuine inputs are in the market also do not effectively perform their duties. Farmers also lack the capacity to implement soil testing to understand soil requirements for fertilizer application. Farmers also lack knowledge of appropriate use of these inputs which may partly be contributed to by a lack of enough agriculture officers. All these problems make farmers inappropriately use agricultural inputs, increasing their vulnerability to climate change.

Other social structure contributing to livelihood vulnerability include the existing tradition of land inheritance. The division of land to every male child in every generation has reduced the land economic value especially for crop production. The problem is compounded by high population in the area, which increases the number of times land has to be divided thereby reducing the size of available land for agriculture. Land shortage also contributes to land degradation because of the inability to rest the farm to allow it to rejuvenate.

The problem of livestock kept by other farmers limits some adaptation strategies and also raises the important point of the role of social structures in terms of where people live in relation to their farm which determines the challenges they face and potential solutions. Livestock keeping (by others) was mentioned as a constraint on planting trees and other drought resistant crops that take a relatively long time to mature (such as cassava), making crop production of farmers from the highland zone who also farm in the lowland zone, vulnerable to climate change because they do not live near their farms to guard against livestock and theft.

Structures within the household contribute to the vulnerability of the household to climate change through lack of synchronisation of production and reproduction, as well as division of ownership and obligation within household.

The lack of alternative water sources to compensate for decreasing rainfall was also reported to contribute to vulnerability to climate change. Farmers reported potential alterative water sources and strategies to get the most out of existing rainfall which is not fully exploited.

Livestock and off-farm income sources are also vulnerable because of a lack of resources (knowledge and finance and infrastructure) to invest in these sub-sectors and poverty levels of the wider community that reduce their purchasing power. For example, in livestock keeping, farmers are finding it difficult to deal with problems like disease not because there is no medicine to cure the existing disease but the prices of veterinary care and medicines are high compared to income.

6.7 Chapter conclusion

This chapter set out to understand the social factors and structures that contribute to small-holder farmer livelihood vulnerability to climate change. The chapter has enhanced our understanding of the social factors that need to be addressed to help small-holder farmers in the study area adapt to climate change. The results show there are several barriers that limit the successful performance of the livelihood strategies contribute to vulnerability to climate change. The existing social problems range from those coming from the household themselves to those emanating outside of the household. The social structures such as those control the crops price, government institutions and organisations, as well as farmers' location that limit capacity to implement some farming practices increase vulnerability to climate change. The next chapter (chapter seven) present how to build small-holder farmers livelihood resilience in the face of climate change.

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7 Increasing livelihoods resilience in the face of climate change

7.1 Introduction

This chapter explores how to build small-holder farmers' livelihood resilience to climate change through adaptation and draws on Biggs *et al.'s*. (2012:2015) resilience principles and DFID (1999) sustainable livelihood framework. The chapter will address issues raised in the previous chapters (Chapter Four, Five and Six) drawing together the results presented by respondents in the study area and the climate change adaptation literature. The aim of this chapter is to present changes needed in practices, structures or processes that increase small-holder farmer vulnerability to climate change. The discussion in this chapter is organised as shown in Figure 7:1. As the household is the focus of this study in lieu of basing the discussion around the results in Chapter Four, Five and Six, I suggest that the starting point in discussing the building household resilience is to consider how a household utilises what is currently available in the home such as income and produce. The next important thing is to consider how to build the household assets base including human capital, social capital, financial and natural assets. In addition, following the resilience framework of Biggs *et al.,* (2012:2015) the management of slow variables and promotion of livelihood diversification is important. The final part of this chapter explores the role of government in dismantling barriers that limit the capacity of a household to build assets, manage slow variables and enhance livelihood diversification.

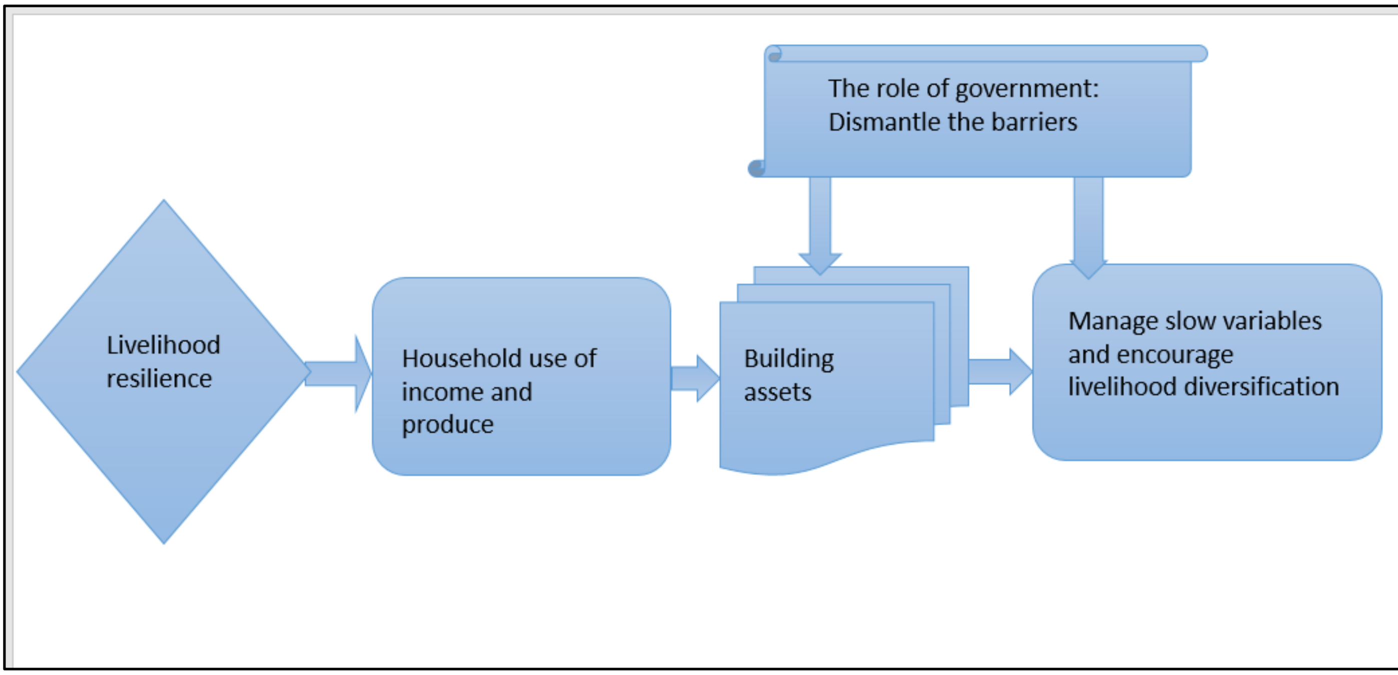


Figure 7:1 Summary of the pathways for building resilience of small-holder farmers in the Kilimanjaro region

7.2 Maximising existing household assets: income and produce

The household and the existing assets in terms of income and produce have a major role to play in building a resilient livelihood. Households have to take action by critically examining how they use income and crop produce. Appropriate use of these resources will ensure proper channelling to key issues that matter to the family such as capital investments to different household assets such as human capital, financial assets just to mention a few. Two key issues can be drawn out of the results from the focus groups and household surveys presented in Chapter Six that require adjustment in the household to enable livelihood resilience to be developed. These were i) the division of household obligations and ii) the lack of synchronisation of production activities and reproduction. These personal issues came up during the focus group discussions in the midland and highland zone in relation to the existence of hunger in the study area. Both male and female focus group participants suggested that the division of household obligations and divided ownership of household resources needed to be replaced with joint ownership and shared household obligations where every partners' resources and what is produced in the households should be considered to belong to the family; with couples coming together to plan how those resources will be spent. This solution, as suggested by the participants would help to enable transparency and a balance of power in decision making. Where this does not exist the more powerful decision maker (with access to resources) has potential to misuse household resources without consideration of what is best for the whole household.

To facilitate shared household obligation and increase transparency in the household use of resources requires other wider policies that promote women empowerment. Women empowerment through access to education and financial capitals gives them power and to take part in decision making within the family as reported in the both gender focus groups discussion in highland and midland. Women empowerment is reported in the literature as one of the practice that can increase household resilience to climate change (ALMARIO-DESOLOC, 2014).

It was reported that, in the past, the right to education was mainly to a male child, while girls would take part in farm and domestic work with her mother. As a result of social change promoting education for all, women have access to education. Also some women have access to financial capital through access to loans which they invest in small businesses to get additional income for the family. Both focus groups participants in the highland and midland zones suggested that the impact of the empowerment of women has gone further than just helping to provide for the family, and has also led to strengthening the relationship with their partners/husbands and giving them more power to participate in family decision making. As reported:

'*In the past, the girl child and mum fed cattle while the boy children went to school but currently every child has equal right to education which can give them opportunity to get a job and income. On top of that, now women have access to loans that helps us to do small businesses. Because of the income we generate, this has made us closer to our husband. Now we sit as a family and plan how we use our income'* (Women's focus group, midland zone).

However, although in the study area women access to education and financial capital was mentioned to contribute to empowerment and balance of power within household, not all of them have access to these opportunities not in all in the Kilimanjaro but in Tanzania in general (Kato and Kratzer, 2013). So the question remain how the rest can survive to cope with the slow pace of measures that can lead to complete transformation for women empowerment? The answer can be found in both gender highland and midland focus group discussion where gender role was reported to help control adversity in the household by women hiding some of the crop produce. As reported:

*'…. when mums harvest beans, she hides one bag to a friend. When those at home get finished, and it happens that dad has got no money, mum informs dad that she is going to borrow some from a friend to be returned when dad gets cash. This is how clever our mother is. This is common for a chagga women even up to now, because even if it is not beans, she ensures she has got some money which can be used in dark days' (*Men's focus group, highland zone).

This result shows that mothers have particular ways of preventing adversity when there is a shortage of food or income in the family. They did so by concealing some of the harvest with a friend without the male household head's knowledge to ensure there is always food available for the family, and fetching it at times of scarcity while telling the male household head that it is a loan to be repaid. Since this was also reported in the male focus group shows that, men also know the strategy exist but they support it to help family cope with shocks.

On the other hand, the present generation was encouraged to consider practices which were seen as normal consideration in the past, in planning the timing for procreation to ensure the wife gives birth at the time of year where there is plenty food in the household, and not during the farming season so as to allow her to contribute to the household labour force.

Other strategy farmers in all focus groups in all zones reported to use to build resilience is food storage systems especially after harvest to give food a longer life and protect it from damage. The focus group participants in all three zones mentioned the use of plastic or tin tanks) which are tightly sealed after filling with food, especially maize and beans, as their main method of storing food. Although there was no specific question asked about food storage systems, it came about in the discussion about hunger periods in the study area. As reported:

'…. we don't have hunger like what happens to some in the country to the extent of requiring food aid, because apart from other opportunities available in this region, we keep food in plastic or tin containers-which can keep food healthy for a relatively long time and prevent us from hunger' (Men's focus group discussion, midland zone).

Respondents particularly in the women's focus groups in the highland and midland zones reported storing other food apart from maize and beans. These include banana particularly for the midland and highland zones, and cassava and sweet potatoes for respondents from the lowland zone. All women focus groups report that they peel the crops and dry them, then keep them in a sack to help add to the family's food stock. Even when they have a limited harvest in certain seasons, they may have some food stocks which can be used to keep them going until the next harvesting season. As reported:

'…. we don't have hunger nowadays, apart from using irrigation which gives us extra food, we also maintain the traditional practice of drying and storing crops like cassava, and sweet potatoes.' (Focus group discussion, lowland zone).

7.3 Building the household assets base

Access to assets, in terms of human capital, social capital, financial and natural capital is vital especially for the poor to construct and maintain their livelihood. Livelihoods depends on the quality of the assets which a household owns and the assets' management and they form the foundation upon which livelihoods are built. The available assets also define the ability of the people in question to execute different livelihoods strategies (Chambers and Conway, 1992; Ellis, 2000; DFID, 1999; Scoones, 2009). Chapter Four describes how the small-holder farmers in the study area perceive their livelihood assets to be decreasing. This subsection explores how to small-holder farmers' livelihoods assets can be increased, as this is an important step in increasing farmers' capacity to construct their living and increase resilience to climate change variability. Note that, there is no specific section about how to build financial capital based on the results from chapter four because it was linked to low production, high production costs and land abandonment which could all be addressed by having livelihoods management strategies and practices that can build livelihood resilience in the face of climate change.

7.3.1 Building human capital

Chapter Four shows how human capital in the household is affected by out migration influenced by climate variability and other factors, and illnesses caused by malaria which is intensified by increasing temperatures allowing the geographic spread of mosquitoes. Also in the same chapter, human capital in the form of quality of knowledge created by coffee research institute is put in danger by increasing rainfall variability and temperature.

7.3.1.1 Dealing with the impacts of migration

Out migration from the study area is reported in chapter four to partly contribute to affecting small-holder farmers' capacity to make a living as a result of reduction in household labour. Although migration has different dynamics in different families, I argue that based on the historical context of rural migration in Tanzania, it is not practical to control out migration completely. Since independence, the government of Tanzania has established different rural development policies to promote development in rural areas and discourage people from moving from rural areas (Hansen, 2012). These established policies included building infrastructure, schools, and health centres but there is still a huge amount of out migration from rural areas particularly to urban areas in search for jobs, education and others for marriage (Hansen, 2012).

Apart from that, migration happening in Tanzania has been associated with urban poverty Bohensky *et al.,* (2015) because of high rate of unemployment particularly in urban areas. Peter (2013) reported that almost 11 percent of Tanzania labour force is unemployed including the graduates where only 6 percent of youth from finishing the University degrees get jobs.

Given the population density in the Kilimanjaro region and the pressure it presents on land resources as also expressed in this study's results, and lack of adequate employment opportunities in Tanzania, there are two suggestions may help. Firstly, is to improve infrastructure in the rural areas such as agro processing industries that can stimulate off farm income activities (Msigwa *et al.,* 2013). Secondly, organised migration can bring positive impacts as well as negative impacts. Tanzania has huge areas of uncultivated land with arable potential which could offer a potential area for relocation of some people from the densely populated Kilimanjaro region. Tanzania has 88.6 million hectares of potential arable land and only 10 million hectares have already utilised for cultivated (NBS, 2014). If necessary infrastructure is developed appropriate incentives put in place, and there are appropriate environmental and social conditions for the successful performance of farming activities, some people can be encouraged to move to these areas to address existing areas of excess pressure on existing farmland.

The idea of moving people into other areas may come with environmental and social complexities as reported in the studies about impacts [12]villagization policy in Tanzania. In this policy farmers were moved from different places in the country to established villages where farmers were provided with considerable capital investments in machinery and services but the programme failed because of poor maintenance of equipment's and low productivity (McCall, 1985).

Some of the potential challenge that can arise especially taking lessons from villagization include increased distance to fields especially if settlements will be relatively far from fields, impact on child care for the families with children and changing and reducing the quality of food taken by households (McCall, 1985). It may also lead to general land deterioration especially if agricultural best practices are not implemented. As part of a successful livelihood strategy, households have to organise mechanisms to ensure that migration does not bring further crisis to households. For example, leaving only the elderly at home and incapable of

[12] Village settlement scheme of early 1960s where over 20 villages set up models developed to work as diffusion centers of modern farming

[13] taking care of both themselves. Households members may develop projects in the home area (place of origin) for example a local shop or small milling machine to encourage a family member to remain in rural areas to look after the elderly if they have got one.

7.3.1.2 Dealing with the impacts of malaria

The study participants report an increase in malaria in the study area in all three zones but the more concern was in in the Highland area where because of cold weather mosquitos that spread malaria disease did not survive. This is, attributed to increased temperature and affects households' financial capital because of the inability to take part in farming activities when ill and costs spent on medication (Onwujekwe *et al.,* 2000; Teklehaimanot and Mejia, 2008; Asenso-Okyere *et al.,* 2011). Adaptation strategies are needed to deal with an increase in malaria and hence improve human capital. Malaria control strategies have been proposed by Ministers of Health from 102 African countries in 1992. Teklehaimanot and Mejia (2008) summarized these strategies as follows:

- ✓ Provision of early diagnosis and prompt treatment
- ✓ Selective and sustainable use of preventive measures, including vector control
- ✓ Prevention, early detection, and containment of epidemics
- ✓ Strengthening local abilities and applied research.

These strategies require actions of both the governments and the households. Households are responsible for using prevention measures such as using mosquito bed nets, and managing the environments to reduce mosquito habitats, and going to the hospital when they get ill for diagnosis and treatment whenever possible. The government is responsible for educating people about control measures, ensuring access to medical services, and investing

[13] In Tanzania, the majority of elderly people are not taken care of in formal institutions but in their families

in research on prevention and treatment of malaria diseases. Since poverty also plays a crucial role in explaining why a certain population group are more vulnerable to malaria, because of the inability to pay for insecticide- treated bed nets, and access to medical health (Teklehaimanot and Mejia, 2008), the government is also responsible for provision of free mosquito bed nets for those unable to afford one. In the study area farmers reported to be provided free mosquito nets by the government but some were reported to use them to as a fence for their vegetable garden to guard against poultry because they do not feel comfortable to sleep on bed with mosquito net. This challenge call for more measures like education to farmers and farmers to realize they are responsible to take actions for matters important to their life.

7.3.1.3 Dealing with issues in coffee Arabica

I am discussing this topic under human capital because of the role of the research institute which is to generate knowledge that can help farmers successfully grow coffee crop in the study area. This study found that climate change presents two major threats to coffee production in the study area. One is the disruption of quality of data in experiment plots in Tanzania Coffee Research Institute plans and the other is the potential change of agro-ecological zone that could threaten the suitability of *Coffee arabica* (the major coffee species grown) in the study area. These two issues discussed below.

As reported on the four about how climate variability affects the role of key informants, The Tanzania Coffee Research Institute faces problems of data quality in their experimental plots and issues around how to deal with emergent pests and diseases. Addressing these problems requires research institutions to ensure access to enough resources both financial resources and skilled personnel to efficiently address the problem in a timely manner. The disruption of data quality in rain-fed coffee experiment plots because of rainfall variability is “a wake-up call” for the institution to consider irrigated plots alongside rain-fed plots because it is not known how viable the rain-fed plots will be in future. This uncertainty is as a result of climate change impacts.

The *Coffea arabica* optimum temperature ranges between 18-21^{o}C, and can tolerate a maximum of mean annual temperature up to about 24^{o}C (Scott, 2015). Temperature increase, particularly the minimum temperature (recorded during the night), has significant contribution to decrease in coffee yield. Literature has recorded the role of climate change -in the reduction of production of *Coffea arabica* in the northern Tanzania Highlands (Kilimanjaro and Arusha region) (Craparo, *et al.,* 2015) that will require development of adaptation strategies and use of external inputs to deal with the weather-related shocks (Craparo, *et al.,* 2015). If the incremental measures such as use of external inputs will not address the challenges, policy measures have to plan for transformative adaptation by supporting farmers to move to different crops or livelihoods that can survive the future changes.

7.3.2 Building social capital

This study has found in the household survey that there is perceived decrease in social capital (described as support that household provide to each other). As reported in Chapter Four, decreasing support between households was associated with three factors: climate variability that reduces production and therefore the capacity of household to support each other, lack of love between households, and monetization of the economy where things that used to be provided for free between households have got monetary value compared to past and so household members prefer to sell to get income instead of providing for free.

To be able to understand how to reduce decreasing social capital between households it is important to reflect on the question whether support between household is important and also if it is important are there ways that household support between each other can be promoted at the same time meeting the existing of challenges of lack of love and monetization of the economy. To answer the first question, social capital is important as it helps household survive impacts of poverty (Baiyegunhi, 2014) through provision of security in time of distress and access to resources (Grech, 2012). Given this advantage, it is preferably household members in this study area to use models that can help household support each other at the same time not be taken necessarily as something that can be provided for free without reciprocity (Baron, *et al.,* 2000).Below I present strategies drawing on the work of Baron *et al.,* (2000) that can promote social capital in such a way that both parties (households) get benefits.

There are different ways that households or individuals can build social capital. Baron *et al.,* (2000) identified two different aspects of social relations that can constitute useful capital resources for individuals i) obligations, expectations, and trust worthiness of the structure; and ii) norms and effective sanctions. These are described below.

One core element of social capital is where people are willing to help each other and do things for each other. An example of this is by having rotating credit association. If an individual (named A) does something for B, and trusts B to reciprocate in the future, this establishes expectations in A and an obligation on the part of the B. As A does the same to more people, and these people are trustworthy and responsible, this creates good safety nets for A in the event that something happens to A. This study revealed one practice based on social capital, in the saving of food resources by one household for another, to be taken back in times of need. This area of social capital was the preserve of females in the communities who reported to support each other in this way.

Another core element of developing social capital explored by Baron *et al.,* (2000) is through the development and use of norms and effective sanctions. However, norms and sanctions can be fragile as some people can misuse them for personal interest. Norms and sanctions relevant to this study include the promoting of norms that encourage family members and neighbours to act selflessly in support of their family and neighbors; this is then sometimes rewarded providing positive motivations when a selfless act is undertaken and a tool of punishment when selfish act is implemented. For example, a household which do not support another household mainly because of lack of love will not be supported in case they need help (negative motivation) while the household which support another during the distress time because of love may be positively motivated by supporting then in case they need help.

To facilitate social capital, Baron, *et al.,* (2000) argues that certain kinds of social structure are especially important in facilitating some norms of social capital. The closure of social structure where there is interconnectedness and interdependency between all actors (see Figure 7.2b) is important not only for the existence of effective norms but it can also be seen as another form of social capital - the trustworthiness of social structures that allows the proliferation of obligations and expectations. Baron, *et al.,* (2000). argue that norms arise as an attempt to limit negative external effects or encourage positive effects. This is more easily achieved if there is connection and interdependencies between households. For example, in an open structure like figure (a) in Figure 7:2 below, the individual A, having relationship with B and C can carry out actions that negatively affect D and E. Since they are not acquaintances, they cannot unite to control negative externality from A, unless they act independently which requires sufficient power. In contrast the combined forces to promote effective norms are relatively possible in network because of the inter-connectness of all actors as shown in (b).

