



Smallholder Farming Systems in Kenya: Climate Change Perception, Adaptation and Determinants.

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Cover picture: Farmer walking through fallow field, Ngenia. Photo by Julia Stefanovic, 2015

*To my parents
and to the farmers of Laikipia*

Statement of Authorship

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Erklärung zur wissenschaftlichen Redlichkeit

(beinhaltet Erklärung zu Plagiat und Betrug)

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Statement of Independency

The field research for this study was sponsored and supported by Syngenta Foundation for Sustainable Agriculture. There was no interference of any staff members of Syngenta foundation regarding research design or interpretation of results.

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List of abbreviations

ASAL	Arid and semi arid lands
CCD	Consecutive dry days
GDP	Gross Domestic Product
IPCC	Inter-governmental panel of climate change
MAM	March, April, May (long rains)
OND	October, November, December (short rains)
PMT	Protection motivation theory
SSA	Sub-Saharan Africa

Summary

Climate change is expected to have a significant negative impact on agricultural productivity and food security in Sub-Saharan Africa. In Kenya, approximately 75% of the total agricultural output relies on rain-fed smallholder farming systems, which are particularly sensitive to climate change. Increasing adaptive capacity of systems by promoting technological and managerial farm adaptation measures has become a major focus of research, as well as politics. However, adaptation planners still face many challenges. More knowledge on climate change perceptions and determinants of adaptation are urgently needed.

Many studies focusing on adaptation in sub-Saharan Africa have used aggregated data and have focused on socio-economic variables. This study aims at contributing to a more system-specific understanding by basing its research on a farming systems approach and including cognitive factors as explanatory variables. It compares farmers from a food crop and a horticultural farming system regarding their climate change perception, applied adaptation measures and factors influencing adaptation. A mixed-method approach has been implemented based on a) a quantitative survey of 267 smallholder farmers in Laikipia County (Kenya) and b) the analysis of recorded temperature and precipitation trends. A binary logistic regression was conducted for single adaptation measures to identify determinants of adaptation. Explanatory variables included household variables and variables on risk perception, namely future risk expectations and perceived impacts from climate change.

Results indicated that the majority of farmers perceived a decrease in rainfall, an increase in temperature and a later onset of the rainy season. Farmers' perception of climate change matched well with recorded temperature data, while for precipitation statements were more variable and in some cases contradictory to measured climatic trends. Farmers' perceptions were influenced by local conditions and agricultural activities during the year.

The adaptation measures primarily employed by food crop farmers were aimed at reducing risk, e.g. mixed- and inter-cropping, using early maturing varieties and early planting. In contrast, horticultural farmers tended to focus more on intensifying crop production, and applied measures such as crop rotation, conservation tillage, irrigation and application of agro-chemicals and artificial fertilizer. Higher revenue from selling cash crops and better information access led to increased willingness and ability to invest in adaptation measures among horticultural farmers.

Factors positively influencing the willingness to employ adaptation measures included access to information and risk perception in the horticultural farming system, and access to human capital and farmers groups in the food crop farming system. While access to resources and financial capital were decisive in the low-income food crop farming system,

cognitive factors and knowledge of adaptation possibilities were important in the higher-income horticultural farming system. Furthermore, food crop farmers with access to less risk-prone income sources than agriculture seemed to have less motivation to adopt measures.

The results showed that, even if located in the same area, different smallholder farming systems were confronted with different challenges and adaptation opportunities.

I. Introduction

The first chapter introduces the reader to the addressed research problem and its context. Current issues discussed in literature regarding climate change adaptation and perception are presented (section 1). Then, research questions and the research design are outlined (section 2). In addition, the reader is introduced to the case study context with more detailed information about climatic and agricultural developments in the Republic of Kenya (section 3). Lastly, a description of the case study area and of the study sites is given (section 4).

1. Problem statement

Approximately 80% of agriculture in sub-Saharan Africa is managed by families cultivating less than 10 hectares of land, which makes smallholder production the backbone of agriculture in sub-Saharan Africa (FAO, 2012). Food supply and the livelihood of billions of people depend largely on the productivity of these systems (FAO, 2012). Although smallholder farming systems have proven to be resilient and viable in risk-prone environments, climate change is likely to outpace their current coping capabilities (Morton, 2007). Low levels of income and technology, coupled with isolation from markets and lack of institutional support are common characteristics of smallholder farming systems that make them particularly vulnerable to changes in external conditions (Morton, 2007). Low-income producers often do not have the means to invest in adaptive technologies and strategies under increasing climatic risks (Vermeulen et al., 2012). However, confronted with unprecedented risks and uncertainties, the need to incorporate new information and technologies into the traditional farming systems becomes imperative (Steenwerth et al., 2014). Taking no action means jeopardizing the efforts of the past decades to improve livelihoods and reduce the number of undernourished people (Niang et al., 2014; Wheeler and von Braun, 2013).

Adaptation to climate change has become a topic of major importance in the scientific and political discourse during the past two decades (Niang et al., 2014). The link between climate, farm productivity and food security is widely recognized (Wheeler and von Braun, 2013). Thus, adapting farming systems to climate change is crucial to maintaining food security for the growing world population. Lack of financial and institutional resources, as well as the smallholder farmers' aversion to take risks, are only a few of the barriers encountered by adaptation planners when developing strategies to enhance adaptive capacity of smallholder farming systems. There is need for more sustainable adaptation strategies to maintain rural livelihoods, increase yields and use natural resources efficiently in order to ensure food security under a changing climate (Bryan et al., 2013; Wheeler and von Braun, 2013).

1.1. Adaptation of smallholder farmers in sub-Saharan Africa

Smallholder farmers in sub-Saharan Africa have historically been confronted with high climate variability. They have developed livelihood strategies to cope with and/or adapt to the harsh conditions (Below et al., 2010; Morton, 2007). The process of adaptation is dynamic, complex and covers every temporal and spatial scale (Below et al., 2010). The range spreads from individual planting decisions of smallholder farmers (micro-level) to long-term strategic decisions made by regional or national governments (macro-level). Both levels are strongly inter-related. Local adaptation decisions are constrained and facilitated by larger scale institutional and governance factors (Eakin et al., 2014; Yohe and Tol, 2002).

Adaptation is an evolutionary process. Livelihood strategies are initially developed, as a result of catastrophic events that farmers need to cope with (“coping”) (Morton, 2007). Gradually, some of these strategies become inherent properties of the farming system and reduce overall vulnerability to climate variability (“adaptation”) (Morton, 2007). Given the fact that adaptation is an iterative process, the boundary between coping and adaptation is often blurred (Morton, 2007).

Furthermore, adaptation rarely evolves in response to one risk alone but to a complex mixture of climatic, socio-economic and political factors and risks (Smit and Skinner, 2002).

The most commonly reported adaptation measures of smallholder farmers to climate change in sub-Saharan Africa are changing crop varieties, changes in planting dates, irrigation, soil conservation measures, tree planting, water harvesting and changing crop types (Bryan et al., 2013, 2009; Deressa et al., 2009; Ofuoku, 2013; Thomas et al., 2007). Generally, these measures aim to protect plants from being exposed to dry periods during critical growth stages (Comoé, 2015). The smallholder farmers in sub-Saharan Africa tend to apply marginal, rather than transformational, changes to the farming system (Kristjanson et al., 2012). Simple measures, such as changing planting dates, are frequently implemented, while changes of water or land management practices, such as introducing an irrigation system or agroforestry, are underutilized (Bryan et al., 2013; Kristjanson et al., 2012). For example, Herrero et al. (2014) have found that as the socio-economic context changes and land size and labor costs further decrease, diversification with cash crops can be a key intensification strategy for smallholders. Cultivating high value crops in mixed farming-systems might enable farmers to explore high market prices during dry seasons, increase their income and lead to a higher adaptive capacity during droughts (Bryan et al., 2009; Ngigi et al., 2005; Waha et al., 2013). However, such strategies are limited to areas with sufficient water access as well as access to irrigation systems (Claessens et al., 2012). In this sense, spatial heterogeneity of adaptive measures is quite large among different countries, regions, systems and groups. This undermines the importance of considering local level factors when conducting research on adaptation and/or developing adaptation interventions (Below et al., 2014; Deressa et al., 2009; Ogalleh et al., 2012).

Due to the complex interdependencies within the smallholder adaptation context, it is difficult to identify and assess the potential constraining and facilitating factors of climate change adaptation in general and of single adaptive strategies in particular. Studies for sub-Saharan Africa that attempt to do so can be classified into two groups: one emphasizing the influence of available resources on adaptive decision making, the other stressing the influence of farmers' risk perception on adaptive decision making.

Regarding the first group, the argument states that available resources trigger or restrict adaptation actions¹. These available resources include access to credit, household income, access to extension services, participation in local institutions, access to weather information, input and output market access, access to fertile land, household size, tenure rights and access to diversified sources of income (Below et al., 2012; Bryan et al., 2013, 2009; Deressa et al., 2009; Hassan et al., 2008). Personal characteristics such as age, gender, farming experience and education have also been found to influence the adoption of certain adaptation practices (Below et al., 2014; Deressa et al., 2009). Influential factors differ between geographical and socio-economic contexts (Deressa et al., 2009; Bryan et al., 2013).

Regarding the second group, the argument states that the farmer's ability to accurately perceive the level of risk of a given stressor is a highly influential factor on adaptive behaviour (Comoé et al., 2014; Marshall et al., 2013; Patt and Schroter, 2008). Studies from South Africa, Kenya and Uganda report that many farmers perceive climatic changes, such as changes in the onset and cessation of rainy seasons, increased rainfall variability, decreasing rainfall and increasing temperatures (Ogalleh et al., 2012; Osbahr et al., 2011; Simelton et al., 2013). Ogalleh et al. (2012) reported that there are significant relationships between drought perception and some adaptation measures, such as migration or sale of livestock.

Only a few studies have attempted to integrate both perspectives, e.g. awareness of risk and availability of resources, to determine drivers or barriers of adaptation in sub-Saharan Africa. Results indicate that the relative importance of cognitive and resource factors depends on the regions, income level and particular adaptation measure addressed (Bryan et al., 2009; Bryan et al., 2013; Deressa et al., 2009).

1.2. Cognitive factors and climate change adaptation

Farmers' perceptions of rainfall and temperature influence farm management decisions (Rao et al., 2011). Which crop variety to grow, on how much land, what inputs to use and what soil and water management strategies to adopt depends on the farmer's expectations of rainfall amount and distribution during the season (Rao et al., 2011). Farmers make these decisions based on their knowledge and experiences from previous years (Rao et al., 2011).

¹ Adaptation actions, adaptation strategies and adaptation measures are used as synonyms in this thesis.

Thus, understanding farmers' interpretation of climate is crucial for explaining the adoption of agricultural practices. Investigation of local climate knowledge has shown that farmers are aware of climate change and that their views match in most cases to historical climate data (Ndaki, 2014; Ofuoku, 2013; Ogalleh et al., 2012). This is especially true for many rainfall parameters (Thomas et al., 2007). For example, smallholder farmers in Uganda and Kenya are adept at recognizing climatic factors related to variability and extreme events but are less adept at recognizing factors related to long-term trends (Rao, 2011; Osbahr, 2011).

Furthermore, farmers' perceptions are likely to be influenced by the agro-economic performance of crops and other enterprises that affect their livelihood (Rao et al., 2011). Crop productivity depends not only on climate but also on the success of farm management, soil fertility and market developments (Rao et al., 2011). Thus, farmers' behavior is a reaction to a complex mixture of environmental and socio-economic factors (Mertz et al., 2009; Osbahr et al., 2011). Considerable ambiguity remains regarding the direct reaction of farmers to climate related factors. For example, Mubaya et al. (2012) found that farmers might have difficulties untangling the contribution of different economic and climatic factors to observed outcomes, especially when confronted with a wide complexity of challenges to deal with. Thus, one needs to distinguish between real exposure to climate change and factors related to crop productivity, if adaptation actions are to be explained (Simelton et al., 2013).