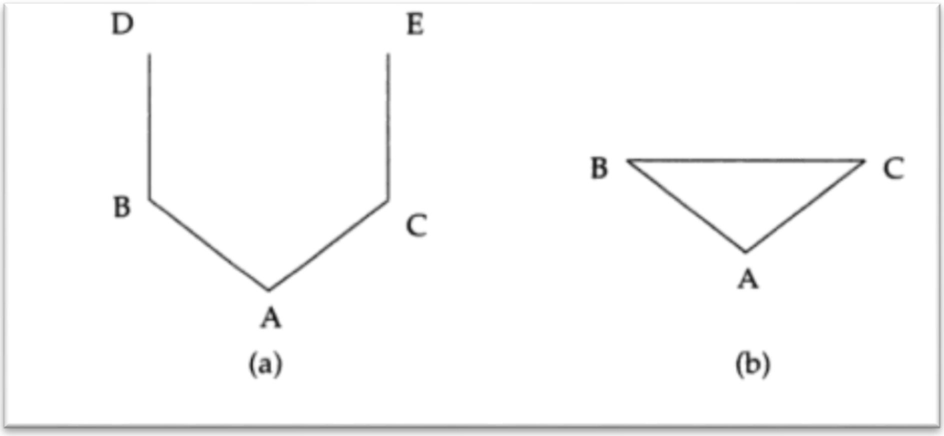


Figure 7:2 Social networks without closure (a) and with (b) closure within the social networks (Source: Baron et al. 2000)

The household survey and information from the community development officer shows that in the study area some households have developed social structures that facilitate some norms of social capital. They support each other by forming groups based on similarities between members such as family relations, friends, the same work space or work type. The groups work as saving and credit institutions, and members get different services such as access to loans and social support in case they face shocks in their life. The groups can also face some problems like loan defaults thereby creating conflicts. Based on information from key informants, there are some non-government organisation building capacity of these groups by providing training into how they can select group leaders, and develop financial management, and group policy. The government encourages group members to register through the community development office to increase accountability but most are reluctant to register because of registration fees accounting to 40,000 Tanzanian shillings (equivalent to around 20 US dollars). The government may consider providing training to more people and waive the registration fees in order to improve social capital in the area.

7.4 Managing slow variables

This subsection adopts the concept of managing 'slow variables' as used in Biggs *et als'.* (2015) resilience framework. Slow variables are those changes much slowly and takes time to notice their changes. The slow variables considered in this study are water and soil management practices as these are trends that can be affected by long-term practices. This section describes strategies to ensure the adequate supply of water for agriculture, and strategies to improve soil fertility considering these in the context of Biggs *et al.'s* 'managing slow variables'. The management of water supply and soil fertility are considered separately below. The management practices that manage slow variables discussed below involve use of on farm climate smart agriculture practices Whitfield, *et al.,* (2018) representing the agriculture practices and technologies that can help farmers in the study area to adapt to climate change, particularly by improving water use efficiency and soil management. This can be seen as managing slow variables because many (although not all) of the factors affecting soil and water quality and availability, and the strategies to improve these assets, occur on relatively longer time scales in comparison to other interventions.

7.4.1 Adaptation strategies to ensure access to an adequate supply water for agriculture

Water access issues were attributed to three main factors as outlined in the three results chapters (Chapters Four, Five and Six). Chapter four attributed the problem to rainfall variability, Chapter Five associated the problem with degradation in water sources from activities such as cutting trees in water sources, and Chapter Six linked the lack of access to water sources and alternatives to government policy. This section explores how to deal with the problem of inadequate water access based on their causal factors. Based on Biggs*, et.al.,* (2012:2015) principle, to manage slow variable is to manage variables that change more slowly and have an impact to fast variables for example the use of soil and water management practices that that affect agricultural productivity. Planting crops that can survive climate variability

Data collected in the study area demonstrated that the types of agricultural produce grown by farmers threatens the capacity of the existing water resources to sustain agricultural production in the area, particularly as available water resources are perceived to have decreased. Cultivation of high value, high water demand crops, particularly horticultural produce such as tomatoes, cucumbers, onions, and carrots has increased, increasing pressure on water resources. Although there are benefits to practising horticulture as produce can be harvested in a relatively short time; the viability of these choices of crop is in question because of the capacity to sustain production in the long term with trends of declining water availability.

In contrast, traditional maize varieties are perceived to take a long time to mature (~six months) which makes them vulnerable to the more variable rainfall patterns, potentially preventing the crops from reaching maturity. One solution is to replace traditional maize seeds with early maturing maize varieties which can survive the increased rainfall variability. Therefore, planting drought-resistant crops such as millet can be seen as another strategy for managing the effects of decreasing rainfall amount and increasing variability. However, the results from the small-holder farmers showed that use of these crops was low in all three zones. As some farmers have negative attitudes towards crops like millet and cassava (another drought-resistant crop), there is the need for the government to encourage farmers to grow these crops through the development of a sufficient market for these crops.

Government can also play a role in supporting further research into alternative drought resistant crops but with a need to ensure that these will meet the needs and wants of small-holder farmers.

7.4.1.1 Farming techniques improving water use

The use in-field water conservation as described in section 2.7.2 which involve use of farming techniques for increasing infiltration, reducing surface runoff and evaporation and improving soil water availability is essential in dealing with weather related shocks (Biazin *et al.*, 2012).The strategies which were mentioned in the study area are terraces as reported in highland zone and minimal tillage reported in the lowland zone. Farmers in the focus group discussion in the highland reported terraces to help control soil erosion but Biazin *et al.*, (2012) argued the technique is important for also for reducing surface run off and increase infiltration. The use of minimal tillage (described as planting crops without tilling the land) was suggested by focus group participant in the lowland to protect the soil moisture.

7.4.1.2 Rainwater harvesting

Rainwater harvesting may also offer opportunity to increase productivity of existing rainfall. The harvesting systems mentioned by focus group participants can be categorised into two types: earth dams and spate irrigation both in the lowland. Earth dams are structures consist of three components which are: the rain collection catchment; the storage structure; and the target area which is the dam itself (Biazin *et al.*, 2012). Focus group participants in all three zones reported the need for earth dams especially in the lowland to harvest available rainwater and use it for supplemental irrigation. Construction of earth dams has helped farmers in semi-arid Kenya to cope with long dry spells (Barron and Okwach, 2005; Fox, *et al.,* 2005). In Dodoma, Tanzania this strategy is used to cope with drought (Hatibu and Mahoo, 1999: Below *et al.*, 2012) and is also reported from Bangladesh (Habiba, *et al.,* 2012) and in Nigeria (Tambo and Abdoulaye, 2013).

Spate irrigation[14] was mentioned in the focus group in the lowland zones where flood waters from the highlands is channeled to nearby fields through gravity or water pumps to irrigate farms in the lowlands. This approach is used to cope with dry spells by taking advantage of the rain happening in upland areas while it has ceased in lowland areas. As explained earlier in chapter four, the rainy seasons in the highland and midland zones are relatively longer than in the lowland zone, as one focus group respondent reports:

'…. before we plant crops during the rainy season in some farms which are close to the floodplain, we usually prepare canals and sunken beds. These are used to irrigate crops using floodwater especially when the rain stops in lowland but still raining in upland.'

This spate irrigation provides alternative water sources that help farmers ensure food security. Apart from providing additional water sources, farmers with access to spate irrigation reported other benefits such as improved soil fertility, and therefore they do not use any fertilizer on their farms because the spate water comes with eroded materials that are nutrient rich. Although this strategy has many benefits it may come with other challenges because large flash floods can potentially cause damage to the crops grown and prepared land (Komakech et al., 2011) although this was not mentioned by any focus group or household survey participant.

[14] The word "spate" refers to floodwater originating from episodic rainfall in the upper part of river catchments, which in the lower part is diverted from ephemeral rivers and spread over agricultural land. The potential relevance of spate irrigation stems from the fact that its water is generated from the hill side during storm events when water is often in excess and of little value at that time to the upstream users' (Komakech *et al.*, 2011,p.1919)

7.4.1.3 Conservation of water sources

Across all three zones there are a number of different practices that were discussed as being important for the conservation of water resources, including encouraging tree planting both on-farm and water catchment and avoiding the cutting down of trees. The relationship between trees and water resources is complicated (Ellison *et al.*, 2017). However, there is some indication that increasing tree planting on farms and water catchments can help preserve water resources through the effect of shading to reduce evaporative loss from soils (Clement *et al*., 2016). The observed impact of cutting trees to water availability comes later and not as soon as trees fall down, and therefore representing the slow variable that affect amount of water in water sources.

However, in addition to direct interventions such as tree planting and water-conservation farming practices, wider systemic issues leading to poverty need to be addressed, because in some cases it is structural problems linked to poverty that push farmers in this area to inappropriately use water sources as a survival strategy. For example, excessive cutting trees both on-farm and near water sources was linked to need for income particularly after collapse of coffee price.

7.4.1.4 Using efficient irrigation methods

The use of efficient irrigation method is essential to deal with decreasing water availability and increasing water users in all three zones. Efficient irrigation method that was mentioned in the lowland was the use of sunken bed, which reduce the amount of time needed for irrigation and therefore amount of water. Although the strategy was not mentioned in midland and highland zone, I personally observed some of them for farmers growing vegetables and cereals in farms with no coffee or banana. And because I did not have access to village agriculture extension officer in this zone, I cannot explain why there is such strong emphasize on farmers in lowland compared to other zones. There are other alternatives that could be used including drip irrigation which reduces loss of water from evaporation by district extension officer to be used by large scale farmers in the area, but small-holder farmers have low financial capacity to use them. Another source of water loss mentioned in all three zone that farmers asked for the government is water loss from surface water irrigation canals. Water loss in from these canals can occur both from evaporation from the surface of canals as well as leakage from the base of unlined canals. Some respondents suggest that it is the responsibility of the government to support farmers in lining canals in this way. Lining canals would be expensive and disruptive in the short term to existing water carrying infrastructure. Lining canals would also have the indirect effect of reducing infiltration and recharge to the groundwater table. Although concrete line come with no challenges, they can reduce the impact by encouraging practices that can increase infiltration and recharge underground water such as planting trees (Clement *et al*., 2016).

7.4.2 Adaptation strategies for improving soil fertility

Drawing from Clair, and Lynch, (2010), some of the soil managenet practices can be categorised into two areas: appropriate use of fertilizer and soil amendments and soil conservation to reduce erosion, maintain soil organic matter. After discussion with farmers on the trends in soil fertility and the amount of trees in their farms, (presented in Chapter Five) the farmers went on to discuss the lessons learnt from past land management practices and the implications to existing practices and adaptation to current climate variability. The results identified several strategies relating to soil fertility which increase agricultural productivity in the face of climate change. These strategies include mulching by retaining crop residue in the farm, inter-cropping, the use of organic fertilizers, minimal tillage and agroforestry. These strategies were reported by respondents to increase soil fertility and conserve soil moisture.

7.4.2.1 Retaining crop residues

Retaining crop residues in lowland farms was reported as a potential adaptation measure that can build livelihood resilience to climate variability. However, respondents in all three zones complained that the use of this strategy is hindered by the free grazing of animals by livestock keepers residing in the lowland zone, and the need for pasture for livestock kept in midland and Lowland but partly depend on transported crops residue from lowland. Respondents believed that, given the increased nature of climate variability and projected climate change, and the benefits available from retaining crop residues in fields, this strategy is more important than ever because of the increased nature of climate variability. It was reported that, it is time for farmers to find the balance between livestock feeds and improving agricultural soils through retaining crops residue.

Retaining crop residue has many benefits. It is reported that when residue from leguminous plants is retained, there is an increase in nitrogen and phosphorus nutrients in the soils, particularly in the top soil (Turmel *et al.*, 2015). Another benefit of leaving crop residues in fields is the improvement of soil structure which increases the capacity of the soil to resist soil erosion (Bot and Benites, 2005). In addition residue retention on the soil surface provides physical soil protection against water and soil loss (Turmel *et al.*, 2015). However, the strategy of retaining crop residue in fields does not have positive results in all climates. Although it is not common for farmers to experience negative effects of retaining crop residues in fields particularly in warm climates like that of the lowland zone, literature has shown that negative effects can result from retaining crop residues in fields in cooler temperature climates as this practice can result in lower soil temperatures which can adversely affect crop production (Turmel *et al.*, 2015). Other potential negative impacts may include water logging of soils especially in areas with high rainfall (Turmel *et al.*, 2015). In this study area discussion about leaving crop residue was dominant for farms located in the lowland, but for farms located in the highland and midland, the district agriculture extension officer reported in the coffee farms, there was alternative source of mulch through tree and banana leaves. However, for crops like cereals and vegetables especially in highland zone, mulching may affect crop production especially during the long rain season. Because of cooler temperature and high rainfall during the long rain season, farmers never grow cereals and wait until near the beginning of short rain season.

In dealing with competing crop residue demands, land intensification can help increase the amount of biomass produced which can be divided between livestock and that which can be retained in the soils. Where there is sufficient biomass production, farmers can leave some residue in the fields, and take some for feeding livestock. To compensate for the residues left in the fields, farmers can plant more animal feed in the farm boundaries in farms located in the highland and midland zones. I am suggesting animal feed to be planted in these zones and farm boundaries because of two reasons: i) farmers are already struggling with farm size, and therefore it is wise to use middle part of the farm for other crops and animal feed on the boundaries. ii) Planting animal feed in the lowland may be consumed by free grazing livestock especially if the feeds take long to time to mature unless measures to discourage free grazing livestock are actually implemented. Measures to control free grazing animal is essential in order to motivate farmers to retain part of the residues in the farms. One of the strategy to address free grazing animal was mentioned by district extension officer was to the government encourage livestock keepers to reduce the number of livestock and remain only with the size that they can feed using their own resources.

7.4.2.2 The role of intercropping and crop rotation

Intercropping (meaning growing two or more different crops together at the same time) and crop rotation (meaning growing different crops at different times of year) was reported as a potential adaptation strategy to increased climate variability in all three zones. Respondents in the focus groups emphasised the importance of rotating maize with leguminous crops or intercropping maize with leguminous crops in order to improve soil fertility. Research has established that there are many benefits of rotating maize crops with leguminous crops which include increased crop yields compared to growing maize consecutively (Brankatschk and Finkbeiner, 2015; Uzoh *et al.*, 2019), and that these benefits are understood by the small-holder farmers. However, I this chapter argues that, given the increased nature of climate variability, farmers practicing intercropping should also consider combining crops with different capacities to tolerate dry conditions, to take into considerations increases in climate variability. These measure should also go together with addressing other wider social problems such as improve market for varieties of crops to motivate farmers to combine different crops in their farms.

7.4.2.3 The role of agroforestry

Agroforestry was also mentioned as a potential adaptation strategy to address issues of declining soil fertility in the study area in all focus group discussions. The strategy has both socioeconomic and environmental benefits as reported in the survey results presented in Chapter Five (section5.4.1). Research literature has also reported several benefits of agroforestry, including an increase in soil organic matter improvements in soil fertility erosion control low sensitivity to harsh weather, natural pest and disease control and provision of an alternative source of income (Reyes, et al., 2005; Nair, 2007; Nguyen et al., 2011; Pumariño *et al.*, 2015; Sepúlveda and Carrillo, 2015 and Schwab et al., 2015). It is important to acknowledge that, in the survey results, there were a small number of respondents who disagreed about the benefits of agroforestry when combined with cereal crops like maize. However, literature from agricultural development has shown the potential of agroforestry in maize production (Garrity *et al.*, 2010). The challenge may remain for the farmers to decide the amount of trees to be planted in their farms as Holler, (2014) found that, in Kilimanjaro region the farmers using trees as adaptation depend on available land size.

7.4.2.4 The role of organic fertiliser

The use of organic fertilizer was another potential climate change adaptation strategy for small-holder farmers that could be used in the study area and was mentioned by all focus groups in all three agro-ecological zones. However, farmers reported that the main challenge of using organic fertilizer was the inconvenience associated with transferring manure from the homestead where cattle are kept to the farm fields which were reported to be up to five kilometres from households.

There are several potential ways to address these issues. The issue of transportation of manure could potentially be addressed by farmers co-operating with neighbouring farm owners to hire transport and share the transportation costs or develop affordable implements for manure transportation (Williams, 1999). This shows the importance of social capital (in terms of a strong supportive community willing to work collectively) to address a range of issues. However, it should be acknowledged that any additional costs may be prohibitive for the poorest farmers highlighting that mechanisms to address financial capital underpin many different solutions.

7.5 Ensure diversity in livelihood

As detailed in chapter six, small-holder farmers in the study area have access to three different areas of livelihood contributions: i) crop production, where both food and commercial crops are produced for the purpose of households' food security and income; ii) livestock keeping, where animals like cow, sheep and goat are kept for food security and income; and iii) off-farm income activities, including small business such as small shops, street vendor and sale of agricultural products for additional income. However, the results from this study show that not all households diversify their livelihoods. In the focus group discussions in all three agro-ecological zones it was reported that households should ensure they have more than one livelihood option as a risk management strategy, particularly important in the face of increased climate change variability.

Another important aspect to be considered is the *extent* to which these different livelihoods options are practiced. In the study area the majority of households produce crops and keep livestock; while few have off-farm income activities. This implies that the dominant livelihood options are mostly from agriculture and that not all farmers perform other activities outside agriculture. Drawing on Biggs et als'. (2015) resilience principles it is clear that greater resilience can be achieved with greater disparity in the diversification options, and therefore having different livelihood options based around agriculture may still provide less resilience than including diversification away from agriculture.

Given the types of livelihood options practiced in the study area, there are some similarities in almost all livelihood options. The crop production and livestock keeping are all dependent on natural capital such as soils and water either from rainfall or surface water sources. This suggests that if the flow and stock of these resources change as a result of factors like climate change or climate variability, the main income sources will be affected. However, all livelihood options are interconnected. For example, since most of the small-holder farmers' income is dependent on agriculture, failure in farming will affect the purchasing power of the household and indirectly affect the market for people performing off-farm income activities. Therefore, even if there is significant diversification of livelihoods to include off-farm activities, these are still vulnerable to impacts of agricultural productivity, and therefore in rural areas, development and maintenance of effective farming practices in the face of increased climate change variability must be a priority.

Chapter Six also discusses the importance of the crop calendar and its relationship to the intensification of crop production as a livelihood strategy. Crop production intensification can be seeing as helping to achieve 'redundancy'. Redundancy is another core element of Biggs et als'. (2015) resilience principle. It is important for farmers to attempt to build in some redundancy within some components of their crop calendar in order for one element to compensate for another in case one fails. For example, farmers can enhance redundancy by growing a mixture of crops such as crops with uneven age structure to increase resilience and be able to adapt to increased climate variability. Strategies like mono-cropping increase vulnerability while intercropping where more than one crop is grown, decreases vulnerability. Intercropping is considered as the better option because at least one crop can survive in case of disturbances like weather-related shocks. Alternatively, that, if the rainfall variability is high in such a way that these two crops are at risk, farmers can maximize yield if they combine crops with different capacities to respond to rainfall variability. For example, in the maize plots, farmers can combine some millets so that, if rainfall is insufficient for the maximize harvest, farmers will at least harvest millet because it is drought resistant.

7.6 The role of the government

This subsection looks at the role of government in helping farmers to adapt to climate change in the Kilimanjaro region of Tanzania. One question that may arise is “why should the government be involved in private matters of households’ livelihoods?” The livelihood framework that this study utilises addresses this question. The livelihood framework recognises the role of structures and public and private organisations that implement policies and legislations and impact upon the livelihoods of individuals and households (Ellis, 2000; DFID, 1999).

One of the main problems that the poor and vulnerable face are the processes which frame their livelihoods and may systematically restrict them unless the government adopts pro-poor policies that, in turn, filter down to legislation and even less formal processes (Serrat, 2017). Understanding of how government structures are needed to support climate change adaptation is essential as climate change adaptation offers opportunities for the government to implement existing rights and responsibilities to build resilience (Pelling, 2011). The livelihood framework also emphasises the importance of human rights, in relation to the right of each human being to be able to meet their basic human needs and that if an individual is unable to meet their basic needs, nation states are held responsible to support their people (DFID, 2000; Tanner *et al.*, 2015). Within the study area there are clearly many different stakeholders involved in the livelihoods of small-holder farmers at different levels, as identified in this project. For example, there are agriculture extension officers (who provide farmers with agricultural knowledge and skills to improve their farming practices from planting stage all the way to harvest and crop storage): community development officers (who provide linkage between different stakeholder working with farmers and also work with community groups to help them contribute to development) and government policies and other institutions. This section divides the discussion on the role of stakeholders and government into three areas: i) the role of agriculture extension officers and community development officers, ii) government policies and directives, and iii) the government's role in addressing the most difficult livelihood problems which small-holder farmer households are unable to address themselves in relation to the resilience of their livelihoods livelihood's resilience to climate change.

7.6.1 The role of extension officers and other government officials

Connections between farmers and agriculture extension services are important as one way of providing farmers with timely and relevant knowledge on agricultural aspects of livelihood management. However, it is clear from the discussion of key informants and some members in household survey that the availability of extension services is not seen as sufficient. Access to extension officers by small-holder farmers could be improved by allocating more extension service providers to farmers as well as providing the service providers with improved means of transport to facilitate their transport to the small-holder farmer villages. Importance of agriculture extension officer is also stressed by other studies (Ndamani and Watanabe, 2015; Shackleton *et al.*, 2015; Belay *et al.*, 2017)

The community development officers differ to agriculture extension officers in that they link farmers with other stakeholders dealing with matters relevant to farmers such as research institute developing new crop varieties to adapt to climate change or non-government organisation providing training to farmers.

Therefore, connection between small-holder farmer households and the community development officers has a role in ensuring access to technologies such as energy efficient cooks, and opportunities for improving financial and knowledge access in particular into how to properly manage off-farm income sources. Currently, one of the roles of community development officers is to link farmers with NGOs interested in empowering farmers to address their financial capital constraints by educating them about informal financial sources such as savings and credit associations. The results in Chapter Four which included a discussion of social capital demonstrated that very few households depend on informal financial institutions as a source of support. This was not an area of direct questioning and the fact that this issue was raised several times, suggests that informal financial institutions may have an important, but as yet undeveloped role in livelihood development in the face of increased climate variability.