Understanding farmers' interpretation of climate is also relevant for the purpose of making meteorological projections accessible and understandable for smallholder farmers. Recently improved meteorological forecasts could be of use to smallholder farmers in terms of strategic planning for upcoming seasons. However, climate needs to be described in terms of events of direct relevance to farmers, such as onset and cessation of rainy season, rather than in simple standard measures, such as annual total rainfall (Coe and Stern, 2011). If communicated in the right way such information could foster adaptation in the farming community.

1.3. Research gap

Explaining climate change perception as it relates to adaptive behavior at the individual farm level is rarely addressed in scientific literature. Often, studies use aggregated data from country or regional levels to assess impacts of climate change and applied adaptation strategies (Bryan et al., 2013, 2009; Wood et al., 2014). The aim is to create generalizable information, which is useful for adaptation planners to foster widespread application of improved agricultural practices. However, results from these studies are highly aggregated, and assessed parameters have little relevance for adaptation planners or farmers at the local level. At the same time, there is a significant body of literature focussing on impacts of climate change on individual crops at field scale (Rurinda et al., 2014; Thornton et al., 2010).

This approach provides useful information for farm management decisions in light of crop-specific biophysical and environmental conditions. However, not enough attention is given to considering socio-economic and cognitive factors that might constrain the realization of the suggested strategies. Information at the micro-level is urgently needed in order to enable policy makers and extension officers to adapt national strategies to local circumstances and promote targeted interventions. In this sense, farming systems research could provide a useful entry point to tackle this issue (Giller et al., 2011). Adaptation research at farming system level considers the complex interactions between biophysical factors, farm management decisions and conditions of the socio-economic context. Specifically, comparative studies of farming systems could improve system-specific information and enable prioritized and targeted investments.

Secondly, while research on climate change adaptation of individuals in industrialized countries has dedicated much attention to psychological factors, determinants of adaptation in developing countries have often been ascribed to socio-economic and environmental variables (Deressa et al., 2009; Ghetibouo, 2009). Cognitive factors have received little attention (Le Dang et al., 2013). In sub-Saharan Africa in particular, the linkage between risk perception, socio-economic constraints and adaptation action has not been adequately explored. Understanding the farmers' decision-making process is important to predict future behavior and appreciate the factors influencing the process (Le Dang et al., 2013).

2. Research goals and design

Given the limited knowledge on climate change perception, adaptation and determinants at farm level, this thesis aims to compare climate change perception and adaptation efforts of two farming systems located in a semi-arid region in Kenya. The chosen farming systems include a food crop and a horticultural farming system, which are both frequently encountered in the study region. Main goals of the thesis are first, to describe farmers' perception of climate change and adaptation measures they have, and secondly, to contribute to the understanding of determinants on a number of adaptation measures, including cognitive factors.

2.1. Research questions

The following goals and research questions have been formulated:

<p>Goal 1: Assess farmers' perception of climate change and compare between food crop and horticultural farmers.</p>

The first goal aims at describing if and what aspects of climate have changed over the past few years according to the perceptions of smallholder farmers. Risk perception is a compelling precondition for adaptation and indispensable to understand and describe climate change adaptation. Therefore, the first research question addresses this issue:

Research question 1: What climate changes are perceived by smallholder farmers?

Since smallholder farmers' perception is described as highly dependent on experiences with crop production it seems justified comparing perception between farming systems.

Research question 2: How does climate change perception differ between farmers growing mainly food crops and horticultural farmers?

Meteorological data could contribute to the understanding of climate change perception. Comparing farmers' perception with measured meteorological data facilitates interpretation of farmers' perceptions. Secondly, a description of climatic trends will give insights into characteristics of the main stressor an farming system is exposed to. This will lead to a better understanding of the study region. Therefore, the third research question reads as follows:

Research question 3: How well do perceived climatic changes correspond to recorded climatic developments?

Goal 2: Comparison of climate change adaptation strategies between food crop and horticultural farmers.

Since farming systems addressed in this study are assumed to exhibit very different characteristics and adaptation preconditions, the second goal aims at comparing adaptation measures between them. The fourth question aims at identifying strategies applied by smallholder farmers to address climatic threats to agricultural production and livelihoods.

Research question 4: What climate change adaptation strategies do the food crop and the horticultural farming systems exhibit?

Goal 3: Assessing factors that influence the adoption of adaptation measures in the food crop and horticultural farming system separately.

The third goal is to identify determinants of adaptation based on the farmers personal characteristics and characteristics of the farming system in general. Determinants of adaptation strategies will be assessed for both systems separately and only for a definite

number of adaptation measures. This generally formulated research question will be split up in different hypotheses (see Chapter II, Section 7).

Research question 5: Which factors influence the adoption of adaptation measures in the food crops and the horticultural farming system?

2.2. Research design

The study is conducted using an interdisciplinary approach. It combines data and methods from the social sciences and meteorology/climatology. A quantitative approach has been chosen to assess and evaluate data from the social science category. This is a common approach for comparative studies because it enables an objective comparison of different population samples (Beckers et al., 2010). Secondly, quantitative data enables verifying the influence of hypothesized factors on a dependent variable, in this case adaptation (Bird, 2009). During the household survey climate change perception, as well as the dependent variables (e.g. adaptation strategies) and independent variables (e.g. risk perception, available resources, personal and farming system characteristics) were assessed.

Meteorological data included measured temperature and precipitation data from two meteorological stations located in the study area. The data was used to describe climatic trends the region is exposed to.

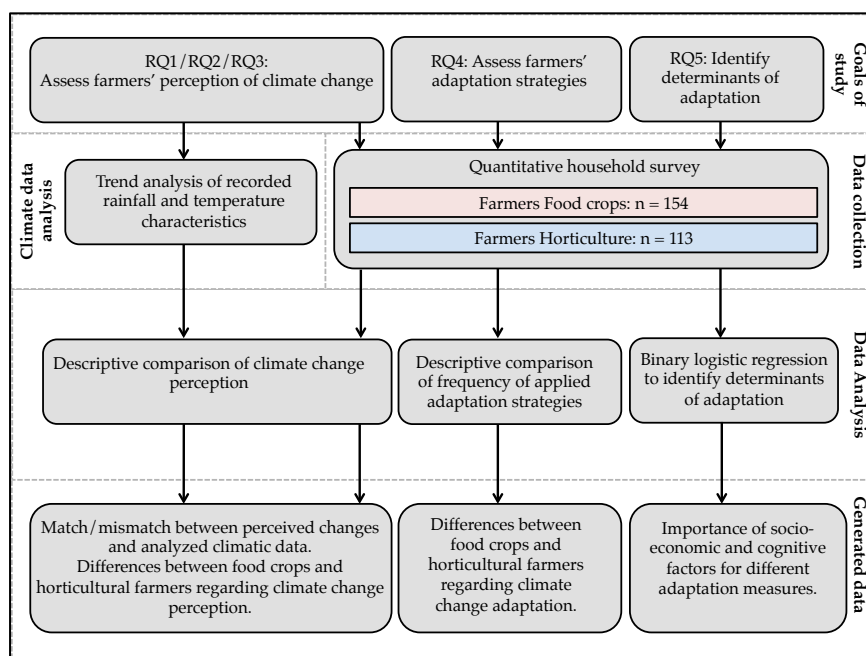


Fig. I-1: Research design.

The analysis included a comparison of meteorological trends with farmers' perception of climate change and a comparison of perception between farming systems. Applied adaptation measures were compared between both farming systems. Finally, a binary

logistic regression analysis was used to test hypothesized determinants of adaptation on specific adaptation measures. For a summary of the research design see Fig. I-1.

2.3. Contribution

The results of this thesis will give insights into differences between farming systems regarding their climate change perception and climate change adaptation. Information about drivers and barriers of adaptation in different farming systems is useful information for adaptation planners - e.g. extension officers from private or governmental institutions - in order to target intervention programs better to specific farming systems. Furthermore, the study aims at enhancing the understanding of climate change perception and cognitive factors for smallholder adaptation, which is still an under-researched topic.

3. The Kenyan context

3.1. Climatic conditions, recent trends and projections

Kenya's climatic conditions vary greatly from the humid zone along the coast to the arid and semi arid inlands that make up approximately 80% of the country (Herrero et al., 2010). The precipitation pattern is bimodal with the long rainy season lasting from March to May and the short rainy season from October to December. During the past decades the country has experienced minor drought events every 3-4 years and major droughts every decade (Herrero et al., 2010).

Recent climate change has led to a noticeable increase of extreme events (GoK, 2013). Both drought and floodings alternate from year to year – particularly in ASAL regions (GoK, 2013). General temperature trends include temperature rising over land (Central Kenya: 0.7–1.0°C increase for maximum daily temperatures) and increased extreme minimum temperatures over the ASAL regions (GoK, 2013). Precipitation trends show mixed signals, with increasing trends in some locations but with no significant trends for the majority of stations (GoK, 2013). Furthermore, shifts in the onset or cessation of both the long and short rainy season are recorded in some places making rainfall more irregular and unpredictable (GoK, 2013).

Climate change projections are very heterogeneous for Eastern Africa, specifically for Kenya. Temperatures in Africa are expected to increase by 3-4°C by the end of the 21st century (Herrero et al., 2010). Precipitation projections have a higher spatial variability. For the highlands in Northern Kenya an increase is suggested by approximately 0.2 to 0.4% per year (Herrero et al., 2010). However, an increase of rainfall doesn't necessarily lead to an increase in agricultural production, as temperature rising might have a significantly negative impact on water availability by increasing evapotranspiration and exacerbating drought conditions

(Herrero et al., 2010). Furthermore, higher variability in timing and spacing of precipitation might exacerbate agricultural production. Heavy precipitation events (rainfall events that occur once every 10 years) are projected to increase all over Eastern Africa and might damage crop production (Herrero et al., 2010).

3.2. Macro-level: developments and adaptation of the Kenyan agricultural sector

The Republic of Kenya is expected to be strongly affected by climate change, despite its economic power compared to other East African countries (Herrero et al., 2010; Hickey et al., 2012). The country's economy is highly dependent on climate sensitive sectors including agriculture, tourism, and energy (Mutai et al., 2011). Agriculture accounts for 24% of the country's GDP and 65% of Kenya's total exports in 2009 (GoK, 2009). While Kenya already experiences an increase in rainfall variability, 75% of the agricultural output remains dependent on rain-fed small-scale agriculture (Herrero et al., 2010).

Kenya's agriculture can be divided into six subsectors of which *horticulture* is the largest and most export-driven sector. The *food crops* sector includes staple crop production and is of major importance to satisfy the country's nutritional requirements (GoK, 2009). 70–80% of maize is produced by smallholder farmers that produce mainly for subsistence (Tongruksawattana, 2013). However, the production of maize, wheat and rice has generally been below the country's consumption requirements and Kenya has been relying on import and food aid for maize since the year 2000 (GoK, 2009; Herrero et al., 2010). Climate change is expected to worsen the situation. Although maize production has increased between the years 2002 and 2006, the sector is currently struggling with high input costs, poor and long marketing chains, low levels of mechanization but also negative effects of extreme events and pests and diseases (GoK, 2009).

In contrast, the cultivation of horticultural crops has undergone a dramatic increase between 2002 and 2006 and an increase of export value by 16% over the same period of time. The increase can be attributed to industrialized large-scale production (GoK, 2009). However, the prosperous development of the horticultural sector has also motivated small-scale farmers to invest in vegetable, fruit and flower farming. Where geographical conditions allow for it and smallholder farmers possess the necessary means, horticulture has become a popular diversification strategy and led to increased up-take of irrigation schemes (Herrero et al., 2014; Kulecho and Weatherhead, 2006). Between 2007 and 2009 horticultural production declined mainly due to political instability (GoK, 2009). Furthermore, insufficient rains in 2009 led to a decrease of horticultural export volume of 15% (GoK, 2009). For a summary of the major characteristics for both the food crop and horticultural farming system see Table I-1.