There is the need for other financial mechanisms which can work alongside these informal financial institutions to support small-holder farmer livelihoods. For example, formalisation[15] of agricultural land can be used as collateral to get loans for further livelihood investment. The community development officer also has other sources of finance that can be used to provide loans. For example, 10% of the district income is used to finance women and youth group projects to empower these groups through access to capital to invest in income generating activities. These may be important investments for the communities as results in Chapter Six suggest that the further empowerment and education of women is having a positive effect on the effective management of household resources, through greater equity in decision making and household resource allocation. However, as reported by the

[15] Farmers land to be surveyed and provided with title deeds

community development officer the amount of money available for these projects is relatively small compared to the demand. In addition, the community development officers are able to organise and provide training to farmers to develop entrepreneurship skills to help farmers identify opportunities for income generation and other livelihood/resource in such a way that they can get profit from their investments.

With such a variety of different stakeholders involved in providing support for small-holder farmers it is essential there is effective participation of all the different stakeholders and that this is based on an understanding of the adaptations and responses needed, and that this is grounded in the experiences and needs of the small-holder farmers themselves. Therefore, it is necessary to ensure the involvement of the farmers themselves in the process of decision making for the sustainable solutions to the existing problems. All key informants stated that they involved local people (farmers) in identifying the problems facing their livelihoods but it was not explicitly stated that they also involve farmers in informing how the problems could be addressed and what farmers would like to see. It is notable from the focus group discussions and household surveys with the farmers themselves that they often discussed a need to return to traditional approaches, and that in combination with the role of external stakeholders could help adapt to climate change.

Although some of the approaches used by the different stakeholders considered here are likely to help address some of the challenges faced by the small-holder farmers, sometimes, they do not match the farmers interest. This was demonstrated through the contradiction reported in relation to the use of drought resistant crops between farmers and key informants. The key informant perceives farmers reluctant to adopt use of drought resistant crops while farmers reporting lack of appropriate drought resist crops. This suggests that the crops promoted to the farmers do not meet the interests of the small-holder farmers themselves, and therefore inevitably such a solution is less likely to be successful. If the solutions were rooted in greater participation of the farmers in framing some of the solutions, stakeholders would have a greater understanding of the farmers' requirements, and either promote the same crops while working to increase farmers' awareness of the available profitable market in that crop, or investigate alternative crops that might be more acceptable to the farmers. Therefore, I argue that stakeholders dealing with small-holder farmers should evaluate the way they make their decisions in order for their actions and decisions to contribute to the livelihood resilience of small-holder farmers to a greater extent.

7.6.2 The role of government policy and institutions

Chapter two, outlined the role of the government of Tanzania in developing policies, and enacting laws and directives that affect small-holder farmers' livelihoods. However, only a small number of policies, came up in the research with the small-holder farmers and key informants. These include: the 2007 Warehouse Receipt System (WRS), introduced to help farmers take advantage of price fluctuations by enabling farmers to store crops in warehouses and sell them when prices are high (MAFAP, 2013); and the 2009 National Agricultural Input Voucher Scheme (NAIVS) introduced to support provision of fertilizer and improved seeds for selected crops (MAFAP, 2013).

In addition, the Seeds Act (2003) which regulates the production and trade of all varieties of agricultural seeds including the mandatory provision of seeds for quality assurance, and the Fertilizer Act (2009) which provides for the regulation and control of the quality of fertilizer, either domestically produced or imported are in place and affect the availability and quality of resources to small-holder farmers. The Fertilizer Act (2009) established the Tanzania

Fertilizer Regulatory Authority (TFRA) which is responsible for the coordination of manufacture, trade, distribution, sale and use of fertilizers. In addition, the Tropical Pesticides Research Institute Act (1979) regulates research on pesticides for the purpose of ensuring their quality. The government directives which were discussed by research participants include an export ban on crops, appropriation of resources (particularly water), and the requirement for scales to be used in measurement, but which was not being implemented in the eyes of the research participants such as focus group members and key informants. no implementation of use of scale.

Table 7.1 summarises some of the issues affecting small-holder farmer livelihoods drawn from chapters four, five and six, and the role of different government policy and other institutions in these challenges.

The Warehouse Receipt System (WRS) is supposed to support farmers by allowing them to store crops to benefit from fluctuating crop prices. However, the MVIWATA interviewee claimed that the warehouse receipt system is not used by most farmers to solve market issues because it does not address the primary problem of farmers' inability to delay selling their crop soon after harvest. The only difference between the warehouse receipt system and farmers' storage of their crop in their own stores is that the WRS is explicitly designed to support farmers in making the most of the market. In order for this intervention to be more successful, there is a need for the government to provide more education to farmers about the scheme and slightly change the way in which the system works. For examples, farmers are often unable to store their crops and wait for higher market prices as they have immediate need for the income after harvest, therefore if farmers were provided with money based on the local market price at the time they take crops to the warehouse they would be able to benefit from storing their crops, and receive additional income from sale at the higher market price. This is also how the scheme (warehouse system) is supposed to be implemented through primary cooperatives, farmers' organizations or savings and credit cooperatives (SACCOs) (MAFAP, 2013). Participating farmers are paid a percentage of the produce price (50 or 70 percent), from which the price of inputs for the following season are deducted (MAFAP, 2013). But it not clear from this study why it is not so.

Table 7:1 The summary of the issues raised in the focus group discussion and key informant interviews and the link to government policy or other institution.

Issue raised	Responsible policy, institutions and government directives
Inability to take advantage of high crop price	❖ Lack of farmers' awareness to use the 2007 Warehouse Receipt System
Low crop price	❖ Implementation of export ban
Cheating by customers buying crop produce	❖ No implementation of use of scale
Fake inputs in the market	There is poor implementation of ❖ The 2003 Seeds Act ❖ The 2009 Fertilizer Act ❖ The Tanzania Fertilizer Regulatory Authority ❖ The 1979 Tropical Pesticides Research Institute Act
Appropriation of resources	❖ Poor implementation of environmental policy ❖ Directive on appropriation of stream

Source; Author, 2020

Another government intervention that frequently affects small-holder farmers is export bans on some agricultural crops particularly maize in order to ensure the country's food security. While it might be true that some parts of the country in that particular season did not produce enough food and so taking crops out of the country may accelerate food shortage, this decision does not actually work for the interest of farmers. It is not common for small-holder farmers to sell crops themselves beyond their country's borders. However, customers of their crops are business people who buy from farmers and take the crops to other markets which may be in other countries. The small-holder farmers see these export bans as having an unfair effect on their livelihoods preventing them from maximising their income when markets are more favourable. Although the government does need to ensure the country's food security, it would be beneficial to support farmers to access markets where they can profitably sell their crops. This paper calls for the government to ensure food security, but still be considerate to farmers. Instead the export burn should go together with farmers support either by buying crops at a profitable price or help them get access to local profitable market where they think there is low agriculture production.

One government intervention in place to try and support small-holder farmers is the use of scales in markets to ensure fair exchange of goods. However, according to the small-holder farmers in this study, this is rarely enforced. Therefore, enforcing the use of scales in the purchase of agricultural produce is a measure requiring immediate action from the government to ensure farmers get the income they deserve from selling agricultural crops. Because the policy exists but is not enforced, farmers' complaints to crop buyers have no teeth, meaning that the farmers have to live with these injustices as there is no alternative. Given this scenario, I argue that the government should take action in implementing this policy because effective laws need effective execution. On the other hand, it is worth noting that the government alone will not succeed in enforcing this law until farmers are also ready to change and support the government through information sharing because not all transactions happen in the market place where law enforcing bodies are present to receive complaints about unscrupulous buyers, as some exchange also occurs within households. Therefore, farmers themselves also need to refuse to sell crops without using measuring scales especially when the government implements this law.

Another significant issue in relation to the government's role in small-holder farmer livelihoods, is the appropriation of resources especially land in zones which are within 60 meters from a water source. Given the amount of investment made on the farms and sometimes the lack of money to buy new land, some families may face significant challenges in maintaining their livelihood where their land has been appropriated by the government without suitable redress. This thesis argues that the current approach government is using (farmers to be asked to move bit by bit) to address the problem of farming near the water sources may help to reduce the pressure of an abrupt change by immediately asking farmers to move 60 meters from the water source but it does not sustainably address the problem. The approach in use in the study village was to ask farmers to start by moving 20 meters from the water sources, and then increase it to 40 and 60 metres as time passes. But these challenge fall short of two main weaknesses. First, it does not give a clear time scale over which these changes are going to be implemented. Second, farmers are required by the government to plant trees within the same area and are required to take care of those trees while managing their crops. For farmers, especially those with no alternative land, many are scared and think that the government wants them to manage trees and when the trees grow, they are going to be kicked away without an alternative livelihood. So this paper posits that, farmers need to know the timescale over which the transition is going to take place so they can develop a plan for adjusting their livelihoods. Furthermore, because the problem of farmers owning and farming on land within 6o meters from water source are the result of failure in government institutions (unlawful providing farmers ownership to this land), government must take responsibility by giving these farmers alternative land especially those who will manage to implement planting and taking care of trees until they mature as they will have contributed to the improvement of ecological services in the wider community in the area.

Fake inputs in the market were reported in all three zones by small-holder farmers, and were acknowledged in several of the key informant interviews. As suggested by the district agriculture officer, the government bodies which are responsible for ensuring there are no fake inputs in the markets do not have adequate resources to police this, nor the human labour and finance to be able to inspect all distributors of agricultural inputs. He insisted that, although as a measure to address the problem only certified distributors are allowed in the market, the same distributors sometimes cheat because they know there are no regular inspections. Therefore, he suggested more education to farmers to ensure they keep receipts and some seeds from their purchases, which they can provide for investigation in case they suspect that the seeds are fake.

An agricultural inputs subsidy policy was developed to support farmers with access to agricultural inputs such as fertiliser and seeds for selected crops through subsidies, where the government pays a certain percentage and farmers pay the rest. However, this policy does not really have an impact on poor farmers because the amount of money they have to pay still remains unaffordable. As suggested by the MVIWATA representative and district agriculture officer, there is an urgent need for the government to either make the amount affordable or think of other modalities in which all people can benefit from access to these agricultural inputs. An alternative approach could involve giving farmers inputs as loans to be paid after harvest. Although this may not necessarily come free of challenges of low repayment of the loans, the challenges maybe addressed by supporting farmers to ensure good outputs which then can be taken to the profitable common market organised by cooperative unions or through the warehouse receipt system and money can be deducted right away to cover the loan and the rest given to farmers.

7.7 Conclusion

This chapter discussed how to build the livelihood resilience of small-holder farmers in the Kilimanjaro region through reflection on the results of the study and drawing on additional literature. From the discussion in this chapter, building small-holder farmers' livelihood resilience need farmers to be responsible and make smart decisions about what they do to ensure their livelihoods can survive and thrive in the face of climate change. The household has to play its role and then government interventions can come in to create an effective environment for successful livelihoods. For households which perceive that there is gender power imbalance within the household that threatens appropriate use of available income and farm produce, shared household obligations and joint ownership of resources and planning of household resources has an important role to play. This can be enhanced by projects to further empower women within these communities. The number and quality of the household's asset base is important, so the household should take measures to reduce the erosion of assets from different stressors. Household should invest in land and water management strategies to adapt to existing rainfall variability and ensure flow and access of the ecological services from water sources. Because of the economic characteristics of the small-holder farmers who are mostly poor, there is high dependence on the government to create a favourable environment for small-holder farmers' livelihoods to flourish. Therefore, the government bodies and institutions have to step up to these responsibilities and build on what they are already doing. Using laws and policies, the government must ensure that they dismantle the barriers that create a wall between farmers achieving a livelihood that can survive in the face of climate change. To arrive at this stage of suggesting measures to build livelihood resilience, several methodological decisions were made. The next chapter will reflect on these decisions and how effective they were.

8 Discussion

This chapter reflects on the research journey, and the role of the combination of underpinning theories as a lens to analyse the challenges of small-holder farmers facing increasing climate variability, as well as considering the limitations of the work and opportunities for future research.

8.1 The research journey

From the outset this research was framed by my own personal background coming from a similar community to the ones studied and a desire for my research to contribute to studies to support small-holder farmers to be able to adapt their livelihoods in the face on climate change impacts. This research therefore fits clearly in the emerging field of sustainability science, with its focus on addressing sustainability challenges through understanding the nature of human-environment interactions, across different scales, and using a transdisciplinary approach (Kates et al., 2001; Clark, 2007).

My research journey began by a detailed review of the existing peer-reviewed and grey literature in order to understand the less costly strategies that are available to small-holder farmers to help them to adapt to climate change. I drew on literature from both African and Asian contexts in order to understand potential adaptation measures relevant to small-holder farmers in the Global South, increasing my understanding of different farm production practices relating to land and water management which have been applied in different part in the Global South, and the conditions under which the different strategies are relevant. I focused on the strategies most relevant to implementation by the small-holder farmers themselves, rather than strategies such as crop insurance, development of new crop varieties, and development of new irrigation schemes, because they are very expensive to implement and because some of them like the use of insurance did not exist in Tanzania (Goslinga *et al*., 2013). This background reading provided me with a greater understanding of farming practices with which to inform my research design and data collection tools.

However, it became clear in my research into different farming practices that the physical management of the farm and its assets were not a sufficient focus with which to view the what is needed for the poor to successfully perform their livelihood, nor the adaptation to climate impacts, of small-holder farmers. It was clear that in addition to land and water management strategies to enhance on-farm productivity, as well as short-term measures relating to household management and community support were also need to help households survive at certain times, such as while waiting for crops to mature. Overarching the household and community scale is the importance of the government regulatory context and external support systems for farmers. In addition to understanding different strategies for adaptation and support, it was clear this it was also important to understand the constraints that may hinder existing livelihood management strategies at different scales that have the potential of helping farmers adapt to climate change.

Based on this understanding emerging from a synthesis of the literature into small-holder farmer adaptation to climate change in the global south, a livelihoods framework was adopted as a suitable approach to bring together the complexities of the small-holder farmers livelihoods in the face of climate change impacts, and informed the research design. Following fieldwork and data collection, two additional theoretical frameworks were adopted as lenses to inform the data analysis: i) a vulnerability framework, drawing on the work of Turner *et (al.*, 2003) and Paavola, (2008) ; and ii) a socio-ecological resilience framework drawing on the work of Biggs *et al.,* (2012:2015). The next section looks in more detail at the role these three theoretical frameworks have played in this research.

8.2 Evaluation of the underpinning theoretical frameworks in the context of small-holder farmer adaptation to climate change

8.2.1 Vulnerability framework

This study drew on Turner et al's. (2003) vulnerability framework which is used to understand vulnerability of socio-ecological systems. The approach seeks to analyse the elements of vulnerability; exposure, sensitivity and resilience, of bounded system at a particular spatial scale, by focusing on interaction between properties of socio-ecological system (Adger, 2006).The framework holds the notion that vulnerability resides in the conditions and operation of the coupled human–environment system, including the response capacities and system feedbacks to the hazards encountered (Turner *et al.*, 2003).

Exposure describes the extent into which the individuals, households, classes, firms, states, flora/fauna, ecosystem is affected by shocks or stress. Exposure components of vulnerability measure the frequency, magnitude and duration into which the study system is exposed to hazards. The hazards may include anything that have potential of causing impact to the system which may include droughts, floods, increased rainfall variability and temperature increase. The second component is sensitivity which can be defined as the degree to which a system is instantly affected by perturbation. The systems sensitivity to any hazard is determined by the conditions of the system in question. Turner *et al.*, (2003) categorised two groups in which conditions of the system can be assessed; human and environmental conditions.

The human conditions are composed of social conditions necessary for survival and adaptation (Birkmann, 2006) determined by human behaviour and societal organisation (Pachauri *et al.*, 2014) and include social/human capital and endowments, institutions (ie role of governance) and economic structures (Turner *et al.*, 2003) such as national policies, international aids and economic globalisation (Birkmann, 2006). Environmental conditions focus on biophysical environment and include natural capital/ biophysical endowments such as soils, water, climate, minerals, ecosystem structure, and function (Turner *et al.*, 2003) as well as topography and land cover (Birkmann, 2006).

The third component is resilience. The resilient component considers coping and adaptation measures to be implemented in order to reduce systems vulnerability to hazards. In this framework, resilience of coupled system is determined by their capacity to adapt to shocks. These adaptations responses can be autonomous or planned, public or private, individual or institutional, tactical or strategic, short or long term, anticipatory or reactive. Turner *et al.*'s (2003) framework was used because it contains elements such as exposure and sensitivity and resilience which are central for analysis of vulnerability intended to guide practical adaptation (Smit and Wandel, 2006; Paavola, 2008).

It essential to emphasise that, this framework is meant to be used in sustainability science, which uses a holistic and interdisciplinary approach to address complex, real life human-nature challenges. So the framework is complex and make it difficult to make a full assessment of vulnerability based on the complexity of factors, processes, and feedback operating within even a relatively simple couple human-environment as it is difficult to determine which aspect of vulnerable system is important in order to focus the analysis on it (Turner *et al.*, 2003).However, Pachauri *et al.*, (2014) provide answer to this dilemma by stressing that, the vulnerability analysis need to be focused on the matters that are significant for the survival of societies or communities or socio-ecological system exposed to weather related hazards. So based on this study other two frameworks; the sustainable livelihood framework and socio-ecological resilience were used to focus the vulnerability analysis and measures to build livelihood resilience into matters that are significant for survival of small-holder farmers livelihoods. So based on insight from three frameworks, the results were organised based on Turner et al's., (2003) vulnerability framework but covering matters significant for endurance of small-holder farmers livelihood to climate change as informed by sustainable livelihood framework and socio-ecological resilience.

The exposure to hazard is discussed in Chapter Four (small-holder farmers' perceptions of climate change and its impact on households' livelihoods assets). In this chapter the study uncovered impacts of climate variability to livelihood 'capitals': human, financial, natural and social capital; as well as the appreciation of other stressors in addition to climate change.

The second component of the framework is sensitivity of the system to hazard, determined by environmental and human condition of the system (Turner *et al.*, 2003). The environmental conditions are dealt with in Chapter Five (household agricultural practices and their impacts on environmental resources). In this chapter the study uncovered agricultural practices that intensified sensitivity and vulnerability to climate variability by affecting natural capital; in particular soil quality and water availability that were taken as proxies for environmental conditions affecting agriculture.

Social structures or human condition is discussed in Chapter Six (livelihood strategies and social factors increasing livelihood vulnerability to climate change). In this chapter the study highlighted how social factors/structures can contribute to increasing livelihood susceptibility to weather-related shocks. Resilience component is dealt with Chapter Seven (measures to build livelihood resilience in the face of climate change). In this chapter, adaptation measures to build livelihood resilience to climate change is uncovered. It should be noted that there are connections to each element of the vulnerability framework in each chapter due to the heavily interconnected and complex systems. This framework helped to explore the impact of climate variability on livelihood assets, social and environmental conditions that contribute to vulnerability as well as how to build resilience of the small-holder farmers livelihood.

The strength of the use of this framework in this study is in broadening our understanding of what actually can affect farmers' livelihoods in the face of climate change. In addition to the hazard itself, (exposure to climate variability in the form of increasing temperature and increased rainfall variability), the interconnectedness of agricultural practices and social structures impacts on environmental conditions (natural capital) as well as human, social, and financial capitals the building blocks of farmers' livelihoods. These capitals are also referred to as livelihood assets.

Use of Turner *et al's*.' (2003) vulnerability framework helps inform us that these farmers are affected by climate variability partly because of the poor nature of their environment (soil quality and water) as well as existing social factors. However, the closer we look at the environmental conditions the more it is clear that they are influenced by underlying wider social problems affecting farmers in this area. Social factors determine the decisions being made about the type of management practices applied to their environmental resources (natural capital), which in many cases are further negatively influencing their livelihoods. Therefore, I argue poor soils and water use inefficiencies in the study area is partly the result of underlying social factors that small-holder farmers in this area faced with. For example, farmers are aware of the impact of mono-cropping but because of collapse of the coffee market which was a cash crop, farmers grow more maize as alternative to cash crop. On the other hand, farmers are aware that, leaving crop residue in the farms particularly located in the lowland could help adapt to climate change, but because of social structures based on where people leave in relation to their farms affect the use of some adaptation strategies. Farmers are also aware of the role fertilizer application and important of appropriate use of fertilizer but because of unfair government policy that discriminate the poorest, and farmers' inability to test soils, limit their capacity to appropriate use of inputs.

This suggests that farmers and other stakeholders in the study area (including government, through policies and government officials) have a significant role to play in the existing livelihood vulnerability to climate change. Understanding these social structures further and their role in the existing vulnerability provides opportunity to identify ways in which individual farmers and the government of Tanzania to change their practices, processes and structures that threaten livelihoods in the face of climate change.

8.2.2 Sustainable Livelihood framework

This subsection briefly explains sustainable livelihood framework, how it was used in this study, and contribution made to this framework by this research. The framework has evolved since 1992 initially developed by Chambers and Conway to the 1999 by the DFID. While there is almost no difference on the way all these scholars define livelihood, there is slight difference on what they consider sustainable livelihood. Sustainable livelihood is the concept used to understand livelihood resilience in the face of stresses and shocks(Scoones, 2009) (Scoones, 1998). Chambers and Conway argues that '*a* livelihood is sustainable which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and which contributes to net benefits to other livelihoods at the local and global levels and in the short and long terms (Chambers and Conway, 1992, p. 6)

Scoones (1998*)* defines sustainable livelihood as the livelihood which can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base. This new definition does not include the requirement that for livelihoods to be considered sustainable they should also '…contribute net benefits to other livelihoods' (Krantz, 2001) also included analysis of institutional process and organisation structures and maintained involvement of local people knowledge, perception and interests.

DFID (1999) argues livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base. The DFID's (1999) sustainable livelihood established set of core principles which guides poverty reduction initiatives and include people centred, responsive and participatory, multilevel, sustainable, human rights based, and dynamic. The DFID also developed sustainable livelihood framework, which is an analytical structure to facilitate understanding of broad factors that constrain or enhance livelihood opportunities. The livelihood framework seeks to understand the livelihood central to individuals and community's life and factors that influence their survival. The livelihood framework put people at the center and ensure access to assets; financial, human, social natural and physical which build the livelihoods (Reed et al., 2013). The sustainable livelihood framework understand multiple stressors that can affect livelihoods; such as shocks, seasonality, and economic or resource trends (Reed et al., 2013) and which then stress important of understanding multiple stressor that affect livelihoods. The framework also considers livelihoods diversification as risk management strategy and the role of institutions', structures and process in shaping peoples' livelihoods (Ellis, 2000). Another important concept in the livelihood framework is the livelihood outcome. This is the end product or the goal of livelihoods which constitute more income, increased well-being, reduced vulnerability, improved food security, more sustainable use of the natural resource base (DFID, 1999). The main proponent of the use of livelihood approach to studies of climate change resilient of the poor communities is (Tanner *et al.*, 2015) where they argued for resilience studies to incorporate livelihood approach in order to pay attention to fundamental issues of human agency and empowerment, putting people at the centre by focusing on capacities for human (rather than environmental) transformation only.

This framework was used to partly guide data collection, by examine impact climate variability to livelihoods assets, understanding the constraints that limits livelihoods development and contribute to livelihood vulnerability to climate change and also the need to involve farmers to discuss factors contributing their livelihood vulnerability to climate change. Also the framework was used to understand measures to build livelihood resilience in the face of climate change. The main strength of the framework was to guide what significant factors are important in exploring vulnerability and resilient measures of small-holder farmers' livelihoods. This include important livelihood assets, the role of structures and processes, and consideration of multiple stressors without assuming climate variability was the only factors affecting farmers' livelihood. Reflection on how this framework was used to guide analysis of the measures to build livelihood resilience together with Biggs, *et al*., (2012:2015) socio-ecological resilience and contribution of this study to sustainable livelihood framework is explored in detail in the section below about socio-ecological resilience.

Sustainable livelihood frameworks identify internal and external sources of vulnerability (DFID, 1999), which allows us to identify areas for the implementation of adaptive measures. In relation to the livelihoods of small-holder farmers in the Kilimanjaro region, one area of adaptive measures is to reconsider the social structures that operate within households that guide income and crop produce use. Issues relating to the household's use of income and its contribution to vulnerability is not a new consideration in livelihood frameworks, as it is known to be a potential source of vulnerability that needs to be addressed to attain livelihood that can survive disturbances (FFID, 1999). However, in the livelihood framework this is considered as external stressor, for example if poor people spend most of their income on food stuff in high price volatile markets (DFID, 1999). However, the way income is spent as internal source of vulnerability in not mentioned within existing livelihood framework approaches. So this research contributes to understand dynamics of the spending income and vulnerability, as in some context like this study area it can be the result of factors within the household itself.

8.2.3 Socio-ecological resilience framework

This subsection reflects on the use of socio-ecological resilience as a framework for analysis of the small-holder farmer livelihood adaptation to climate change. The main writers of socio-ecological resilience as used in this project are (Biggs *et al.*, 2012; Biggs, *et al.,* 2015).There is the distinction between resilience as property of the SES and resilience as an approach and set of assumptions for analysing, understanding and managing change in SES. As a system property, they defined resilience of SES as the capacity of an SES to sustain human wellbeing in the face of change, both through buffering shocks and also through adapting or transforming in response to change (Biggs, *et al*., 2015).

Resilience as an approach' focuses on principles that build the capacity of socio-ecological systems to continue providing key ecosystem services that underpin human well-being in the face of unexpected shocks and gradual, ongoing change. These principles include diversity, involve the provision of different options for responding to change. Diversity is achieved by ensuring variety (how many different elements), balance (how many representatives of each element) and disparity (how different the elements are from one another). Redundancy describes the replication of elements as a means of risk management. The second principle is to manage connectivity. This focuses on 'the way in which parts of an SES interact with each other. The third principle is to manage slow variables feedbacks. The fourth principle is to foster complex adaptive system (CAS) thinking. The fifth principle is to encourage learning and experimentation. The sixth principle is to broaden participation. The seventh principle is to promote polycentric governance systems.

Although chapters were not explicitly organised around the socio-ecological resilience framework used in this study, this and the other two frameworks (sustainable livelihoods and vulnerability) do run as a theme throughout the analysis within the chapters. Socio-ecological resilience, unlike sustainable livelihood framework (which was used to also guide data collection) was brought into this study during data analysis. Drawing on discussions in Chapter Seven about the adaptations needed to build resilient livelihoods for small-holder farmers in the face of climate change, I will discuss below the use of the socio-ecological systems resilience framework, and its interaction with the sustainable livelihoods framework (section 8.2.2). In addition, I will draw in Tanner *et al's.*, (2015) arguments about the use of a resilience lens in the context of the livelihoods of poor people, particularly in the global south.

Another (apart from the role of income use discussed in section 8.2.2) adaptation need identified in Chapter Seven is the need to build livelihood capitals (or assets) to build resilience and hence tackle small-holder famer vulnerability. As shown in Table 8:1 Within the Biggs *et al's*. (2015) socio-ecological resilience framework there is no specific principle relating to building assets to build resilience. In contrast, this is a vital component of the sustainable livelihood framework. The livelihood framework emphasis access to assets such as human, physical, social, financial and natural capitals (DFID, 1999). However, one of the weakness of livelihood framework is lack of emphasise on how access to ecological services from natural capital such as land and water can be maintained (Reed et al., 2013). These weakness was addressed by combining livelihood sustainable livelihood framework with socio-ecological resilience as it seeks to manage of slow variables explained in detail below.

One of the principles of Biggs *et al's*. (2012:2015) socioecological resilience framework is the management of 'slow variables.' Biggs *et al's.* (2012:2015) describes slow variables are those which changes relatively slowly and therefore not easy to detect changes immediately as they occur, for example change in soil nutrients. In relation to this project, managing slow variables, relates (amongst others) to the management of natural capital in the form of soil and water assets, to ensure access to the ecological services that these provide. This can be seen as managing slow variables because many (although not all) of the factors affecting soil and water quality and availability, and the strategies to improve these assets, occur on relatively longer time scales in comparison to other interventions.

Table 8:1 Summary of the comparison between livelihood framework and SES resilience as analysed from this study

Adaptation need	Livelihood framework	SES resilience
Income, crop produce use as internal source of vulnerability	-	-
Building assets base	✓	-
Manage slow variables	-	✓
Diversification	✓	✓
Role of stakeholders	✓	✓
Government policies and institutions	✓	✓
Learning	✓	✓

Source: Author

Another principle within Biggs *et al.'s* (2012:2015) socio-ecological resilience framework is the use of complex adaptive thinking. CAS thinking as described by (Biggs *et al.*, 2012; Biggs, *et al.,* 2015) shows that a system is made up of many interacting components that are individually and collectively adaptive to change, so management decision and practices must appreciate the existing linkages. As emphasised by Bohensky *et al.* (2015) complex adaptive thinking implies changes in management paradigm from strategies that focus on immediate gratification and short-term problem solving, to a focus on adapting with change and uncertainties over longer time scale, and therefore generating long-term solutions.

Diversity within a system is a principle within Biggs *et al.'s* (2012:2015) socio-ecological resilience framework as well as the livelihoods framework. However, there is a difference in the way that both frameworks discuss diversity, which has implications to the role of diversity in contributing to the capacity of a livelihood to withstand a perturbation. I learned that Biggs *et al.'s* (2012:2015) socio-ecological resilience framework is more detailed in its discussion of diversity than the livelihood framework. In the resilience framework diversity is presented as having three distinct components; variety, balance and disparity. For example, the livelihoods framework may consider that farmers keeping livestock and producing crops demonstrates diversity, hence reducing vulnerability. However, with the resilience studies and analysis of diversity would look at how many *different* livelihood options farmers have (variety); how many *of each* livelihood options farmers have (balance); and *how different* the elements are from each other (disparity) (Biggs *et al.*, 2012:2015).

Processes and structures such as the role of policies, laws and government institutions are a key component of the livelihoods framework (Reeds, 2013). Structures can be taken to mean the public and private sector organizations that set and implement policy and legislation (DFID, 1999). In this study the agriculture extension officers and community development officers were an example of representatives of public institutions which are needed to function more effectively to better support farmers' livelihoods to manage the impacts of climate variability. Policies and laws fall under the definition of 'processes' that determine the way in which structures operate. In the Biggs *et al.'*s (2012:2015) socio-ecological resilience, the concept of processes and structures used in the sustainable livelihood framework is represented by the principle of connectivity (Biggs *et al.,* 2015). The connection and quality of relationship between farmers and public institutions through representatives such as agriculture extension officers and community development officers needs to be improved to ensure the flow of resources such as training opportunities and financial capital to farmers. The connectivity principle of the resilience framework, can be used as a framework to explore the relationship of government, through their policies and institutions, with the small-holder farmers, to develop greater understanding of the manner in which social actors interact and can contribute to resilience through enhancing governance opportunities (Biggs *et al.*, 2012; 2015).

Two other principles of Biggs *et al.'s* (2015) socio-ecological resilience framework including i) encouraging participation, and ii) learning and experimentation. These two resilience principles are also reflected in the sustainable livelihood framework (Scoones, 1998: DFID, 1999). Participation is vital in ensuring that small-holder farmers are part of the developing the solutions to the problems they are facing. Learning and experimentation is also critical in being able to reflect on, evaluate, and learn from changes made to any aspects of small-holder farmers' livelihoods in order to continually improve positive outcomes (DFID, 1999;Ellis, 2000). A culture of learning and experimentation is appropriate for both the small-holder farmers themselves as well as key stakeholders whose decisions have indirect impacts on small-holder farmers' livelihoods.

Considering the socioecological resilience frameworks and livelihoods framework it is clear that these two frameworks have complemented each other as frameworks for analysis in this study. The socio-ecological resilience framework highlights the importance of managing natural capital to ensure the flow of ecological services such as fertile soil and water supply to support agricultural productivity, as well as management approaches that consider long-term benefits of increasing the capacity of natural capital to provide ecological services in the face of uncertainties. The socio-ecological resilience framework also highlights the different components of diversification of livelihoods that can contribute to livelihood that can thrive in the face of climate change. Use of the livelihoods framework highlights the need to build the livelihood assets base and consider the ways in which household income or crop produce are utilised at the household scale.

However, there has been some criticism relating to the limitations of resilience scholarship as has been used in the context of poor people, such as the small-holder farmers in this study (Tanner *et al.*, 2015). Tanner *et al*., (2015) argues for the need to incorporate a livelihoods framework into resilience scholarship, as has been demonstrated above and throughout this study. However, I argue that based on the similarities, of these framework as s demonstrated above, if resilience is considered as an approach guided by the principles highlighted by Biggs *et al.*, (2012:2015) it has a clear role to play in the context of poor people. The resilience principles of fostering diversity, managing slow variables, fostering complex adaptive systems thinking, connectivity, encouraging participation, and learning and experimentation, are clearly addressing the livelihood challenges of poor people as seen in this project dealing with small-holder farmers in the Global south.

This study also highlights how the household resource use may need to be reconsidered within the livelihood framework in the context of household livelihood vulnerability. Within existing livelihood frameworks (DFID, 1999) household resource use is considered as an external source of vulnerability as external factors can clearly affect access to income within the household. However, this study has demonstrated how social structures (including social capital) can have a significant effect on the way that income (and crop produce) is used *within* the household, and therefore an understanding of household practices and the social structures that may influence these practices is also important in understanding household livelihood vulnerability and therefore the potential for household level (or overarching social structure level) interventions to enhance household resilience and decrease vulnerability.

In summary this subsection evaluated three frameworks which underpin this research; the DFID, (1999) sustainable livelihood framework, Turner *et al's*. (2003) and socio-ecological resilience. These framework was useful in exploring exposure and sensitivity of small-holder farmers in the Kilimanjaro region, and measures to build resilience against climate change. Although there are many frameworks for the analysis of vulnerability, Turner *et al.'*s. (2003) framework was used because it contains elements such as exposure and sensitivity which are central for analysis of vulnerability intended to guide practical adaptation (Smit and Wandel, 2006; Paavola, 2008).The use of livelihood framework and socio-ecological resilience complemented each other. Although there are some elements which are common to each framework, they also have some differences.

8.3 Reflections on the case study

This study focused on the Kilimanjaro region of Tanzania. The sample population was taken from three villages, each one representing a different agro-ecological zone. The study's structure around the different agro-ecological zones aimed to understand both the similarities between zones, and the unique issues existing for each zone, rather than assuming uniformity in the region. The results from this study of villages in these three zones demonstrated that there are significant similarities in the social structures (in terms of culture), environmental conditions, and nature of the hazard (the experience of climate change) between the midland and highland zones, and significant difference between these zones (midland and highland) and the lowland zones. For example, in the midland and highland zones, although decrease was reported, there were still some trees in the farms, while in the lowland zone the number of trees within farms was much lower. The midland and highland zone villages also speak the same vernacular language while the lowland zone village had a different language, although this is not typical for all villages in the lowland zone.

The language differences between these zones did not bring any challenge to this research as all respondents could speak the national language, Swahili.

In the lowland zone, the results demonstrated that there were more strategies for improving water use efficiency, while in the highland and midland zones there were reported fewer water use efficiency strategies because of less water availability especially from rainfall. There was also more concrete lined canal in the lowland compared to those in highland midland. These differences can better be explained by the differences in the environment in terms of climate and therefore government priority to invest more in the lowland in terms of improving water use efficiency in the lowland zone. This is probably the because the government give priority to invest in water infrastructure to the lowland study village because they do not have alternative in case rainfall is not enough compared to highland and midland zone, who can rely on producing crops in the areas where they live (highland and midland) in case rainfall is not enough in the lowland because there is relatively more rainfall compared to lowland zone. And most farmers in the lowland study village do not have farms in other zones. It is essential to also clarify that, although highland and midland farmers some had farms located in the lowland, these farms are not in the areas with access to irrigation infrastructure like those owned by respondents residing in the lowland study village.

Focus group discussions of issues relating to household resource uses and the differentiation of roles based on gender within the household and the impact this had on household resource utilisation different between the highland and midland zones on the one hand and the lowland zone on the other. However, a key difference is in the data collection between these zones, as for logistical reasons the lowland zone focus group had to combine men and women, whereas there were separate focus groups for men and women in the midland and highland zones. Combining men and women in one focus group in the lowland zone, may have meant that participants were not confident in articulating the truth about these issues, or it may reflect a difference in culture in the division of ownership between the zones, and that there is no negative impact to household resilience because of a division in resource ownership.

In the midland and highland focus groups the same issues regarding division of resource ownership within households and the negative effect that this had were articulated in both gender discussion groups. The split of the gender in focus group has been argued to empower the women by giving them confidence to challenge others and discuss matters that matters to them (Chambers, 1994: Mwongera *et al.*, 2017). However, gender issues that came up in this study some came up in both gender groups in highland and midland but some in only male focus groups. For example, the impact of division of ownership and obligation between households and the mothers' trick of hiding food came up in both gender focus groups. But the role of synchronising production process and procreation was mentioned only in male focus groups. What these differences tell us is that, sometimes, participants in the focus group can candidly discuss gender matters even if they are the source of the problem. For example, male focus group participants honestly discussed how some men contribute to household vulnerability by using money for their personal interest and neglect their families.

This study is done in the Kilimanjaro region of Tanzania and is framed as a case study of small-holder farmers' livelihood adaptation to climate change. There is therefore a question of how applicable to other regions are the findings of this research. Since this study is based on practical adaptation, which begin by analysis of exposure and sensitivity of specific communities to climate change, the overall results are not meant to be generalised to the entire population of small-holder farmers in Tanzania (Smit and Wandel, 2006; Paavola, 2008).

However, comparison with other studies on small-holder farmers' vulnerability and adaptation to climate change may highlight what can be generalised from this study to guide government interventions. However, if I attempt to compare overall results to other studies in Tanzania it will be irrelevant because, there was no study which used the method used in this research to understand how small-holder farmers could adapt to climate change. The study closet to this in terms of methods was done by Paavola, (2008) in Morogoro region and he explored exposure, and social and environmental factors that contribute to livelihood vulnerability to climate change. But he did not use farmers themselves to explore vulnerability and also he did not go further to understand how to build livelihood resilience because it was out of his focus. The comparison of Paavola (2008) and this research is done in the conclusion section.

8.4 Reflections on the use of data collection tools and approaches

8.4.1 Participatory Rural Appraisal (PRA) tools

This study involved working with small-holder farmers and other relevant stakeholders in the Kilimanjaro region, to understand adaptation needs through an exploration of the factors that contribute to vulnerability to climate change in the study area. To prevent assumptions being made about the specific variables that affect sensitivity to climate change the use of the PRA tools were used. The PRA is the method of engaging with community members through participatory exercise s in a focus group setting to assess community perception of various issues including status of natural resources, impact of climate change (Chambers, 1994a: Mwongera *et al.*, 2017). The PRA tools used in this study include historical calendar to understand how community perceive changes in climate, natural resources such as soil, water trees, and agriculture activities (crop production and animal keeping) over time and what might have been the driver for these changes (Chambers, 1994a: Mwongera *et al.*, 2017).

Questions in the focus group discussions were framed around specific aspects of farmers' livelihoods such as trends in weather, crops, soil fertility, and animal keeping, and more open question's rather than asking what respondents do to adapt to climate change specifically or what factors increases their vulnerability to climate change specifically. The strength of these PRA tools is in maintaining objectivity and avoiding assuming that decisions made about livelihood management are mainly in response to climate variability, as there are potential multiple stressors or opportunities that may influence changes to their management strategies. Asking farmers about what they do to adapt to climate change would have led farmers 'to identify only strategies that they perceived to be useful for climate change adaptation and potentially leave out strategies that increase or reduce livelihood vulnerability overall.

Hence this could paint the picture that there are no agricultural practices that need to be changed because farmers have already started adapting to climate variability, or it could miss other important aspects of understanding of the farmers' livelihoods. These tools were useful in providing rich information on how small-holder farmers have learned from past generations and from their own experiences, and the outcomes of various practices and strategies for livelihood management. This participatory approach is vital to avoid a top down approach which is based only on experts' opinions (Smit and Wandel, 2006), and also is in keeping with the frameworks underpinning this study. These lessons helped both the researcher and the farmers themselves identify what strategies could be promoted and what could be discouraged to make the farmers' livelihoods more resilient to weather-related shocks and decrease their vulnerability.

The strength of the PRA approach is not just in the research and data collection itself but in the process itself, providing focus group participants with the opportunity to reflect upon and consider different strategies, and therefore the focus group itself is potentially a useful intervention. The participants realized that there are many things they can do to improve their livelihoods just by taking time to think and reflect on the knowledge that they already have from their experiences. This provides a lesson for farmers to realize they can improve their livelihoods by taking the time to think and reflect on their past and recent experiences, in keeping with the learning and experimentation principle within Biggs *et al.*'s. (2012:2015) socioecological resilience framework.

However, there were some weaknesses of using the PRA tools within this project. The first relates to the detail of the responses given in relation the trends in weather in the study area. Because the focus group participants were from different age groups, they could not recall specific years over which rainfall variability and temperature changes occurred. They had a more general understanding of the variability experienced and rainfall and temperature changes did not come up much in the discussion. Therefore, there is limited detail of the perceptions of the small-holder farmers of climate change in the study area. Secondly, it is not clear from this study the extent to which some of the strategies identified in the focus groups are actually utilized in the study area, as these strategies were not covered in the household surveys. The surveys asked farmers what they do to improve soil fertility and improve water use efficiency rather than to reflect on the use of specific strategies, and therefore some strategies may not have been mentioned in surveys simply because they were not recalled at the time, rather than that they were not practised.

This project examined small-holder farmers' vulnerability to climate variability happening in the study area. The strategies discussed are intended to improve the resilience of household livelihoods in the face of climate variability and future climate change in the area. However, the effectiveness of the identified strategies will ultimately depend on what the nature of future climate change.

8.4.2 The livelihood assessment tool kit

The post-disaster livelihood assessment tool kit (FAO and ILO, 2007) was used in this study to inform the development of the data collection tools and examine the impact of climate change on livelihood asset. The tool uses sustainable livelihood framework as guide to explore how disaster affects household livelihood assets. The tool studies the impact by collecting information about the nature of household's livelihood assets before and after the disaster. For example, to understand the impact of disaster to human capital the tool asks the head of household questions like; how many people resided in this household before the occurrence of disaster? How many people are living now in the household? Has anyone left as a result of the disaster? What impact has this had on the household's ability to make a living?

However, some questions as described in this tool kit can be viewed as leading questions to respondents and assumes that climate change exists (and that participants perceive that) in the study area. Therefore, this toolkit was modified to avoid leading questions and putting words in the mouth of respondents. For example, instead of asking how many people resided in this household before the occurrence of disaster? Has anyone left as a result of the disaster? What impact has this had on the household's ability to make a living? I chose instead to ask about the number of people in the household and if any member had moved away and the reason for migration. On reflection, unless a participant makes the certain link themselves between an activity or impact and a disaster (ie climate change), questions of this nature are not very useful to in exploring the impacts of slow onset disasters such as climate variability. Although climate change can be viewed as a disaster in some senses, toolkits such as this are more appropriate for sudden transient shocks to a system.

8.5 Research ethics

The research ethics required for this study required respondents to be fully informed about the research and to willingly take part in the research. Sending or reading invitation letters and information sheets to respondents and ensuring that they sign a consent form before taking part in the research is part of the procedures to meet research ethic requirements for a study of this nature. Although it is common in Tanzania researcher to ask consent verbally, the research culture in Tanzania traditionally have been out of paper works to respondents compared to the United Kingdom. In my research the paper requirements of the ethics process made some respondents uncomfortable. Although this discomfort was not common for focus group participants and the household survey respondents, it was more common for some of the key informants. This is probably because many were representing government institutions and could potentially be identified because of the nature of their roles (which their attention was drawn to through the ethics procedure). Procedures such as the signing of consent forms and recording the interview using a voice recorder were perceived by some as evidence that taking part in the research could put them in trouble later on and potentially risk their jobs. I had to clarify some of the worries as part of the ethics process of discussing concerns with the participants. However, one key informant was so uncomfortable about taking part that he asked if a colleague could be present during the interview. Although there was no pressure put on participants to take part, with this potential participant because of the level of lack of confidence and trust in the process I had to cancel his interview because I also lost confidence in the quality of the data that I would have got from him. This situation presents an opportunity to reflect on the need for public servants in Tanzania to view as a responsibility the provision of support to researchers, and development of a culture of trust and confidence to speak about their work, so that the research carried out can better contribute to the country's development.