In the *Climate Change Adaptation Strategy 2009 – 2030* the Government of Kenya recognizes that adaptation to climate change is the main priority of the country. In particular

adaptation of the agricultural sector plays a key role when it comes to national food security (GoK, 2013). A number of strategies, policies and governmental bodies have been launched in order to sustain the recent positive agricultural growth, protect national economy and rural livelihoods (examples are the *Agricultural Sector Development Strategy 2009 – 2020*, the *National Drought Management Authority (NDMA)* in 2011 and the *National Climate Change Response Strategy (NCCRS)*). Special attention is given to drought impacts in arid and semi-arid lands (ASAL), which are highly vulnerable to climate change impacts and host 30% of the country's population (GoK, 2013). On-going adaptation programs include the promotion of irrigated and conservation agriculture, value addition to agricultural products, developing weather indexed crop insurance schemes and support for community-based adaptation (GoK, 2013). By 2030 Kenya's agriculture shall be transformed "into a profitable, commercially oriented and internationally and regionally competitive economic activity that provides high quality gainful employment to Kenyans" (GoK, 2009).

Although these strategies exist on paper, the benefits have not yet reached the majority of smallholder farmers in Kenya. Many of these national strategies have been criticized for being unable to incorporate already existing knowledge and technologies at local level (Ogalleh et al., 2012). Appropriate institutional frame conditions are still absent in many parts of the country, leaving resource poor smallholder farmers alone with their struggle against climatic and economic challenges. Existing projects either lack continuity, fall victim to corruption or do benefit only a few already privileged people. The number of Kenyans requiring food assistance rose from 650,000 in 2007 to almost 3.8 million in the drought period during 2009/2010 (GoK, 2013).

Table I-1: Characteristics of the food crop and horticultural farming system (Source: GoK, 2009; Claessens et al., 2012).

	Food crops	Horticulture
Major crops	Cereals (maize, wheat, sorghum, rice, millet); pulses (beans, peas, green grams); roots and tubers (sweet potatoes, irish potatoes, cassava, arrow roots, yam)	Cut-flowers, vegetables, fruits, nuts, herbs and spices
Significance for national economy	32% of GDP; 0.5% of exports	33% of GDP; 38% of exports (mostly from industrialized production)
Significance for small-holder agriculture	Basic staple food; traditionally grown by smallholder farmers; mostly rain-fed; low fertilizer input, mixed maize-bean systems	Increasingly adopted by smallholders, where conditions are favorable; demands irrigation and leads to higher returns (cash crops).

3.3. Micro-level: developments and adaptation of smallholder farming systems

Smallholder farming systems in Kenya are very heterogeneous. Depending on the area smallholder systems are often of semi-subsistence nature with mixed crop-livestock production (Claessens et al., 2012). Furthermore, on-farm diversification by cultivating

several crops at the same time is a common strategy to reduce climatic induced risks, which leads to a high diversity among smallholder farming systems even in small areas (Ogalleh et al., 2012). In general, yields are below potential and crop failure is a common phenomenon (Claessens et al., 2012). Farmers have limited access to fertilizer due to its high price and usually apply it only on plots with low risk of crop failure (Claessens et al., 2012). Access to clean chemicals, as well as good quality and certified seeds is limited due to missing quality control mechanisms (Bryan et al., 2013). Where water is available irrigation enables the growth of higher value crops, such as vegetables (kales, cabbages, tomatoes). Irrigation also profits rain-fed staple crops such as maize and common beans (Claessens et al., 2012).

Climate change is perceived as a threat to agricultural productivity by smallholders in most parts of Kenya (Bryan et al., 2013; Tongruksawattana, 2013). However, lack of resources, limited water access and not enough information pose major barriers to the adoption of more costly adjustments in farming practice (Bryan et al., 2013). In many of the poorer households replanting, selling assets, reducing consumption and borrowing assets are common strategies to cope with consequences from drought, floods and impacts from pests and diseases (Tongruksawattana, 2013). Adaptation measures often include simple measures, such as changes of planting dates, mixed cropping, migration and sale of livestock (Ogalleh et al., 2012).

Livelihood strategies in the Kenyan rural society have been shaped by a changing socio-economic context during the past two decades, with market liberalization during the 1990s leading to major changes in market conditions for smallholder farmers (Kimenju et al., 2009). Since then, livelihood diversification but also specialization has taken place (Kimenju et al., 2009). Diversification includes farmers improving their income with various non-agricultural business activities, such as charcoal production or seeking casual employment on other farms and near towns and cities. Furthermore, in financially critical periods smallholder farmers often rely on income from children or other relatives. Regarding food crops, on-farm diversification by mixed planting of maize with common beans or pigeon peas is a recently promoted agricultural strategy in order to minimize impacts from low and irregular rainfall (Tongruksawattana, 2013). Agricultural specialization and transformation is still in its infancy in Kenya (Kimenju et al., 2009). Exceptions occur in areas with sufficient water access or access to irrigation systems, for example on the foothills of Mount Kenya, where the cultivation of higher value crops becomes an increasingly popular adaptation strategy (Claessens et al., 2012).

4. Study sites

4.1. Laikipia County

Laikipia County ($0^{\circ}18''$ - $0^{\circ}51''$ Latitude and $16^{\circ}11''$ - $37^{\circ}24''$ Longitude) is a Rift Valley province located in central Kenya on the equator (GoL, 2013) (see Fig. I-2). It covers an area of $9'462 \text{ Km}^2$ with an altitude between 1500m and 2611m above sea level (GoL, 2013). The major part of Laikipia consists of a plateau bordered by the Great Rift Valley to the West, the Aberdare Mountain Range to the South and Mt. Kenya massifs to the Southeast all of which have an influence on the climatic conditions and provide important water sources (GoL, 2013). The Ewaso Nyiro North Basin is the dominant watershed in the region and includes all major rivers, on which most human and animal water consumption as well as irrigation activities depend (GoL, 2013). Due to its heterogeneous topography, climatic conditions are heterogeneously distributed in Laikipia County. Annual average rainfall is highest on the slopes of Mount Kenya and the Aberdare Mountain ranges, while the rest of the County experiences between 400 and 700 mm of annual average rainfall (GoL, 2013). The rainfall pattern is bi-modal, with the long rainy season lasting from March to May and the short rainy season from October to December (GoL, 2013). Some parts experience so called continental rains between August and September (Ulrich et al., 2012). The annual mean temperature of the county ranges between 16°C and 26°C (GoL, 2013).

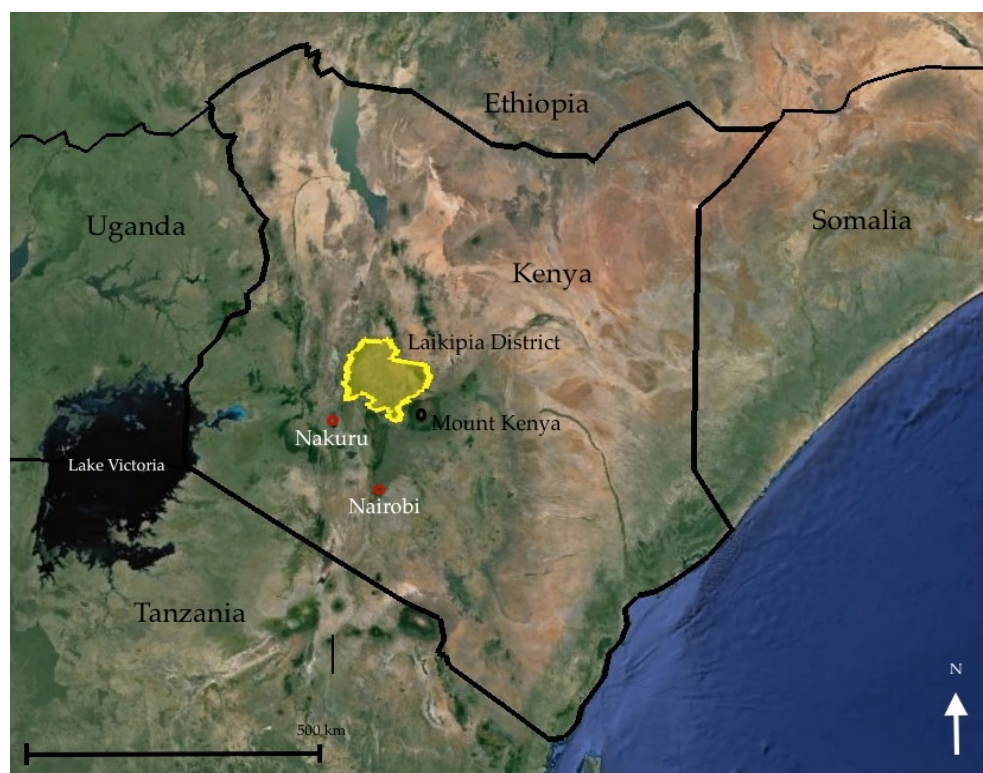


Fig. I-2: Location of Laikipia County. Source: GoogleEarth

Analysis of climatic trends during the past decades has shown that total rain failures during rainy seasons has increased and that major river systems indicate a declining runoff (Ulrich et al., 2012). Thus, the most limiting factor for agricultural production is high rainfall variability and unpredictability of onset, duration and cessation of rainy seasons (Ulrich et al., 2012). 79.5% of the counties area is classified as unsuitable for farming (GoL, 2013). Laikipia County can be described as a typical tropical highland-lowland system. Smallholder crop production mostly takes place in Southern parts of Laikipia on the semi-humid foothills of Mount Kenya and the semi-arid parts of Laikipia Plateau. Towards the arid North pastoralism becomes the predominant livelihood strategy.

4.2. Smallholder farming systems in Laikipia County

Laikipia County has experienced extreme population growth since independence in 1963 (Kiteme et al., 2008). Settlers mainly from the Kikuyu and Meru Ethnic Group have immigrated during the 1960's and 1970's and transformed the land from large-scale ranching to small-scale mixed agriculture (Wiesmann, 1998). Nowadays, livelihoods are primarily based on crop production and livestock keeping with land-holdings typically around 1.2 ha to 2.4 ha (Ulrich et al., 2012). However, population growth has increased pressure on the limited natural resources in the area, such as rivers and land, which impedes agricultural growth and keeps smallholder farmers caught in the poverty trap (Ulrich et al., 2012). Indeed, the limited resource potential of the area and the persisting low resource asset base of households were found to leave farmers with no other option but to seek off-farm employment (Ulrich et al., 2012). Livelihood diversification is thus a widely spread strategy to cope with failed seasons and improve income and nutritional security (Ulrich et al., 2012). Typically grown crops are maize, beans and potatoes, which all belong to Kenya's most important staple crops. However, during the last two decades a number of farmers have started to expand their farms and add horticultural products, thereby improving their income (Ogalleh et al., 2012; Ulrich et al., 2012). Furthermore, smallholder farmers try to compensate for the absence of governmental support with community participation, mainly to improve access to credit financing (Ulrich et al., 2012). The last drought event has occurred during the year 2014. During this event, Laikipia County has experienced declining water resources, drying up of crops and destruction of harvest by parasites, human-wildlife conflicts and malnutrition of children (NDMA, 2014).

4.3. Survey sites

The survey was conducted with farmers from eight different Sub-locations that represent areas suitable for agricultural production within Laikipia County (see Fig. I-7). Samples were taken from each of the indicated yellow polygons. Each of the sampling sites can be assigned to one of Laikipias three constituencies, Laikipia East, Laikipia West or Laikipia North.

Ngenia/Nyariginu Sub-location (Laikipia East): Study sites 1 & 2 are located approximately 15 – 30 km East of Nanyuki towards Meru County on an altitude above 2000 m a.s.l. and in the semi-humid to semi-arid zone (Fig. I-3). The area experiences a tri-modal rain pattern (long rains, short rains and continental rains) and is densely populated (Schäfer, 2009). Land use consists mainly of crop cultivation and to a lesser extent of animal husbandry.

Matanya/Lamuria Sub-location (Laikipia East): Study sites 3 & 4 are located approximately 20 km West of Nanyuki in the semi-arid highland plateau (Schäfer, 2009). A very dry climate and only few seasonal rivers characterize the area. Main agricultural activities include crop cultivation and animal husbandry. Large unsettled parts can be found, which are also used for uncontrolled grazing (Schäfer 2012) (see Fig. I-).