8.6 Future research

8.6.1 Evaluation of strategies linked to current and future climate change

There are many uncertainties regarding future climate change in Tanzania and the world at large. This uncertainty is also evident in the farmers themselves form discussions of their perceptions about future climate change. Because of this uncertainty, not only do the strategies to build livelihood resilience identified in this study need to be evaluated under current climate conditions, but the will also require monitoring to understand how effective they will be as climate change unfolds. Therefore, future research is needed in evaluation of the strategies in current and future climates, and in developing future projections of climate change for the region and exploring the impacts on small-holder farmers. Research with small-holder farmers and other relevant stakeholders is needed to identify potential future exposure and sensitivity of small-holder farmers in different agro-ecological zones, and the future adaptive capacity and opportunities to reduce future vulnerability.

8.6.2 Combining empirical climate data with climate change perceptions in small-holder farming communities

This study combined qualitative and quantitative methods to both explore issues in depth and explore the extent to which those issues matter to the wider community in the study area. However, one limitation of this research is the fact that an understanding of the climate change experienced in the study area, as well as the land and water management practices and their impacts is mostly based on the perceptions of the small-holder farmers. Although multiple sources of information were used to triangulate information provided by the respondents in order to increase the reliability of the results, there are some aspects such as the perception of land management practices and use of water efficient strategies that could benefit more from the addition of more quantitative data to give a greater sense of the magnitude of different strategies and their impact In addition, as climate variability in the study area is based on the perception of the small-holder farmers, further objective empirical data of trends in climate change, as well as natural resource availability would be beneficial, as would a greater understanding of potential deviation of farmers perceptions from the empirical data.

8.6.3 Studying small-holder farmers and natural resource-dependent communities in other regions in Tanzania

The overall results from this case study of the Kilimanjaro region of Tanzania, cannot necessarily be scaled up or generalised to other areas, because it was based on the analysis of vulnerability of small-holder farmers specifically within the Kilimanjaro region their experiences may not necessarily reflect what is going on in other regions. Future research is needed to explore exposure and sensitivity to climate change of small-holder farmers' livelihoods in other regions in Tanzania, and to compare the results of this study with other regions. This is important to the production of government structures which are likely to be applied country-wide and need to be appropriate to small-holder farmers across different regions. In addition, the combinations of different theoretical frameworks which has proven useful to the holistic exploration of strategies to address vulnerability to household livelihoods within this study, could be useful for the study of other community groups that depend on natural resources such as water resources in coastal communities, and forest dependent communities which also face challenges relating to climate change.

9 Conclusion

9.1 Introduction

This study is the first comprehensive, empirical examination of how small-holder farmers' livelihoods can be managed to adapt to climate change based on practical adaptation measures and using an integrated lens incorporating vulnerability, sustainable livelihoods and socio-ecological frameworks. The study contributes to the area of sustainability scholarship inquiring into practical adaptation measures which focuses on specific communities and involves participatory vulnerability analysis (Smit and Wandel, 2006; Paavola, 2008). This research identifies adaptation measures that small-holder farmers in the Kilimanjaro region can take to build resilience in the face of climate change. The first step was to examine the adaptation needs of the small-holder farmers in the Kilimanjaro region based on the perceptions of the local community about exposure and sensitivity of their livelihoods to climate change. The second step was to identify adaptation measures that could be taken by farmers and the government to enhance the ability to adapt the small-holder farmers' livelihoods to climate change. In this chapter, the main findings from each chapter will be explained briefly and summarised in order to answer the research questions and outline the original contribution this thesis makes to both research and practice.

9.2 Small-holder farmer perceptions of climate change

The results show that in the views of the farmers, before the 1980s rainfall was sufficient to support the growth of crops to maturity in the study area. This is what is referred to as a baseline in this study. The rains in the study area are divided into two main season: i) what are locally called, the long rains or major rains, which used to begin mid-February and end in June in the midland and February and end in June highland zone, and begin March and end in June in the lowland zone; and ii) what are called the short rains, which used to begin in

October and end in December in all three zones. However, from the 1980s farmers perceived a significant shift in the temporal distribution of rain and an increase in drought, especially in the midland and lowland zones both in the long and short rain seasons. The major changes reported were in the short rain season when it was reported that in many years it does not rain at all in the lowland and midland zones. These changes in the rains affect the highland zone farmers too as some households own farms in the lower zones. The short rains in the highland zone have changed in temporal distribution and in the duration of months for which it rains, raining for fewer months than it used to.

The long rains in all zones were perceived to be unpredictable, with reductions in length and changes in temporal distribution. The number of rainfall events during the long rains were perceived by farmers to have reduced in all three zones compared to the period before 1980s. Instead of raining for four and a half, four and three months in the highland, midland and lowland zones respectively, it currently rains sometimes for three, two and one month (s) respectively. The rains are also perceived to be unpredictable as to when they will begin in contrast to farmers' past experience of before 1980s. The current rainfall patterns are at odds with the patterns that farmers use to organise their farming activities, and the changes in rainfall patterns is affecting agricultural productivity.

In summary, in the Kilimanjaro region, there are perceived changes in both long and short rains in terms of spatial distribution, the number of months of rainfall, and the ability to predict the beginning of the rainfall. All of these changes affect the capacity of the small-holder farmers to utilise the available rainfall for agriculture. Although the farmers' perception is not detailed enough to provide evidence of climate change it does highlight a perceived impact of changes in rainfall on agricultural activity. These perceptions support the empirical evidence of climate variability in the study area and highlight its impacts on small-holder farmers. For example, Luhunga (unpublished) reports decreasing rainfall trends in all three zones for the period between 1971 to 2013, and a significant increase in both minimum and maximum temperature in all zones over the same period. The study by Otte *et al.* (2017) also reports climate variability in the region, especially in the lowland zone. From the above information, it can be concluded that climate change is already happening in the Kilimanjaro region, and that these changes are evident in all three zones but affecting more the lowland zone because it was already low rainfall area and therefore existing changes make the rainfall scarce.

9.3 The impact of climate change on the livelihoods of small-holder farmers

One of the research questions this research tackled in relation to understanding practical measures small-holder farmers in the Kilimanjaro region can take to adapt to climate change, was to understand the impact on farmers' livelihoods assets of climate change. The results from the focus groups and household surveys showed that climate change in the form of rainfall variability and increased temperature directly or indirectly affect four livelihoods assets (or capitals): human, natural, financial and social capital. The most negative impacts were felt by households with no access to irrigation, households headed by elderly people and women, and those who did not receive remittances. There was no reported impact on physical assets, such as selling bikes, motorbikes and other household physical assets.

Climate change affected human capital through increased incidence of malaria, which also had implications on financial capital because people needed to spend money on medication, and also experienced a reduction in family labour for production. Human capital was also affected where climate change indirectly encouraged migration from households, which had negative impacts on some households, although others benefited through remittances. It was clear from the results that people in the study area also migrated for other reasons apart from weather-related shock, such as marriage and the search for alternative employment opportunities. However, the most negative impacts were to households who had members who had migrated away, and where remittances were not received, meaning that they could not hire farm labour to compensate for the loss of labour force from the household. Another impact on human capital as a result of climate change was reduced farming motivation because of the persistent failure of crops, caused by rainfall shortages, making a farming-based livelihood less attractive to the younger generation.

The impact of climate change on financial capital included shrinking income because of low agricultural production, rising farm production costs and the extra costs needed to buy food (due to less food being produced by the household and increasing food prices). Respondents complained about how the increased climate variability contributed to low yield which consequently led to a lack of surplus to sell for income. In addition, families were forced to buy food which would otherwise be produced on the farm. Increased production costs resulted from the need to invest in early maturing maize and replanting in cases where rainfall ceased unexpectedly killing off initial plantings. Some households had to abandon their farms and hire land in areas with access to irrigation. All these activities consume the little financial capital that households have and threaten to put more of the population into greater poverty.

The results also showed a decrease in social capital, particularly households' support to each other. Although other factors such as increased monetisation of the economy contributes to this decrease in social capital, the main culprit for the problem was seen by majority of farmers as a scarcity caused by crop failure. The implication of a decrease in social capital for the majority of the households was negative, due to evidence of an increase in life difficulty because of lower resilience in times of trouble, an increase in living costs by purchasing services that were offered by free between households. However, a somewhat positive impact of decreased social capital was the increase in independence of households through encouraging saving for the dark days.

Climate change also affected natural capital such as the availability of surface water sources (rivers and streams) as many participants reported that there was a reduction in the amount of water available for irrigation. The majority of respondents in all three zones agreed that water volume was decreasing because of climate change which was resulting in a reduction of the number of hours that farmers had access to irrigation (known as shift hours), and in some cases a reduction in farm size (affecting the natural capital of land). These negative effects had more impact on households with more limited ability to deal with complications of sourcing water for irrigation purposes (particularly elderly and women).

This is more so to these vulnerable group because of the need of physical fitness to guard water to protect an authorised users redirecting water to their farms. In some cases, this made them stop horticulture which normally takes place in dry season through irrigation, and crops to dry and wilt because of inadequate of water. Although decreasing water volume in surface water sources was reported in all three zones, the more negative impacts were felt in the lowland zone because the area is already under high pressure of other water sources for agriculture such as rainfall. Climate change in the form of increased temperature, may potentially change the agricultural potential of the highland zone where coffee is produced, which is sensitive to temperature and is grown as a cash crop, therefore affecting a household's financial capital.

These results are the first comprehensive results on the impact of climate variability on the livelihood assets of small-holder farmers in the Kilimanjaro region of Tanzania and Africa in general. A related study has been carried out in Bangladesh to understand how climate change, through increased flooding and other extreme events may affect livelihood assets. In this study Alam, *et al.,* (2017) found that extreme weather events such as storm surges and floods in Bangladesh affect natural, social, physical, and financial capital. However, a limitation of the Bangladesh study was that a comprehensive discussion about how slow onset hazards like rainfall variability affects small-holder farmers' livelihood capitals was missing.

9.4 Livelihood management practices and their impact on environmental conditions

While there are a lot of studies about what small-holder farmers are doing to adapt to climate change, little is known about context specific farming practices that contribute to livelihood vulnerability to climate change. The results in Chapter Five show that some farmers use practices that negatively affect soil quality and the efficient use of water resources; both natural assets which are vital for agricultural productivity. These strategies increase the farmers' livelihoods' vulnerability to climate change and reduce farmers' capacity to adapt to existing climate variability. There are several practices that contribute to negatively affecting environmental conditions, affecting agricultural productivity and increasing vulnerability to climate variability. After crop harvest in the lowland zone, nowadays the crop residues are removed from the field and taken to feed livestock, or are free grazed by livestock, leaving the soil bare making it not only susceptible to erosion but also reducing nutrient replenishment. Mono-cropping, where a single crop particularly maize is prioritized is carried out by some farmers, leading to reduced resilience through reduced diversity, as well as leading to problems with pests and nutrient availability.Deforestation, where trees are cut down and not replaced with the new ones is also practiced by some farmers, losing the many benefits that trees can bring to a farm. Chemical fertilizers are also used inappropriately by some farmers. The above discussion shows that there were several practices which were discussed which are known to potentially have negative effects on agricultural productivity. In contrast, very few households reported the use of some agricultural land practices which are known to be effective in enhancing productivity or increasing resilience to climate variability, such as intercropping, terracing, mulching, bush fallowing, crop rotation and the use of manure especially in farms located in midland and lowland zones as there were less talk about these practices.

Farmers were also reported to degrade surface water sources by cutting down trees in water catchments which discourage infiltration and reducing soil erosion which prevents sediments from entering stream. There was relatively limited evidence of the use of effective strategies to increase the efficiency of water use on farms. For example, especially during the dry season where irrigation is more prevalent, farmers planted more water-demanding-crops such as those grown in horticulture such as tomatoes, cucumber, onions, which intensifies pressure on water demand. For crops grown in the rain seasons, although almost 70 percent of respondents in the highland and midland zones reported to use early maturing maize, some farmers, particularly in the lowland zone either recycled early maturing maize (selected some seeds from previously harvested hybrid maize to be planted the following season or planted traditional maize varieties which are not compatible with the decreasing rainfall experienced. Water is also lost in unlined irrigation canals which convey water. Although some canals in the midland and lowland zones were lined, there were no lined canals discussed in the highland zone. A related study was carried out by Paavola, (2008) in Morogoro, Tanzania who found that farmers in Morogoro inadvertently increase their vulnerability to climate change by using agricultural practices such as extending crop cultivation into forest areas. Although these studies have been conducted in two different regions, and therefore issues raised in Morogoro may not necessarily be relevant to the Kilimanjaro region, there are still two more distinctions to make. Firstly, the vulnerability analysis carried out by Paavola (2008) was based on a literature review and expert interviews; and therefore the most significant stakeholders, the small-holder farmers, were not involved. Therefore, although the identified practices might be contributing to livelihood vulnerability, the opinions of the people who depend on the livelihoods, and actually have to testify that they are vulnerable or not are not presented.

9.5 Livelihood strategies and Social structures increasing livelihood vulnerability to climate change

In Chapter Six, the role of social structures in increasing livelihood vulnerability to climate change was discussed, and considered the different livelihood options available to the farmers. Amongst the respondents in the study area, some take part in three different livelihood options: crop production, livestock keeping, and off-farm income activities. However, these subsectors all face several challenges that limit the capacity of farmers' livelihoods to adapt to climate change. The crop sector which is the dominant source of income for farmers faces several constraints that limits the ability of the subsector to adapt to changing climate. Other livelihoods options such as livestock keeping and off farm income activities are facing challenges that reduce the full potential of the subsectors to contribute to adaptation. The constraints that limit the crop subsector to adapt to climate change include lack of capital to invest in agricultural inputs such as improved seeds, fertilizers and insecticides and decreasing rainfall which sometimes is too low for the early maturing maize to survive.

Decreasing rainfall is complicated by lack of adequate alternative water sources to supplement rainfall deficits and expand production outside of the rain season. Livestock which are free-grazed on the farms located in the lowland zone, discourage farmers to implement certain adaptation strategies such as planting trees and the use of drought resistant crops that take a longer to get to harvest compared to maize. Low crop prices are also a setback for adaptation as it contributes to a reduction in income which can be invested in the farm. High price fluctuations and farmers' circumstances make farmers victims of selling at a low price which makes them un able to take opportunities to sell at higher price. Other problems affecting the crop subsector include the presence of fake inputs in the markets which have reduced effectiveness and also use up farmers' financial capital. These constraints are intensified by existing social structures such poor functioning market institutions, government policies, and farmers' location in relation to location of their farms.

Land shortages contribute to land degradation because it limited farmers to rest parts of the farm to allow fields to rejuvenate. In addition, population pressure and inheritance traditions which promote the division of land to provide land to each male child and transforming farm land into settlement has also contributed to land shortages. Government policies such as export bans, the appropriation of water sources (without providing alternative water sources for irrigation), and input voucher schemes (which still don't help the poorest farmers who cannot afford the amount they have to pay) all contribute further to challenges within the crop subsector. In addition, the lack of adequate agriculture extension officers and their poor working environment limits their capacity to provide the required support and services to farmers, further affecting the crop subsector.

Livestock keeping and off-farm income activities face some challenges which are similar to those of the crop subsector. Some of the constraints of the livestock subsector include animal diseases, expensive medicines, inadequate access to fodder for the animals, and lack of access to veterinary services. The barriers to successful off-farm income activities include a lack of capital which farmers could use to start and develop off farm income activities, insufficient customers; irregular prices and taxation; and lack of good infrastructure. In addition, there are certain social structures that govern how households use their income such as the way in which household obligations are divided between a husband and wife, and where decision making lies in the allocation of household resources. It was reported that in some households with two parents there was sometimes inappropriate use of household resources. There was also some discussion about how the empowerment of women led in some cases to better use of household resources.

Generally, social structures can increase livelihood vulnerability within households as they limit capacity of existing livelihoods strategies to contribute to livelihood development. Each livelihood strategy was facing a number of constraints which were from both external and internal to the household. These results also show that household vulnerability to climate change is not just dependent on access to resources but also the way in which the household utilises the available resources in the form of income and crop produce. The same observation about the role of both resource *access* and resource *use* in contributing to vulnerability to stressor like food insecurity was observed in Côte d'Ivoire, where Kiewisch (2015) reported that together with measures to enhance production, separation of household income and division of household obligations between men and women contributed to household vulnerability to food security. However, this study brings the question of the role of household resource use and its role in livelihood vulnerability into studies of climate change vulnerability and adaptation. This research contributes to livelihood frameworks by highlighting the contribution of household use as an *internal* source of vulnerability rather than the previous focus on just *external* sources of vulnerability (DFID, 1999).

9.6 Building livelihood resilience in the face of climate change

Observations from the study area demonstrate that small-holder farmers are already impacted by climate variability and that there are social and environmental structures that increase their vulnerability to climate change. The existing vulnerability of small-holder farmers is a wake-up call to the adaptation needs of small-holder farmers in the Kilimanjaro region in order to avoid significant negative impacts of climate change and in order to exploit the opportunities that may also arise with climate variability. This study presents a comprehensive discussion of the adaptations needed for small-holder farmers in the Kilimanjaro region to be able to adapt to climate variability. These measures address how both ways in which farmers and government can contribute to supporting small-holder farmers' livelihoods in the Kilimanjaro region adapt to climate change.

Managing the impact of climate variability on livelihood assets (human, social, financial and natural capitals), requires dealing with different factors beyond just climate variability itself due to the multiple stressors on small-holder farmers livelihoods and assets. Migration away from the small-holder farmers' households, was attributed to climate variability as well as other factors such as marriage, and searching for jobs and other income opportunities. Therefore, dealing with this issue requires strategic planning to ensure it works for the interest of those moving away and for the people and other resources left behind. There is the need to provide adequate services in rural areas including opening opportunities for non -farm income sources to reduce pressure on the available land. Also since there is already high rate of unemployment in there is the need for the government to plan for organised migration to potentially productive arable land elsewhere in the country where there is a conducive environment for successful agriculture. However, the government should take necessary precaution to control social and environmental impacts that may arise as a result of resettlement.

The need to address issues associated with malaria is country-wide. Solutions to help prevent the spread of malaria include the use of insecticide-treated mosquito bed nets and an environment free from stagnant water to remove mosquito breeding grounds. There is a role for government in accessing nets, and in education of farmers about the disease transmission pathways and these solutions, or the government could make such actions mandatory. The government can support farmers to access medical care by establishing health centres at reasonable distance and allow early diagnosis and early treatment of the patients by increasing local medical care capacity.

Dealing with issues in coffee production linked to climate change such as increasing temperatures is essential for knowledge generation which can increase coffee productivity in the Kilimanjaro region. The coffee research institute will need to ensure the availability of adequate human and financial resources to deal with emergent pests and diseases in the coffee experiment plots. The institute will also need to undertake some experiments in the use of irrigated farming rather than depending only on rainfall because if the present trend in rainfall persists, it will be difficult for rain-fed coffee production to be maintained.

Addressing the problems associated with decreasing social capital will need to work on three areas. Firstly, is by encouraging reciprocity when a household extend support to another, the recipient household should be expected to return the act of kindness. Second is to motivate individuals doing act of kindness by providing positive motivation by reciprocating in case they also get affected by stressor. For example, a household which was kind enough to help another household to go through a difficult time can be supported when they are in need. However, for households which support another household so that they can be paid back, they need to establish closure (Baron *et al.,* 2000) in their support network in order to make it easy to establish accountability.

Dealing with impact of climate change on the farmers' natural capital such as decreasing water volumes requires actions to conserve of water sources, such as prohibiting human activities close to water sources and also controlling water wastage from the water sources to the farm through the conveyance systems. This can be achieved by using efficient irrigation methods such as sunken beds which use less time to irrigate crops compared to farm plots without them and building concrete liners into irrigation canals is essential.

The livelihood management practices that reduce soil fertility need to be stopped and replaced with practices that increase soil fertility. For example, instead of removing crop residues from fields after harvest, farmers should retain at least part of them in the farm to increase nutrient retention and reduce soil erosion and land degradation. This can be facilitated by government to encourage livestock keepers to keep the number of livestock which can be taken care off by owners' resources and not free-grazing livestock in other peoples' farms. Farmers' livelihood vulnerability to climate change would also benefit from stopping mono-cropping and instead practising crop rotation or inter-cropping, as well as planting new trees in their farms to replaces one that have been felled. There are also issues relating to the inappropriate application of fertiliser. Farmers could be support in this, by accessing support through government institutions to conduct nutrient tests of the soil on their farms. Although farmers may understand that the quality of the soil is deteriorating, they may not know exactly what nutrients are missing. Soil fertility could also be improved without recourse to expensive (and potentially fake) artificial fertilizers if there was a greater use of manure as a fertilizer. This practice in particular could be practiced more in the lowland zone because they are doing less of it. One of the barriers to the use of manure is that agricultural fields can be up to five kilometres away from the homestead where the livestock, and manure source, is kept. However, cooperation between farmers could potentially overcome issues of transporting of manure through the sharing of transport resources.

There are several roles for government and government institutions in dealing with the problem of access to water sources and water inefficiency. In some instances, support with water infrastructure would be beneficial for example through the construction of dams for water storage and rainwater harvesting. Where government appropriation of water has taken place for domestic and urban use, rural farmers need support to access sufficient water for their livelihoods. Farmers would also benefit from support, potentially through education, to reduce growing high water demand crops. Government funded research into drought resistant crops that could be grown by farmers, and support developing a profitable market for these crops would also be beneficial.

Farmers in the study area need to diversify their livelihoods to decrease their vulnerability to climate change. However, livelihoods need to be diverse enough to ensure that there is sufficient disparity between the livelihoods such that there is very low risk of the livelihoods being equally impacted by the same hazard.

There is a need to ensure that small-holder farmers have sufficient access to agriculture extension officers and the community development officers who can help to find other sources that can aid farmers with capital and ensure effective participation and education of farmers in addressing their problems. There is also the need to re-examine some existing government institutions and policies which are in place to provide services to farmers. For example, it would be beneficial for the government to revisit the input voucher schemes to allow poor farmers to be able to afford to use this benefit. There are also arguments to stop export bans on crops while still maintaining national food security and to create favourable local market for agriculture. The government can also enforce the use of scales in measuring crops in the markets to prevent farmers from being cheated by unscrupulous buyers, and ensure that there is compensation or alternatives given to farmers in situations where the government want to appropriate resources from farmers.