Ngobit Location (Laikipia East): Study site 5 is a remote area located about 35 km southwest of Nanyuki and is a geographically diverse area. It consists on one side mainly of a river valley, that allows for vegetable farming and on the other side it has a drier area, where maize production is dominating (see Fig. I-6).



Fig. I-3: Sub-location Ngenia: Farmer discussing with a research team member in his field. Own picture (14.05.2015)



Fig. I-4: Sub-location Matanya: Homestead with neighboring field (mixed maize, beans and tomatoes) Own picture (20.05.2015)

Segera Sub-location (Laikipia East/North): Situated on the boarder to Laikipia North study site 6 is a flat area and consists mainly of plain grassland, which is used by pastoralists. A seasonal river enables horticultural production. However, land-use conflicts between

farmers and nomads, as well as bad road conditions to Nanyuki exacerbate successful agricultural production.

Kinamba & Melwa Sub-location (Laikipia West): Study sites 7 and 8 are located approximately 80–100 km west of Nanyuki. The area is known for having many water dams built during colonial times. It is characterized by a semi-arid climate. Often, monocultivation of maize on large field is encountered. (see Fig. I-).



Fig. I-5: Laikipia West: Large maize field. Own picture (23.05.2015)



Fig. I-6: Location Ngobit: River valley with cabbage field in the background. Own picture (21.05.2015).

Lastly, temperature and precipitation data from two meteorological stations located in the Southeast of Laikipia were obtained for climate analysis.

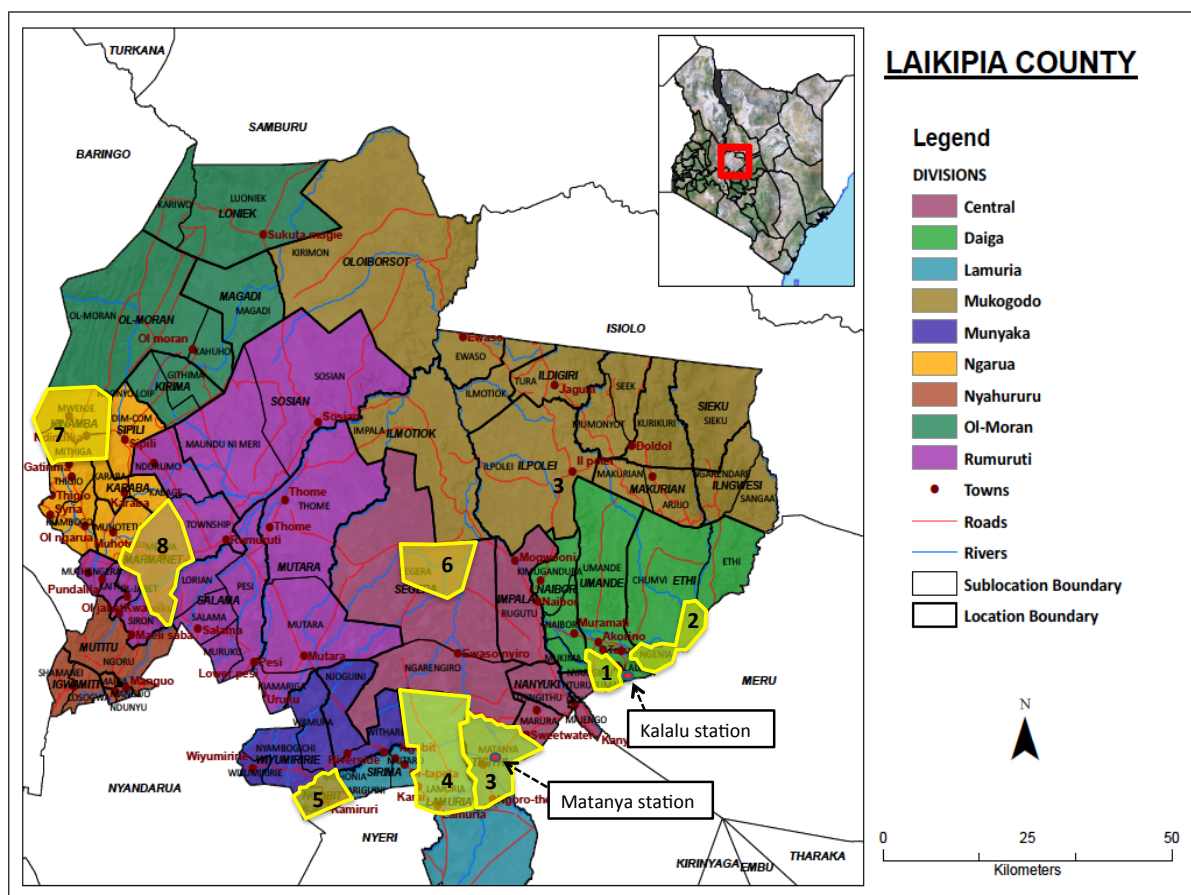


Fig. 1-7: Study sites in Laikipia County (1: Nyariginu; 2: Ngenia; 3: Matanya; 4: Lamuria; 5: Ngobit; 6: Segera; 7: Kinamba; 8: Melwa) and location of Kalalu and Matanya meteorological stations.

II. Theoretical background

In this chapter theoretical concepts from the climate change adaptation literature are outlined. The reader is introduced to the underlying theory and definitions of adaptive capacity (section 5). In the subsequent section, an introduction is given to the most important adaptation measures, which will be the dependent variable in the analysis (section 6). Thereafter, explanatory variables are introduced (section 7). To determine influencing factors on climate change adaptation, a framework is used based on Grothmann and Patt (2005) and combined with elements from the concept of sustainable rural livelihood by Scoones (1998). For each variable, corresponding hypothesis are formulated. In the last section, important definitions and boundaries of the farming system analysis are presented (section 8).