9.7 Methodological reflections

In Chapter Eight, I offered a methodological reflection of the study and reflection on the use and development of the interconnected tools and theoretical frameworks used in the research design and data analysis. It is hoped that the reflection will help other case study researchers (concerned about building livelihood resilience) learn from the decisions made in the study. This study found that the Turner et al. (2003) vulnerability framework was an effective framework to explore the exposure and sensitivity of small-holder farmers' livelihoods to climate change. The study demonstrated that sensitivity of the farmers' livelihoods to climate variability was mainly the result of farmers agricultural practices that affected the natural resource base important for livelihood which were soils and water. Also it was observed that social structures that increased vulnerability came from both internal and external drivers to households. Moreover, this study shows how the livelihood framework by (DFID, 1999) and socio-ecological resilience frameworks by (Biggs *et al.,*2012: 2015) complement each other, with the latter helpful in understanding ways to develop resilience across the breadth of the small-holder farmer livelihood. Adopting these frameworks also highlights the importance of understanding the role of household income use as well as the importance of the different livelihood capitals or assets.

The use of case study design which focused on small-holder farmers' adaptation in Kilimanjaro region has positive and negative outcomes. On the positive side is the generation of a number of adaptation measures for building livelihood resilience based on the analysis of adaptation needs of the specific community and by the community members. However, overall results are not necessarily appropriate or cannot be scaled up to other small-holder farmers in Tanzania.

The use of PRA tools was useful in providing a framework to analyse vulnerability without assuming certain factors and allowing focus group participants to explore and arrive at answers without being led. The use of a modified livelihood assessment tool kit also helped to explore livelihood vulnerability without assuming the presence of climate change in the study area, but it was felt had limitations for slow onset disasters such as those related to climate change. There is much scope for future research relating to this study, including research into livelihood vulnerability to climate change of small-holder farmers in other regions and the study of livelihood vulnerability in other natural resource dependent communities such as coastal communities and forest dependent communities. Further work would also be beneficial in understanding how farmers' perceptions of climate change relate to the empirical evidence of climate variability.

10 References

Adger, W. N. (2000) ‘Social and ecological resilience: are they related?’, *Progress in human geography*. Sage Publications Sage CA: Thousand Oaks, CA, 24(3), pp. 347–364.

Adger, W. N. *et al.* (2003) ‘Adaptation to climate change in the developing world’, *Progress in Development Studies*, 3(3), pp. 179–195. doi: 10.1191/1464993403ps060oa.

Adger, W. N. (2006) ‘Vulnerability’, *Global environmental change*. Elsevier, 16(3), pp. 268–281.

Afifi, T., Liwenga, E. and Kwezi, L. (2014) ‘Rainfall-induced crop failure, food insecurity and out-migration in Same-Kilimanjaro, Tanzania’, *Climate and Development*, 6(1), pp. 53–60. doi: 10.1080/17565529.2013.826128.

Akinbile, L. A., Aminu, O. O. and Kolade, R. I. (2018) ‘Perceived effect of climate change on forest dependent livelihoods in Oyo State, Nigeria’, *Journal of Agricultural Extension*. Agricultural Extension Society of Nigeria, 22(2).

Akinnifesi, F. K. *et al.* (2002) ‘Domesticating priority miombo indigenous fruit trees as a promising livelihood option for small-holder farmers in Southern Africa’, in *XXVI International Horticultural Congress: Citrus and Other Subtropical and Tropical Fruit Crops: Issues, Advances and 632*, pp. 15–30.

Alam, G. M.Monirul, Alam, K. and Mushtaq, S. (2017) ‘Climate change perceptions and local adaptation strategies of hazard-prone rural households in Bangladesh’, *Climate Risk Management*. The Authors, 17, pp. 52–63. doi: 10.1016/j.crm.2017.06.006.

Alam, G M Monirul, Alam, K. and Mushtaq, S. (2017) ‘Climate change perceptions and local adaptation strategies of hazard-prone rural households in Bangladesh', *Climate Risk Management*. Elsevier, 17, pp. 52–63.

ALMARIO-DESOLOC, M. S. (2014) 'Women empowerment and climate change adaptation in Northern Quezon', *Asia Pacific Journal of Multidisciplinary Research| Vol*, 2(4).

Alobo Loison, S. (2015) 'Rural Livelihood Diversification in Sub-Saharan Africa: A Literature Review', *Journal of Development Studies*. Routledge, 51(9), pp. 1125–1138. doi: 10.1080/00220388.2015.1046445.

Altieri, M. a and Nicholls, C. (2012) 'The scaling up of agroecology : spreading the hope for food sovereignty and resiliency A contribution to discussions at Rio + 20 on issues at the interface of hunger , agriculture , environment and social prepared by The scaling up of agroecology : spread', *Socla*, p. 20.

Andrade-Piedra, J.L., Bentley, J.W., Almekinders, C.J., Jacobsen, K., Walsh, S. and Thiele, G., 2016. Case studies of Roots, Tubers and Bananas seed systems.

Anik, S. I. and Khan, M. A. S. A. (2012) 'Climate change adaptation through local knowledge in the north eastern region of Bangladesh', *Mitigation and Adaptation Strategies for Global Change*, 17(8), pp. 879–896. doi: 10.1007/s11027-011-9350-6.

Antwi-Agyei, P., Stringer, L. C. and Dougill, A. J. (2014) 'Livelihood adaptations to climate variability: Insights from farming households in Ghana', *Regional Environmental Change*, 14(4), pp. 1615–1626. doi: 10.1007/s10113-014-0597-9.

Arndt, C. *et al.* (2012) 'Climate Change, Agriculture and Food Security in Tanzania', *Review of Development Economics*, 16(3), pp. 378–393. doi: 10.1111/j.1467-9361.2012.00669.x.

Asfaw, A. *et al.* (2019) 'Determinants in the adoption of climate change adaptation strategies: evidence from rainfed-dependent smallholder farmers in north-central Ethiopia (Woleka sub-basin)', *Environment, Development and Sustainability*. Springer, 21(5), pp. 2535–2565.

Assembly, G. (2015) 'Sustainable development goals', *SDGs Transform Our World*, 2030.

Ayeri, O. S. *et al.* (2012) 'Local perceptions and responses to climate change and variability: The case of Laikipia District, Kenya', *Sustainability*, 4(12), pp. 3302–3325. doi: 10.3390/su4123302.

Baiyegunhi, L. J. S. (2014) 'Social capital effects on rural household poverty in Msinga, KwaZulu-Natal, South Africa', *Agrekon*. Taylor & Francis, 53(2), pp. 47–64.

Balama, C. *et al.* (2016) 'Forest adjacent households' voices on their perceptions and adaptation strategies to climate change in Kilombero District, Tanzania', *SpringerPlus*. Springer, 5(1), p. 792.

Bandara, J. S. and Cai, Y. (2014) 'The impact of climate change on food crop productivity, food prices and food security in South Asia', *Economic Analysis and Policy*. Elsevier, 44(4), pp. 451–465.

Barkemeyer, R. *et al.* (2014) 'What happened to the 'development'in sustainable development? Business guidelines two decades after Brundtland', *Sustainable development*. Wiley Online Library, 22(1), pp. 15–32.

Baron, S., Field, J. and Schuller, T. (2000) *Social capital: Critical perspectives*. OUP Oxford.

Barrett, C. B. and Constas, M. A. (2014) 'Toward a theory of resilience for international development applications', *Proceedings of the National Academy of Sciences*. National Acad

Sciences, 111(40), pp. 14625–14630.

Barrett, C. B., Reardon, T. and Webb, P. (2001) 'Nonfarm income diversification and household livelihood strategies in rural Africa: concepts, dynamics, and policy implications', *Food policy*. Elsevier, 26(4), pp. 315–331.

Barron, J. and Okwach, G. (2005) 'Run-off water harvesting for dry spell mitigation in maize (Zea mays L.): Results from on-farm research in semi-arid Kenya', *Agricultural Water Management*, 74(1), pp. 1–21. doi: 10.1016/j.agwat.2004.11.002.

Barron, S. *et al.* (2012) 'A climate change adaptation planning process for low-lying, communities vulnerable to sea level rise', *Sustainability*. Molecular Diversity Preservation International, 4(9), pp. 2176–2208.

Basit, T. (2003) 'Manual or electronic? The role of coding in qualitative data analysis', *Educational research*. Taylor & Francis, 45(2), pp. 143–154.

Bee, F. K. (2009) *Fair Trade-Fair Futures: The Kilimanjaro Native Cooperative Union scholarship programme for children made vulnerable by AIDS*. ILO.

Belay, A. *et al.* (2017) 'Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia', *Agriculture and Food Security*. BioMed Central, 6(1), pp. 1–13. doi: 10.1186/s40066-017-0100-1.

Berkes, F. and Ross, H. (2013) 'Community resilience: toward an integrated approach', *Society & Natural Resources*. Taylor & Francis, 26(1), pp. 5–20.

Berman, R. J., Quinn, C. H. and Paavola, J. (2015) 'Identifying drivers of household coping strategies to multiple climatic hazards in Western Uganda: implications for adapting to future climate change', *Climate and Development*. Taylor & Francis, 7(1), pp. 71–84.

Biazin, B. *et al.* (2012) 'Rainwater harvesting and management in rainfed agricultural systems in sub-Saharan Africa - A review', *Physics and Chemistry of the Earth*. Elsevier Ltd, 47–48, pp. 139–151. doi: 10.1016/j.pce.2011.08.015.

Biggs, R. *et al.* (2012) 'Toward principles for enhancing the resilience of ecosystem services', *Annual review of environment and resources*. Annual reviews, 37, pp. 421–448.

Biggs, R., Schlüter, M. and Schoon, M. L. (2015) *Principles for building resilience: sustaining ecosystem services in social-ecological systems*. Cambridge University Press.

Bigsten, A. and Danielsson, A., 1999. Is Tanzania an emerging economy?

Birkmann, J. (2006) 'Measuring vulnerability to promote disaster-resilient societies: Conceptual frameworks and definitions', *Measuring vulnerability to natural hazards: Towards disaster resilient societies*, 1, pp. 9–54.

Bohensky, E. L. *et al.* (2015) 'Principle 4—foster complex adaptive systems thinking', *Principles for building resilience: sustaining ecosystem services in social-ecological systems. Cambridge University Press, Cambridge, UK*, pp. 142–173.

Bossio, D., Geheb, K. and Critchley, W. (2010) 'Managing water by managing land: Addressing land degradation to improve water productivity and rural livelihoods', *Agricultural water management*. Elsevier, 97(4), pp. 536–542.

Bot, A. and Benites, J. (2005) *The importance of soil organic matter: Key to drought-resistant soil and sustained food production*. Food & Agriculture Org.

Bourke, B. (2014) 'Positionality: Reflecting on the research process.', *Qualitative Report*, 19(33).

Brankatschk, G. and Finkbeiner, M. (2015) ‘Modeling crop rotation in agricultural LCAs—challenges and potential solutions’, *Agricultural systems*. Elsevier, 138, pp. 66–76.

Bryan, E. *et al.* (2013) ‘Adapting agriculture to climate change in Kenya: Household strategies and determinants’, *Journal of Environmental Management*. Elsevier Ltd, 114, pp. 26–35. doi: 10.1016/j.jenvman.2012.10.036.

Bryant, G., Dabhi, S. and Böhm, S. (2015) ‘“Fixing” the climate crisis: capital, states, and carbon offsetting in India’, *Environment and Planning A*, 47(10), pp. 2047–2063. doi: 10.1068/a130213p.

Bryman, A. (2016) *Social research methods*. Oxford university press.

Burnard, P. *et al.* (2008) ‘Analysing and presenting qualitative data’, *British dental journal*. Nature Publishing Group, 204(8), p. 429.

Burnham, M. and Ma, Z. (2016) ‘Linking smallholder farmer climate change adaptation decisions to development’, *Climate and Development*. Taylor & Francis, 8(4), pp. 289–311. doi: 10.1080/17565529.2015.1067180.

Burrows, M. T. *et al.* (2011) ‘The pace of shifting climate in marine and terrestrial ecosystems’, *Science*. American Association for the Advancement of Science, 334(6056), pp. 652–655.

Carpenter, S. *et al.* (2001) ‘From metaphor to measurement: resilience of what to what?’, *Ecosystems*. Springer, 4(8), pp. 765–781.

Chambers, R. (1994a) ‘Participatory rural appraisal (PRA): Challenges, potentials and paradigm’, *World development*. Elsevier, 22(10), pp. 1437–1454.

Chambers, R. (1994b) ‘The origins and practice of participatory rural appraisal’, *World development*. Elsevier, 22(7), pp. 953–969.

Chongela, J. (2015) ‘Contribution of agriculture sector to the Tanzanian economy’, *American Journal of Research Communication*, 3(7), pp. 57–70.

Clark, W. C. and Dickson, N. M. (2003) ‘Sustainability science: The emerging research program’, *Proceedings of the National Academy of Sciences of the United States of America*, 100(14), pp. 8059–8061. doi: 10.1073/pnas.1231333100.

Clement, M., Mwakalila, S. and Norbert, J. (2016) ‘Implications of Land Use and Climate Change on Water Balance Components in the Sigi Catchment, Tanzania’, *Journal of the Geographical Association of Tanzania*, 39(1).

Collier, P., Conway, G. and Venables, T. (2008) ‘Climate change and Africa’, *Oxford Review of Economic Policy*, 24(2), pp. 337–353. doi: 10.1093/oxrep/grn019.

Conway, D. *et al.* (2015) ‘Climate and southern Africa’s water–energy–food nexus’, *Nature Climate Change*. Nature Publishing Group, 5(9), pp. 837–846.

Conway, D., Mittal, N. and Vincent, K. (2017) ‘Future climate projections for Tanzania’. Climate and Development Knowledge Network (CDKN).

Council, N. R. (1989) *Alternative agriculture*. National Academies Press.

Danermark, B., Ekström, M. and Karlsson, J. C. (2019) *Explaining society: Critical realism in the social sciences*. Routledge.

Deppisch, S. and Hasibovic, S. (2013) ‘Social-ecological resilience thinking as a bridging concept in transdisciplinary research on climate-change adaptation’, *Natural hazards*.

Springer, 67(1), pp. 117–127.

Deressa, T. T., Hassan, R. M. and Ringler, C. (2011) ‘Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia’, *The Journal of Agricultural Science*. Cambridge University Press, 149(1), pp. 23–31.

Descheemaeker, K. *et al.* (2016) ‘Climate change adaptation and mitigation in smallholder crop–livestock systems in sub-Saharan Africa: a call for integrated impact assessments’, *Regional Environmental Change*. Springer Berlin Heidelberg, 16(8), pp. 2331–2343. doi: 10.1007/s10113-016-0957-8.

Dhanush, D. *et al.* (2015) ‘Impact of climate change on African agriculture: focus on pests and diseases’.

Downing, T. E. *et al.* (1997) ‘Adapting to climate change in Africa’, *Mitigation and adaptation strategies for global change*. Springer, 2(1), pp. 19–44.

Eakin, H. and Luers, A. L. (2006) ‘Assessing the vulnerability of social-environmental systems’, *Annu. Rev. Environ. Resour.* Annual Reviews, 31, pp. 365–394.

Ebi, K. L. and Burton, I. (2008) ‘Identifying practical adaptation options: an approach to address climate change-related health risks’, *Environmental Science & Policy*. Elsevier, 11(4), pp. 359–369.

Eisenhauer, D. C. (2016) ‘Pathways to climate change adaptation: Making climate change action political’, *Geography Compass*. Wiley Online Library, 10(5), pp. 207–221.

Ellis, F. (1993) *Peasant economics: Farm households in agrarian development*. Cambridge University Press.

Ellis, F. (2000) *Rural livelihoods and diversity in developing countries*. Oxford university press.

Ellis, F., Kutengule, M. and Nyasulu, A. (2003) 'Livelihoods and rural poverty reduction in Malawi', *World Development*, 31(9), pp. 1495–1510. doi: 10.1016/S0305-750X(03)00111-6.

Ellison, D. *et al.* (2017) 'Trees, forests and water: Cool insights for a hot world', *Global Environmental Change*. Elsevier, 43, pp. 51–61.

Di Falco, S. and Veronesi, M. (2013) 'How can African agriculture adapt to climate change? A counterfactual analysis from Ethiopia', *Land Economics*, 89(4), pp. 743–766. doi: 10.3368/le.89.4.743.

Farmer, G. T. and Cook, J. (2013) 'Understanding climate change denial', in *Climate change science: a modern synthesis*. Springer, pp. 445–466.

Folke, C. (2006) 'Resilience: The emergence of a perspective for social–ecological systems analyses', *Global environmental change*. Elsevier, 16(3), pp. 253–267.

Follett, R. H., Murphy, L. S. and Donahue, R. L. (1981) *Fertilizers and soil amendments.* Prentice-Hall, Inc.

Ford, J. D. *et al.* (2018) 'Vulnerability and its discontents: the past, present, and future of climate change vulnerability research', *Climatic change*. Springer, 151(2), pp. 189–203.

Fosu-Mensah, B. Y., Vlek, P. L. G. and MacCarthy, D. S. (2012) 'Farmers' perception and adaptation to climate change: a case study of Sekyedumase district in Ghana', *Environment, Development and Sustainability*. Springer, 14(4), pp. 495–505.

Friel, S. *et al.* (2011) 'Urban health inequities and the added pressure of climate change: an action-oriented research agenda', *Journal of Urban Health*. Springer, 88(5), p. 886.

Garrity, D. P. *et al.* (2010) 'Evergreen Agriculture: a robust approach to sustainable food security in Africa', *Food security*. Springer, 2(3), pp. 197–214.

Gebbers, R. and Adamchuk, V. I. (2010) 'Precision agriculture and food security', *Science*. American Association for the Advancement of Science, 327(5967), pp. 828–831.

Gedefaw, M. *et al.* (2018) 'Farmer's Perceptions and Adaptation Strategies to Climate Change, Its Determinants and Impacts in Ethiopia: Evidence from Qwara District', *J Earth Sci Clim Change*, 9(481), p. 2.

Gomm, R., Hammersley, M. and Foster, P. (2000) *Case study method: Key issues, key texts*. Sage.

Goslinga, R., Brugger, F. and Seuret, E. (2013) 'System and method for providing a site-related weather insurance contract'. Google Patents.

Gramzow, A., Batt, P.J., Afari-Sefa, V., Petrick, M. and Roothaert, R., 2018. Linking smallholder vegetable producers to markets-A comparison of a vegetable producer group and a contract-farming arrangement in the Lushoto District of Tanzania. *Journal of Rural Studies*, *63*, pp.168-179.

Grbich, C. (2013) 'Integrated methods in health research', *Research methods in health: Foundations for evidence-based practice*, pp. 312–322.

Grech, S. (2012) 'Disability, communities of poverty and the global South: Debating through social capital', in *Inclusive communities*. Brill Sense, pp. 69–84.

Greene, M. J. (2014) 'On the inside looking in: Methodological insights and challenges in conducting qualitative insider research', *The qualitative report*. Citeseer, 19(29), pp. 1–13.

Habiba, U., Shaw, R. and Takeuchi, Y. (2012) 'Farmer's perception and adaptation practices to cope with drought: Perspectives from Northwestern Bangladesh', *International Journal of Disaster Risk Reduction*. Elsevier, 1(1), pp. 72–84. doi: 10.1016/j.ijdrr.2012.05.004.

Hansen, P. (2012) 'Revisiting the remittance mantra: a study of migration–development policy formation in Tanzania', *International Migration*. Wiley Online Library, 50(3), pp. 77–91.

Hatibu, N. and Mahoo, H. (1999) 'Rainwater harvesting technologies for agricultural production: A case for Dodoma, Tanzania', *Conservation tillage with animal traction*, 161.

Henson, R. (2011) *The rough guide to climate change*. Dorling Kindersley Ltd.

Hepelwa, A. S., Selejio, O. and Mduma, J. K. (2013) 'The voucher system and the agricultural production in Tanzania, is the model adopted effective'. University of Dar es Salaam (UDSM).

Hertel, T. W., Burke, M. B. and Lobell, D. B. (2010) 'The poverty implications of climate-induced crop yield changes by 2030', *Global Environmental Change*. Elsevier, 20(4), pp. 577–585.

Hertel, T. W. and Rosch, S. D. (2010) *Climate change, agriculture and poverty*. The World Bank.

Hoddy, E. T. (2019) 'Critical realism in empirical research: employing techniques from grounded theory methodology', *International Journal of Social Research Methodology*. Taylor & Francis, 22(1), pp. 111–124.

Holler, J. (2014) 'Is sustainable adaptation possible? Determinants of adaptation on Mount Kilimanjaro', *The Professional Geographer*. Taylor & Francis, 66(4), pp. 526–537.

Hopkins, D. (2015) 'Applying a comprehensive contextual climate change vulnerability framework to New Zealand's tourism industry', *Ambio*. Springer, 44(2), pp. 110–120.

Houston, S. (2010) ‘Prising open the black box: Critical realism, action research and social work’, *Qualitative Social Work*. SAGE Publications Sage UK: London, England, 9(1), pp. 73–91.

Howden, S. M. *et al.* (2007) ‘Adapting agriculture to climate change’, *Proceedings of the national academy of sciences*. National Acad Sciences, 104(50), pp. 19691–19696.

Huckle, J. (2019) ‘Powerful geographical knowledge is critical knowledge underpinned by critical realism’, *International Research in Geographical and Environmental Education*. Taylor & Francis, 28(1), pp. 70–84.

Imperatives, S. (1987) ‘Report of the World Commission on Environment and Development: Our common future’, *Accessed Feb*, 10.

Ishaya, S. and Abaje, I. . (2008) ‘Indigenous people’s perception on climate change and adaptation strategies in Jema’a local government area of Kaduna State, Nigeria’, *Journal of Geography and Regional Planning*, 1(8), pp. 138–143. doi: 10.1007/s11069-008-9249-z.

Issahaku, A., Campion, B. B. and Edziyie, R. (2018) ‘Climate variability, water levels, and fish catch in the Upper East Region of Ghana’, *Environmental Quality Management*. Wiley Online Library, 27(3), pp. 43–51.

Jayne, T. S., Mather, D. and Mghenyi, E. (2010) ‘Principal Challenges Confronting Smallholder Agriculture in Sub-Saharan Africa’, *World Development*. Elsevier Ltd, 38(10), pp. 1384–1398. doi: 10.1016/j.worlddev.2010.06.002.

Jerneck, A. (2018) ‘Taking gender seriously in climate change adaptation and sustainability science research: Views from feminist debates and sub-saharan small-scale agriculture’, *Sustainability Science*. Springer Japan, 13(2), pp. 403–416. doi: 10.1007/s11625-017-0464-y.

Jones, Peter G and Thornton, P. K. (2009) 'Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change', *Environmental Science & Policy*. Elsevier, 12(4), pp. 427–437.

Jones, Peter G. and Thornton, P. K. (2009) 'Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change', *Environmental Science and Policy*, 12(4), pp. 427–437. doi: 10.1016/j.envsci.2008.08.006.

Kangalawe, R. Y. M. (2012) 'Food security and health in the southern highlands of Tanzania: A multidisciplinary approach to evaluate the impact of climate change and other stress factors', *African Journal of Environmental Science and Technology*. Academic Journals, 6(1), pp. 50–66.

Kangalawe, R. Y. M. (2017) 'Climate change impacts on water resource management and community livelihoods in the southern highlands of Tanzania', *Climate and Development*. Taylor & Francis, 9(3), pp. 191–201. doi: 10.1080/17565529.2016.1139487.

Kassie, B. T. *et al.* (2013) 'Adapting to climate variability and change: experiences from cereal-based farming in the Central Rift and Kobo Valleys, Ethiopia', *Environmental management*. Springer, 52(5), pp. 1115–1131.

Kates, R. W. *et al.* (2001) 'Sustainability science', *Science*. American Association for the Advancement of Science, 292(5517), pp. 641–642.

Kates, R. W. (2011) 'What kind of a science is sustainability science?', *Proceedings of the National Academy of Sciences*. National Acad Sciences, 108(49), pp. 19449–19450.

Kates, R. W., Travis, W. R. and Wilbanks, T. J. (2012) 'Transformational adaptation when incremental adaptations to climate change are insufficient', *Proceedings of the National Academy of Sciences*. National Acad Sciences, 109(19), pp. 7156–7161.

Kato, M. P. and Kratzer, J. (2013) 'Empowering women through microfinance: Evidence from Tanzania'. ACRN Journal of Entrepreneurship Perspectives.

Keskitalo, E. C. H. and Kulyasova, A. A. (2009) 'The role of governance in community adaptation to climate change', *Polar Research*, 28(1), pp. 60–70. doi: 10.1111/j.1751-8369.2009.00097.x.

Kiewisch, E. (2015) 'Looking within the household: a study on gender, food security, and resilience in cocoa-growing communities', *Gender & Development*. Taylor & Francis, 23(3), pp. 497–513.

Knox, J. *et al.* (2012) 'Climate change impacts on crop productivity in Africa and South Asia', *Environmental Research Letters*. IOP Publishing, 7(3), p. 34032.

Komakech, H. C. *et al.* (2011) 'Water allocation and management in an emerging spate irrigation system in Makanya catchment, Tanzania', *Agricultural water management*. Elsevier, 98(11), pp. 1719–1726.

Komakech, H. C., Van der Zaag, P. and Van Koppen, B. (2012) 'The Last Will Be First: Water Transfers from Agriculture to Cities in the Pangani River Basin, Tanzania.', *Water Alternatives*, 5(3).

Komba, C. and Muchapondwa, E. (2012) 'Adaptation to climate change by smallholder farmers in Tanzania', *Economic research Southern Africa (ERSA) working paper*, 299(5).

Kotir, J. H. (2011) 'Climate change and variability in Sub-Saharan Africa: A review of current and future trends and impacts on agriculture and food security', *Environment, Development and Sustainability*, 13(3), pp. 587–605. doi: 10.1007/s10668-010-9278-0.

Kulkarni, M. A. *et al.* (2016) '10 years of environmental change on the slopes of Mount Kilimanjaro and its associated shift in malaria vector distributions', *Frontiers in public health*. Frontiers, 4, p. 281.

Kyule, M. N., Konyango, J. J. J. and Nkurumwa, A. O. (2015) 'Promoting evergreen agriculture among secondary schools in arid and semi-arid lands of Kenya'.

Lal, R. (2001) 'Soil degradation by erosion', *Land degradation & development*. Wiley Online Library, 12(6), pp. 519–539.

Leichenko, R. M., O'Brien, K. L. and Solecki, W. D. (2010) 'Climate change and the global financial crisis: a case of double exposure', *Annals of the Association of American Geographers*. Taylor & Francis, 100(4), pp. 963–972.

Lema, M. A. and Majule, A. E. (2009) 'Impacts of climate change, variability and adaptation strategies on agriculture in semi arid areas of Tanzania: The case of Manyoni District in Singida Region, Tanzania', *African Journal of Environmental Science and Technology*. Academic Journals, 3(8), pp. 206–218.

Locatelli, B. *et al.* (2008) 'Facing an uncertain future: How forests and people can adapt to climate change'. CIFOR.

Lofchie, M.F., 2014. *The political economy of Tanzania: Decline and recovery*. University of Pennsylvania Press.

Loftus, M. (2011) 'CODE GREEN-A CLIMATE EMERGENCY: O90', *Internal Medicine Journal*, 41(2).

Lonsdale, K., Pringle, P. and Turner, B. (2015) 'Transformative adaptation: What it is, why it matters and what is needed'.

Lowder, S. K., Skoet, J. and Singh, S. (2014) 'What do we really know about the number and distribution of farms and family farms in the world ?', *ESA Working Paper*, 14–02(14), p. 38.

Lyimo, J. G. and Kangalawe, R. Y. M. (2010) 'Vulnerability and adaptive strategies to the impact of climate change and variability. The case of rural households in semi-arid Tanzania', *Environmental Economics*, (1, Iss. 2), pp. 89–97.

MAFAP (2013). Review of food and agricultural policies in the United Republic of Tanzania. MAFAP Country Report Series, FAO, Rome, Italy.

Mancini, A. *et al.* (2012) 'Conceptualizing and Measuring the Economic issues in the Evaluation of Socio-ecological Resilience: A Commentary', *Int. J Latest Trends Fin. Eco. Sc. Vol*, 2(3), p. 190.

Martin, A. and Huckle, J. (2001) 'Environments in a Changing World', *Essex: Pearson Education*.

McLaughlin, P. and Dietz, T. (2008) 'Structure, agency and environment: Toward an integrated perspective on vulnerability', *Global Environmental Change*. Elsevier, 18(1), pp. 99–111.

McPhaden, M. J. (2015) 'Playing hide and seek with El Niño', *Nature Climate Change*, 5(9), pp. 791–795. doi: 10.1038/nclimate2775.

Mebratu, D. (1998) 'Sustainability and sustainable development: historical and conceptual review', *Environmental impact assessment review*. Elsevier, 18(6), pp. 493–520.

Mendelsohn, R., Dinar, A. and Dalfelt, A. (2000) 'Climate change impacts on African agriculture', *Preliminary analysis prepared for the World Bank, Washington, District of Columbia*, 25.

Miller, T. R. *et al.* (2014) 'The future of sustainability science: a solutions-oriented research agenda', *Sustainability science*. Springer, 9(2), pp. 239–246.

Misana, S. B., Majule, A. E. and Lyaruu, H. V. (2003) 'Linkages between changes in land use, biodiversity and land degradation on the slopes of Mount Kilimanjaro, Tanzania'. ILRI.

Mmbando, F.E., Wale, E.Z. and Baiyegunhi, L.J., 2015. Welfare impacts of smallholder farmers' participation in maize and pigeonpea markets in Tanzania. *Food Security*, *7*(6), pp.1211-1224.

Mnimbo, T. S. *et al.* (2016) 'A gendered analysis of perception and vulnerability to climate change among smallholder farmers: the case of Same District, Tanzania', *Climate and Development*. Taylor & Francis, 8(1), pp. 95–104.

Mohamed, A. Ben (2011) 'Climate change risks in Sahelian Africa', *Regional Environmental Change*, 11(SUPPL. 1), pp. 109–117. doi: 10.1007/s10113-010-0172-y.

Mongi, H., Majule, A. E. and Lyimo, J. G. (2010) 'Vulnerability and adaptation of rain fed agriculture to climate change and variability in semi-arid Tanzania', *African Journal of Environmental Science and Technology*. Academic Journals, 4(6).

Morton, J. F. (2007) 'The impact of climate change on smallholder and subsistence agriculture', *Proceedings of the National Academy of Sciences of the United States of America*, 104(50), pp. 19680–19685. doi: 10.1073/pnas.0701855104.

Moyo, D., 2010. *Dead aid: Why aid makes things worse and how there is another way for Africa*. Penguin.

Moyo, M., Simson, R., Jacob, A. and de Mevius, F.X., 2012. Attaining middle income Status-Tanzania: growth and structural transformation required to reach middle income status by 2025. *London: International Growth Centre, London School of Economics and Political Science*.Sachs, J., 2009. Aid Ironies. *Huffington Post*, *24*.

Msongaleli, B. M. *et al.* (2015) 'Impacts of Climate Variability and Change on Rainfed Sorghum and Maize: Implications for Food Security Policy in Tanzania', *Journal of Agricultural Science*, 7(5), pp. 124–142. doi: 10.5539/jas.v7n5p124.

Mul, M.L., Kemerink, J.S., Vyagusa, N.F., Mshana, M.G., Van der Zaag, P. and Makurira, H., 2011. Water allocation practices among smallholder farmers in the South Pare Mountains, Tanzania: The issue of scale. *Agricultural water management*, *98*(11), pp.1752-1760.

Müller, C. *et al.* (2011) 'Climate change risks for African agriculture', *Proceedings of the National Academy of Sciences of the United States of America*, 108(11), pp. 4313–4315. doi: 10.1073/pnas.1015078108.

Munishi, L. K., Lema, A. A. and Ndakidemi, P. A. (2015) 'Decline in maize and beans production in the face of climate change at Hai District in Kilimanjaro region, Tanzania', *International Journal of Climate Change Strategies and Management*, 7(1), pp. 17–26. doi: 10.1108/IJCCSM-07-2013-0094.

Mwandosya, M. J., Nyenzi, B. S. and Lubanga, M. L. (1998) *The assessment of vulnerability and adaptation to climate change impacts in Tanzania.* Centre for Energy, Environment, Science and Technology.

Mwinjaka, O., Gupta, J. and Bresser, T. O. N. (2010) 'Adaptation strategies of the poorest farmers in drought-prone Gujarat', *Climate and Development*. Taylor & Francis, 2(4), pp. 346–363.

Mwongera, C. *et al.* (2017) 'Climate smart agriculture rapid appraisal (CSA-RA): A tool for prioritizing context-specific climate smart agriculture technologies', *Agricultural Systems*. Elsevier, 151, pp. 192–203.

Ndamani, F. and Watanabe, T. (2015) 'Farmers' perceptions about adaptation practices to climate change and barriers to adaptation: A micro-level study in Ghana', *Water (Switzerland)*, 7(9), pp. 4593–4604. doi: 10.3390/w7094593.

Nelson, D. R., Adger, W. N. and Brown, K. (2007) 'Adaptation to environmental change: contributions of a resilience framework', *Annu. Rev. Environ. Resour.* Annual Reviews, 32, pp. 395–419.

Ngigi, S. N. *et al.* (2005) 'Hydro-economic evaluation of rainwater harvesting and management technologies: Farmers' investment options and risks in semi-arid Laikipia district of Kenya', *Physics and Chemistry of the Earth*, 30(11-16 SPEC. ISS.), pp. 772–782. doi: 10.1016/j.pce.2005.08.020.

Nigussie, Y. *et al.* (2018) 'Evaluation of Climate Change Adaptation Alternatives for Smallholder Farmers in the Upper Blue-Nile Basin', *Ecological Economics*. Elsevier, 151(May), pp. 142–150. doi: 10.1016/j.ecolecon.2018.05.006.

Norris, F. H. *et al.* (2008) 'Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness’, *American journal of community psychology*. Wiley Online Library, 41(1–2), pp. 127–150.

O’Brien, K. L. and Leichenko, R. M. (2000) ‘Double exposure: assessing the impacts of climate change within the context of economic globalization’, *Global environmental change*. Elsevier, 10(3), pp. 221–232.

O’Keefe, P. (2015) ‘Changing Vulnerabilities in a Changing Climate: Farming Opportunity and Constraint in Kilimanjaro Region, Tanzania’.

Ofgeha, G. Y. (2017) ‘Communitys perception on soil erosion and their participation in soil conservation practices: A case study of Alaltu watershed of Najo District, Ethiopia’, *Journal of Soil Science and Environmental Management*. Academic Journals, 8(2), pp. 17–24.

Ojoyi, M., Mutanga, O., Kahinda, J.M., Odindi, J. and Abdel-Rahman, E.M., 2017. Scenario-based approach in dealing with climate change impacts in Central Tanzania. *Futures*, *85*, pp.30-41.

Okonya, J. S., Syndikus, K. and Kroschel, J. (2013) ‘Farmers’ Perception of and Coping Strategies to Climate Change: Evidence From Six Agro-Ecological Zones of Uganda’, *Journal of Agricultural Science*, 5(8). doi: 10.5539/jas.v5n8p252.

Opiyo, F. E. O., Wasonga, O. V and Nyangito, M. M. (2014) ‘Measuring household vulnerability to climate-induced stresses in pastoral rangelands of Kenya: Implications for resilience programming’, *Pastoralism*. SpringerOpen, 4(1), p. 10.

Osborn, D., Cutter, A. and Ullah, F. (2015) ‘Universal Sustainable Development Goals: Understanding the transformational challenge for developed countries’, *Universal*

Sustainable Development Goals, (May), pp. 1–24. Available at: https://sustainabledevelopment.un.org/index.php?page=view&type=400&nr=1684&menu=35.

Otte, I. *et al.* (2017) 'Multidecadal trends and interannual variability of rainfall as observed from five lowland stations at Mt. Kilimanjaro, Tanzania', *Journal of Hydrometeorology*, 18(2), pp. 349–361.

Oweis, T. and Hachum, A. (2006) 'Water harvesting and supplemental irrigation for improved water productivity of dry farming systems in West Asia and North Africa', *Agricultural water management*. Elsevier, 80(1–3), pp. 57–73.

Oweis, T., Hachum, A. and Kijne, J. (1999) *Water harvesting and supplemental irrigation for improved water use efficiency in dry areas*. IWMI.

Paavola, J. (2008) 'Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania', *Environmental Science & Policy*. Elsevier, 11(7), pp. 642–654.

Pachauri, R. K. *et al.* (2014) *Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change*. Ipcc.

Park, S. E. *et al.* (2012) 'Informing adaptation responses to climate change through theories of transformation', *Global Environmental Change*. Elsevier, 22(1), pp. 115–126.

Pelling, M. (2011) 'Adaptation to climate change: from resilience to transformation Routledge', *Oxon, UK*.

Phillips, R. E. *et al.* (1980) 'No-tillage agriculture', *Science*. American Association for the

Advancement of Science, 208(4448), pp. 1108–1113.

Pimm, S. L. (1984) 'The complexity and stability of ecosystems', *Nature*. Nature Publishing Group, 307(5949), pp. 321–326.

Postel, S. *et al.* (2001) 'Drip irrigation for small farmers: A new initiative to alleviate hunger and poverty', *Water International*, 26(1), pp. 3–13. doi: 10.1080/02508060108686882.

Quinlan, A. E. *et al.* (2016) 'Measuring and assessing resilience: broadening understanding through multiple disciplinary perspectives', *Journal of Applied Ecology*. Wiley Online Library, 53(3), pp. 677–687.

Rapsomanikis, G. (2014) 'The economic lives of smallholder farmers; an analysis based on household surveys', *Rome: Food and Agriculture Organization*.

Redman, C. L. (2014) 'Should sustainability and resilience be combined or remain distinct pursuits?', *Ecology and Society*, 19(2). doi: 10.5751/ES-06390-190237.

Reed, M. S. *et al.* (2013) 'Combining analytical frameworks to assess livelihood vulnerability to climate change and analyse adaptation options', *Ecological Economics*. The Authors, 94, pp. 66–77. doi: 10.1016/j.ecolecon.2013.07.007.

Reed, M S *et al.* (2013) 'Combining analytical frameworks to assess livelihood vulnerability to climate change and analyse adaptation options', *Ecological Economics*. Elsevier, 94, pp. 66–77.

Revi, A. *et al.* (2014) 'Towards transformative adaptation in cities: the IPCC's Fifth Assessment', *Environment and Urbanization*. SAGE Publications Sage UK: London, England, 26(1), pp. 11–28.

Reyes, T., Quiroz, R. and Msikula, S. (2005) ‘Socio-economic comparison between traditional and improved cultivation methods in agroforestry systems, East Usambara Mountains, Tanzania’, *Environmental management*. Springer, 36(5), pp. 682–690.

Rigg, J., Salamanca, A. and Thompson, E. C. (2016) ‘The puzzle of East and Southeast Asia’s persistent smallholder’, *Journal of Rural Studies*. Elsevier Ltd, 43, pp. 118–133. doi: 10.1016/j.jrurstud.2015.11.003.

Rockström, J., Barron, J. and Fox, P. (2003) ‘Water productivity in rain-fed agriculture: challenges and opportunities for smallholder farmers in drought-prone tropical agroecosystems’, *Water productivity in agriculture: Limits and opportunities for improvement*. CABI International, Wallingford, UK, 85199(669), p. 8.

Roose, E. and Barthes, B. (2001) ‘Organic matter management for soil conservation and productivity restoration in Africa: a contribution from Francophone research’, in *Managing Organic Matter in Tropical Soils: Scope and Limitations*. Springer, pp. 159–170.

Rosenzweig, C. *et al.* (2001) ‘Implications for food production, plant diseases, and pests’, *Global Change and Human Health*, 2(2), pp. 90–104. doi: 10.1023/A:1015086831467.

Rosset, P. (2000) ‘The multiple functions and benefits of small farm agriculture in the context of global trade negotiations1’, *Development (Basingstoke)*, 43(2), pp. 77–82. doi: 10.1057/palgrave.development.1110149.

Rowley, J. (2002) ‘Using case studies in research’, *Management research news*. MCB UP Ltd, 25(1), pp. 16–27.

Salami, A. O., Kamara, A. and Brixiová, Z. (2010) *Working Paper 105-Smallholder Agriculture* *in East Africa: Trends, Constraints and Opportunities*.

Saldana, J. (2009) 'An introduction to codes and coding', *The coding manual for qualitative researchers*, 3.

Salinger, J., Sivakumar, M. V.K. and Motha, R. P. (2005) *Increasing climate variability and change: Reducing the vulnerability of agriculture and forestry*, *Increasing Climate Variability and Change: Reducing the Vulnerability of Agriculture and Forestry*. doi: 10.1007/1-4020-4166-7.

Salinger, J., Sivakumar, Mannava V K and Motha, R. P. (2005) *Increasing Climate Variability and Change: Reducing the vulnerability of agriculture and forestry*. Springer Science & Business Media.

Samberg, L. H. *et al.* (2016) 'Subnational distribution of average farm size and smallholder contributions to global food production', *Environmental Research Letters*. IOP Publishing, 11(12). doi: 10.1088/1748-9326/11/12/124010.

Samuel, M. P. and Satapathy, K. K. (2008) 'Concerted rainwater harvesting technologies suitable for hilly agro-ecosystems of Northeast India', *Current Science*. JSTOR, pp. 1130–1132.

Scholz, R. W. *et al.* (2006) 'Transdisciplinary case studies as a means of sustainability learning: Historical framework and theory', *International Journal of Sustainability in Higher Education*. Emerald Group Publishing Limited, 7(3), pp. 226–251.

Scoones, I. (2009) 'Livelihoods perspectives and rural development', *The journal of peasant studies*. Taylor & Francis, 36(1), pp. 171–196.

Seitz, J. and Nyangena, W. (2009) 'Economic impact of climate change in the East African community (EAC)', *Final Report, GTZ Project "Support to the Integration Process in the EAC Region. Arusha, Tanzania*.

Sen, A. (1981) 'Ingredients of famine analysis: availability and entitlements', *The quarterly journal of economics*. MIT Press, 96(3), pp. 433–464.

Sen, A. (1983) 'Development: Which way now?', *The economic journal*. JSTOR, 93(372), pp. 745–762.

Serdeczny, O. *et al.* (2017) 'Climate change impacts in Sub-Saharan Africa: from physical changes to their social repercussions', *Regional Environmental Change*, 17(6), pp. 1585–1600. doi: 10.1007/s10113-015-0910-2.

Serrat, O. (2017) 'The sustainable livelihoods approach', in *Knowledge solutions*. Springer, pp. 21–26.

Shackleton, S. *et al.* (2015) 'Why is socially-just climate change adaptation in sub-Saharan Africa so challenging? A review of barriers identified from empirical cases', *Wiley Interdisciplinary Reviews: Climate Change*. Wiley Online Library, 6(3), pp. 321–344.

Sheahan, M. and Barrett, C. B. (2014) *Understanding the agricultural input landscape in sub-Saharan Africa: Recent plot, household, and community-level evidence*. The World Bank.

Shetto, R. and Owenya, M. (2007) *Conservation agriculture as practised in Tanzania: Three case studies: Arumeru district, Karatu district, Mbeya district*. ACT, FAO, CIRAD, RELMA.

Silva, C. M., Sousa, V. and Carvalho, N. V. (2015) 'Evaluation of rainwater harvesting in Portugal: Application to single-family residences', *Resources, Conservation and Recycling*. Elsevier B.V., 94, pp. 21–34. doi: 10.1016/j.resconrec.2014.11.004.

Silva, J. A., Eriksen, S. and Ombe, Z. A. (2010) ‘Double exposure in Mozambique’s Limpopo River basin’, *Geographical Journal*. Wiley Online Library, 176(1), pp. 6–24.

Singh, R., Kundu, D. K. and Bandyopadhyay, K. K. (2010) ‘Enhancing agricultural productivity through enhanced water use efficiency’, *Journal of Agricultural Physics*, 10(2), pp. 1–15.

Sivakumar, M. V. K., Das, H. P. and Brunini, O. (2005) ‘Impacts of present and future climate variability and change on agriculture and forestry in the arid and semi-arid tropics’, in *Increasing climate variability and change*. Springer, pp. 31–72.

Sivakumar, M. V. K. and Motha, R. P. (2008) *Managing weather and climate risks in agriculture*. Springer Science & Business Media.

Smit, B. and Skinner, M. W. (2002) ‘Adaptation options in agriculture to climate change: A typology’, *Mitigation and Adaptation Strategies for Global Change*, 7(1), pp. 85–114. doi: 10.1023/A:1015862228270.

Smit, B. and Wandel, J. (2006) ‘Adaptation, adaptive capacity and vulnerability’, *Global environmental change*. Elsevier, 16(3), pp. 282–292.

Smith, D. M., Scaife, A. A. and Kirtman, B. P. (2012) ‘What is the current state of scientific knowledge with regard to seasonal and decadal forecasting?’, *Environmental Research Letters*, 7(1). doi: 10.1088/1748-9326/7/1/015602.

Smith, J. and Firth, J. (2011) ‘Qualitative data analysis: the framework approach’, *Nurse researcher*. RCN Publishing Company, 18(2), pp. 52–62.

Smucker, T. A. and Wisner, B. (2008) ‘Changing household responses to drought in Tharaka, Kenya: vulnerability, persistence and challenge’, *Disasters*. Wiley Online Library, 32(2), pp.

190–215.

Sneddon, C., Howarth, R. B. and Norgaard, R. B. (2006) 'Sustainable development in a post-Brundtland world', *Ecological Economics*, 57(2), pp. 253–268. doi: 10.1016/j.ecolecon.2005.04.013.

Soini, E. (2005) 'Land use change patterns and livelihood dynamics on the slopes of Mt. Kilimanjaro, Tanzania', *Agricultural systems*. Elsevier, 85(3), pp. 306–323.

Solarz, M. W. (2012) 'North–South, Commemorating the First Brandt Report: searching for the contemporary spatial picture of the global rift', *Third World Quarterly*. Taylor & Francis, 33(3), pp. 559–569.

Spaiser, V., Ranganathan, S., Swain, R.B. and Sumpter, D.J., 2017. The sustainable development oxymoron: quantifying and modelling the incompatibility of sustainable development goals. *International Journal of Sustainable Development & World Ecology*, *24*(6), pp.457-470.

Stewart, J. I. (1988) *Response farming in rainfed agriculture*. Foundation for World Hunger.

Tacoli, C. (2001) 'Urbanisation and migration in Sub-Saharan Africa: Changing patterns and trends', *Mobile Africa: Changing patterns of movement in Africa and beyond*. Brill Leiden, Boston, 141, p. 152.

Tambo, J. A. and Abdoulaye, T. (2013) 'Smallholder farmers' perceptions of and adaptations to climate change in the Nigerian savanna', *Regional Environmental Change*, 13(2), pp. 375–388. doi: 10.1007/s10113-012-0351-0.

Tanner, T. *et al.* (2015) 'Livelihood resilience in the face of climate change', *Nature Climate*

Change. Nature Publishing Group, 5(1), p. 23.

Taylor-Powell, E. and Renner, M. (2003) ‘Analyzing qualitative data’. University of Wisconsin--Extension, Cooperative Extension.

Teklehaimanot, A. and Mejia, P. (2008) ‘Malaria and poverty’, *Annals of the New York Academy of Sciences*. Wiley/Blackwell (10.1111), 1136(1), pp. 32–37.

Thierfelder, C. *et al.* (2015) ‘Conservation agriculture in Southern Africa: Advances in knowledge’, *Renewable Agriculture and Food Systems*. Cambridge University Press, 30(4), pp. 328–348.

Tugade, M. M., Fredrickson, B. L. and Feldman Barrett, L. (2004) ‘Psychological resilience and positive emotional granularity: Examining the benefits of positive emotions on coping and health’, *Journal of personality*. Wiley Online Library, 72(6), pp. 1161–1190.

Tuivavalagi, N. S., Hunter, D. J. and Amosa, F. (2001) ‘Tackling land degradation and unsustainable land use in Samoa–with emphasis on the Agriculture sector’, in *Environment Forum*, p. 40.

Turmel, M.-S. *et al.* (2015) ‘Crop residue management and soil health: A systems analysis’, *Agricultural Systems*. Elsevier, 134, pp. 6–16.

Turner, B. L. *et al.* (2003) ‘A framework for vulnerability analysis in sustainability science’, *Proceedings of the National Academy of Sciences of the United States of America*, 100(14), pp. 8074–8079. doi: 10.1073/pnas.1231335100.

Turner, Billie L *et al.* (2003) ‘A framework for vulnerability analysis in sustainability science’, *Proceedings of the national academy of sciences*. National Acad Sciences, 100(14), pp. 8074–

8079.

Turpie, J., Ngaga, Y. M. and Karanja, F. (2005) *Catchment ecosystems and downstream water: the value of water resources in the Pangani Basin, Tanzania*.

UN (1993) 'Agenda 21: Earth Summit–The United Nations Programme of Action from Rio'. New York: United Nations Reproduction.

Urwin, K. and Jordan, A. (2008) 'Does public policy support or undermine climate change adaptation? Exploring policy interplay across different scales of governance', *Global Environmental Change*, 18(1), pp. 180–191. doi: 10.1016/j.gloenvcha.2007.08.002.

Vale, L. J. and Campanella, T. J. (2005) *The resilient city: How modern cities recover from disaster*. Oxford University Press.

Vanlauwe, B. *et al.* (2010) 'Integrated soil fertility management: operational definition and consequences for implementation and dissemination', *Outlook on agriculture*. SAGE Publications Sage UK: London, England, 39(1), pp. 17–24.

Vanlauwe, B. *et al.* (2014) 'A fourth principle is required to define conservation agriculture in sub-Saharan Africa: the appropriate use of fertilizer to enhance crop productivity', *Field Crops Research*. Elsevier, 155, pp. 10–13.

Wambura, F. *et al.* (2014) 'Tanzania CMIP5 climate change projections'. Climate Change Impacts, Adaptation and Mitigation (CCIAM) Programme.

Webb, N. P. *et al.* (2017) 'Land degradation and climate change: building climate resilience in agriculture', *Frontiers in Ecology and the Environment*. Wiley Online Library, 15(8), pp. 450–459.

Wheeler, T. and Von Braun, J. (2013) ‘Climate change impacts on global food security’, *Science*. American Association for the Advancement of Science, 341(6145), pp. 508–513.

Whitfield, S., Challinor, A. J. and Rees, R. M. (2018) ‘Frontiers in climate smart food systems: outlining the research space’, *Frontiers in sustainable food systems*. Frontiers, 2, p. 2.

Williams, T. O. (1999) ‘Factors influencing manure application by farmers in semi-arid West Africa’, *Nutrient Cycling in Agroecosystems*. Springer, 55(1), pp. 15–22.

Wilson, G. A. (2014) ‘Community resilience: Path dependency, lock-in effects and transitional ruptures’, *Journal of Environmental Planning and Management*, 57(1), pp. 1–26. doi: 10.1080/09640568.2012.741519.

Witcher, C. S. G. (2010) ‘Negotiating transcription as a relative insider: Implications for rigor’, *International Journal of Qualitative Methods*. SAGE Publications Sage CA: Los Angeles, CA, 9(2), pp. 122–132.

Yazar, A. and Ali, A. (2016) ‘Water harvesting in dry environments’, in *Innovations in Dryland Agriculture*. Springer, pp. 49–98.

Yu, B., Fulginiti, L. E. and Perrin, R. K. (2002) *Agriculture Productivity in Sub-Saharan Africa*.

Zachariadis, M., Scott, S. and Barrett, M. (2013) ‘Methodological implications of critical realism for mixed-methods research’, *MIS quarterly*. JSTOR, pp. 855–879.

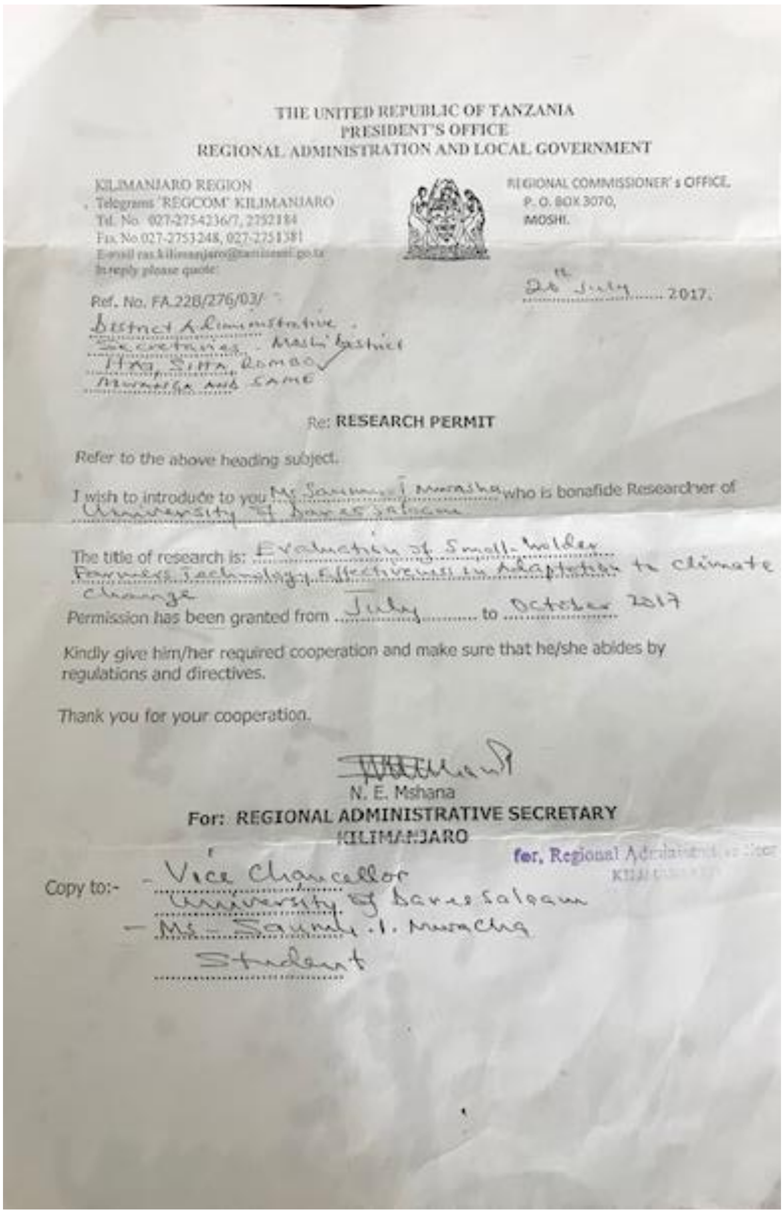
Zemedu, L. and Mesfin, W. (2014) ‘Smallholders’ vulnerability to food insecurity and coping strategies: In the face of climate change, East Hararghe, Ethiopia’, *Journal of Economics and sustainable development*. Citeseer, 5(24), pp. 86–99.

Zhang, W., Jiang, F. and Ou, J. (2011) ‘Global pesticide consumption and pollution: with China as a focus', *Proceedings of the International Academy of Ecology and Environmental Sciences*. International Academy of Ecology and Environmental Sciences (IAEES), 1(2), p. 125.

Zingore, S. and Johnston, A. (2013) 'The 4R nutrient stewardship in the context of smallholder agriculture in Africa', in *Agro-Ecological Intensification of Agricultural Systems in the African Highlands*. Routledge, pp. 97–104.

11 Appendices

Appendix A



THE UNITED REPUBLIC OF TANZANIA
PRESIDENT'S OFFICE
REGIONAL ADMINISTRATION AND LOCAL GOVERNMENT

KILIMANJARO REGION
Telegrams 'REGCOM' KILIMANJARO
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Fax No.027-2753248, 027-2751381
E-mail ras.kilimanjaro@tamisemi.go.tz
In reply please quote:

REGIONAL COMMISSIONER's OFFICE,
P. O. BOX 3070,
MOSHI.

26th July 2017.

Ref. No. FA.228/276/03/

District Administrative Secretaries - Moshi District, Hai, Siha, Rombo, Mwanga and Same

Re: **RESEARCH PERMIT**

Refer to the above heading subject.

I wish to introduce to you Ms Saumu I. Murasha who is bonafide Researcher of University of Dar es Salaam

The title of research is: Evaluation of Small-holder Farmers Technology Effectiveness in Adaptation to climate change

Permission has been granted from July to October 2017

Kindly give him/her required cooperation and make sure that he/she abides by regulations and directives.

Thank you for your cooperation.

N. E. Mshana
For: REGIONAL ADMINISTRATIVE SECRETARY
KILIMANJARO

for, Regional Administrative Secretary
KILIMANJARO

Copy to:- - Vice Chancellor
University of Dar es Salaam
- Ms. Saumu I. Muracha
Student

Appendix B

INTERVIEW GUIDE ON SUSTAINABLE LIVELIHOODS IN THE CONTEXT OF CLIMATE CHANGE

FOR FOCUS GROUP DISCUSSION PARTICIPANTS

Category: Women/household heads__________ Zone____________________

Date_________________

1. By responding to the following questions, you will help us understand agricultural activities and the cropping calendar in this area.
    I. Which months in a typical year in which rain start and cease?
    II. What are the important crops in this area?
    III. Who prepares the land and at what time in the calendar year?
    IV. Who weeds the crops and at what time in the calendar year?
    V. Who harvests the crops and what time in the calendar year?
    VI. Who dries the crops and at what time in the calendar year?
    VII. Who does the storage of the crops and what time in the calendar year?
    VIII. Who (in terms of gender) produces what crops?
    IX. How important is each crop to the livelihoods of the groups that produce?
    X. How is revenue from particular crops used?
    XI. Is there a 'hungry period'? and how long is it?
    XII. How variable is the length of the hungry period?
2. What other livelihoods strategies in this area and when do they take place in the calendar year.
3. What is historical calendar on:
    I. Livestock
    II. Soil fertility
    III. Trees cover
    IV. crop production
4. How temperature and Rainfall has changed over 30 years?
5. How temperature and rainfall is likely to change in the next 30 years?
6. Does climate change have any impact the livelihoods in Kilimanjaro region?
7. How will you overcome the impacts?
8. Given the trend of temperature and rainfall, and farmers' socioeconomic characteristics, what agricultural best management practices can be used to reduce impacts in agriculture?

THANK YOU FOR YOUR PARTICIPATION

Appendix C

INTERVIEW GUIDE ON SUSTAINABLE LIVELIHOODS IN THE CONTEXT OF CLIMATE CHANGE

FOR KEY INFORMANTS

Serial No.__________ Organisation__________________

Department/Unit/Division__________________ Date________________

1. Let us talk about your organisation and the role of this organisation

2. What factors affect the livelihoods of small-holder farmers in the Kilimanjaro region?

3. Are impact of climate change to small-holder farmers actually being seen in this area?

4. How is future climate change likely to affect the livelihoods in Kilimanjaro region?

5. Does climate change have any impact on performing your roles in Kilimanjaro Region?

6. How much is climate change a concern for the work of organisation?

7. How much attention is there on climate change in the planning of the work in your organisation?

8. What factors guide your organisation's decisions on priority areas of work and action (for example government policy? The farmers themselves?)

9. How do policies under your area address the problems related to your region?

10. What challenges facing your organisation especially in addressing problems related to climate change?

11. Is there any other issue related to climate change and livelihoods you would like to share?

THANK YOU FOR YOUR PARTICIPATION

Appendix D

INTERVIEW GUIDE ON CLIMATE CHANGE IMPACTS ON LIVELIHOODS AND PROPOSED METHODS FOR ADAPTATION

HOUSEHOLD

Household ID __________ Zone___________________

Date_________________

1. **Household characteristics**

Age of household head	Occupation of household head	No of above 15 in the household	Education of household head	Sex	Marital status

Introduction

1.We want to understand your life and the ways of making a living and how it has changed over time.

Let's talk about your assets.

a) Human capital

I. Has any member of the household moved away? If yes, why/for how long?

II. What is the health condition of the members of your household? Has this changed over time?

III. How does absence of members (if any) and prevalence of illness impact the ability of the household to make a living?

b) Natural capital

I. What is the source of water you use for your farming and any other ways you use to make a living that involve the use of water?
II. Are there any changes to access, availability or proximity to water? If yes, please expand on this.
III. Do these changes affect the ability of the household to make a living from water related income sources?

c) Household physical assets

- Let's talk about your house? bicycle? etc

I. How did you get them?
II. Has ownership and access to these assets changed over time? Why?
III. What do these changes in access mean for ability to of household to make a living?

d) Financial capital; -

- Let's talk about financial affairs
  I. Where do you get money to invest in your farm or other livelihoods activities? (access to formal credit or/and informal credits or/and savings ie in terms of cash or flow like livestock?)
  II. Have these sources or access to money changed over time? If yes expand.
  III. What do these changes in access mean for the ability of the household to make a living?
  IV. What strategies are being used to cope with impacts?
  V. Are these strategies have impacts to your ability to make a living and why?

e) Social capital

I. Under normal circumstances, what are the sources of support that households expect to be able to call on for assistance in hard times (clan members, family members, self-help groups, credit and saving groups, religious group, community leaders etc)
II. Under normal circumstances, what are the obligations of household to provide support for others? To whom would support be provides? How much and in what forms eg. Cash, food, labour and access to other resources?
III. Has these changed over time? How and why?
IV. What do these changes in access mean for the ability of the households to make a living?

2. We want to understand measures you use for enhancing land productivity.

I. What types of fertilizer do you use (None, organic, inorganic or both)?
II. What is the type of your maize seeds?
III. What is source of water for irrigation for your farming changed?
IV. Do you use pesticides (chemical and traditional?)

V. What soil management practices do you use to reduce erosion and sustain fertility?

VI. Do you have trees in your farm? Has amount changed over time?

2 Farmer's perceptions and future plan on using soil and water conservation measures

- **Please choose one answer in the questions below.**

I. In your opinion, the frequency of drought/rainfall variability has
   1. Increased
   2. Decreased
   3. No change

II. In your experience, is rainfall variability getting worse?
   1. No
   2. Somewhat
   3. Very much

III. If rainfall variability occurred sometime in the next 20 years, how severe would the impacts be?
   1. Mild
   2. Moderate
   3. Severe

IV. Is planting trees an effective way to cope with rainfall variability?
   1. Ineffective
   2. Somewhat effective
   3. Very effective
      1.

V. Please give reason for your answer.

VI. Is planting early maturing maize an effective way to cope with rainfall variability?
   1. Ineffective
   2. Somewhat effective
   3. Very effective

VII. Please give reasons for your answer

VIII. Is planting cassava and millet an effective way to cope with rainfall variability?
   1. Ineffective
   2. Somewhat effective
   3. Very effective

IX. Please give reasons for your answer

3. Please identify the most difficult problem facing livelihoods development for you to deal with in the following categories

- Crops sector

1. Lack of capital to buy inputs like pesticides, fertilizers, good seeds, land
2. Lack of labour
3. Low price of coffee
4. Extension services not available
5. Lack of preservatives or place of storage
6. Decreasing rainfall
7. Others-please specify
8. None of the above

- Livestock
  1. Diseases
  2. Medicines are expensive
  3. Not enough fodder and money to buy fodder and concentrates
  4. Veterinary services not available
  5. Others -please specify
  6. None of the above
- Off farm activities
  1. Lack of capital to start/expand or maintain business or an occupation
  2. Not enough customers to buy or give assignments
  3. Irregular prices and random taxation
  4. Lack of good infrastructure like good road leading to the market.
  5. Limited time to take care of the business
  6. Others
  7. None of the above
- Is there any other subsector important to your livelihoods? What is it and its associated challenges?

THANK YOU FOR YOUR PARTICIPATION

Appendix E

Keele University

Ref: ERP2326

10th May 2017

Saumu Ibrahim Mwasha
Geography, Geology and the Environment
47 The Covert
Keele University

Dear Saumu,

Re: Best management practices for climate change adaptation for small-holder farming in Kilimanjaro region, Tanzania

Thank you for submitting your revised application for review.

I am pleased to inform you that your application has been approved by the Ethics Review Panel. The following documents have been reviewed and approved by the panel as follows:

Document(s)	Version Number	Date
Research Themes	1	13-04-2017
Invitation Letter to Women to participate in Focus Group Discussion	2	26-02-2017
Information Sheet – Women Focus Group Participation	1	13-04-2017
Consent Form – Women Focus Group Discussion	2	13-04-2017
Invitation Letter – Key Informants	1	26-02-2017
Information Sheet for Key Informants	1	13-04-2017
Consent Form – Key Informants	1	13-04-2017
Invitation Letter – Household Heads Focus Group Discussion	4	13-04-2017
Information Sheet – Household Heads Focus Group Discussion	4	13-04-2017
Consent Form - Household Heads Focus Group Discussion	4	13-04-2017
Invitation Letter – Head of Households	3	13-04-2017
Information Sheet – Head of Households	3	13-04-2017
Consent Form – Household Heads	3	13-04-2017

If the fieldwork goes beyond the date stated in your application, 30th September 2017, or there are any other amendments to your study you must submit an 'application to amend study' form to the ERP administrator at research.governance@keele.ac.uk stating ERP2 in the subject line of the e-mail. This form is available via http://www.keele.ac.uk/researchsupport/researchethics/

Directorate of Engagement & Partnerships
T: +44(0)1782 734467

Keele University, Staffordshire ST5 5BG, UK
www.keele.ac.uk +44 (0)1782 732000

Appendix F

18/01/2018

Dear Saumu

PI: Saumu Mwasha
Title: Best management practices for climate change adaptation for small-holder farming in Kilimanjaro region, Tanzania
Ref: ERP2326

Thank you for your request to amend your study.

I am pleased to inform you that your request, submitted on 17th August 2017, has been approved by the Ethical Review Panel.

If the fieldwork goes beyond the date stated or there are any other amendments to your study you must submit an 'application to amend study' form to the ERP administrator at research.governance@keele.ac.uk stating **ERP2326** in the subject line of the e-mail. This form is available via http://www.keele.ac.uk/researchsupport/researchethics/

If you have any queries, please do not hesitate to contact me.

Yours sincerely
PP.

Dr Colin Rigby
Chair – Ethical Review Panel