5. The concept of adaptive capacity

5.1. Historical origin

The term adaptation has its origin in biology and anthropology, where it refers to the development of genetic or behavioral attributes, that helps organisms to reproduce and survive (Engle, 2011). The concept of adaptive capacity has later emerged in organizational theory and sociology and finally made its way into climate change research in the beginning of the 1990s, when it appeared in reports and papers for the first time. Nowadays, adaptation goes far beyond the ability to reproduce and survive, but means rather the ability to maintain or increase quality of human live and of social and economic activities in light of climate change (Gallopín, 2006). The Intergovernmental Panel of Climate Change (IPCC) quickly incorporated it as an underlying concept and characterized climate change adaptation as an “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects” (Parry et al., 2007). Since then, a large number of definitions and approaches have been developed and adaptive capacity became a major concept of climate change research.

5.2. Unit of analysis: farm and farming system

Central to the concept of adaptive capacity is the system as unit of analysis, in this case the smallholder farm household or *farm system*² (Gallopín, 2006). Each household has its own characteristics depending on available resources, resource flows and interactions within itself and with other farms (Dixon et al., 2001). Besides on-farm crop-livestock production and post-harvest processes, a household is also characterized by off-farm activities and

² Farm system is used here synonymously to farm household.

incomes, as well as conditions of the external rural environment, such as institutions, markets and information linkages (Dixon et al., 2001). Thus, socio-economic, human and ecological factors are mutually interrelated and shape the complex structure of a farm system (Dixon et al., 2014). Single farm systems can be summarized to *farming systems* according to similar characteristics. A commonly used definition stems from Dixon et al. (2001), defining farming systems as:

'...a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. Depending on the scale of the analysis, a farming system can encompass a few dozen or many millions of households.'

Farming systems research is considered to provide a flexible and useful framework to determine appropriate agricultural development strategies (Dixon et al., 2001). The power of the approach lies in the fact that it considers both socio-economic and biophysical aspects and that it is able to integrate multi-disciplinary analysis of agricultural production (Dixon et al., 2011).

The approach is also useful in combination with adaptation research. On farm-decision making is influenced by farm external and farm internal factors and conditions (Smit and Skinner, 2002). Thus, the farm household is a useful unit of analysis since at this scale decisions are made regarding resource allocation and adaptation (Giller et al., 2006). Furthermore, it is changes on the spatial scale of farm systems that are likely to have the greatest impact on crop production and thus increase adaptive capacity of households (Challinor et al., 2007). This thesis focuses on adaptation at the micro-scale, with the farm household being the unit of analysis. For system comparison farm households will be summarized to farming systems and adaptive capacity will be discussed in light of the corresponding farming systems characteristics.

5.3. Definition of adaptive capacity and adaptation

For this thesis, an approach based on a concept by Gallopín (2006) and the IPCC (2014) is adopted (see Fig. II-1). Here, adaptive capacity is defined as *"the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences."* (IPCC, 2014). In this sense, adaptive capacity describes a positive system-inherent characteristic that exists prior to perturbation and that should be increased or at least maintained in light of climate change (Gallopín, 2006).

Initially, the system is exposed to a certain stressor. The characteristics of the stressor determine *exposure*. Exposure corresponds to length, intensity, duration and spatial

distribution of a perturbation a system is exposed to (Gallopín, 2006). How well the system is able to react to the stressor depends on the systems internal characteristics, that is on its *adaptive capacity*. Adaptive capacity itself is composed of three dimensions, namely *mitigation*, *coping* and *adaptation*. *Mitigation* reduces exposure to the risk, by taking measures acting upon the origin and attributes of the stressor (Gallopín, 2006). *Coping* describes a system's capacity to absorb shocks while maintaining function, exhibiting thereby similarities with the concept of resilience (Folke, 2006). In other words, it describes direct reactions to impacts from climate change. Furthermore, improving coping capabilities reduces residual impacts of climate change after perturbation. Consequently, increasing adaptive capacity reduces vulnerability of a system (Gallopín, 2006). Lastly, *adaptation* describes adjustments to long-term trends, which have transformational character and contribute to the exploration of positive opportunities. In contrast to mere coping, adaptation is of risk-reducing nature and minimizes the systems *sensitivity* in the long-term (Bryan et al., 2013). To sum up, the three cornerstones of adaptive capacity are (1) to reduce the exposure of the system (mitigation), (2) to increase resilience of the system by coping with changes (coping) and (3) to reduce the sensitivity of a system to climate change (Neil Adger et al., 2005).

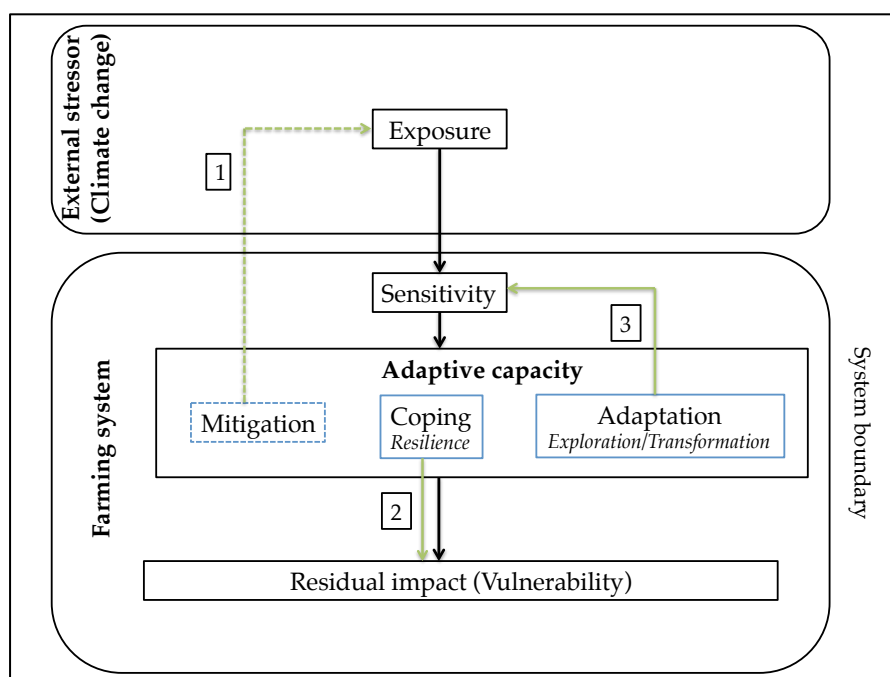


Fig. II-1: The concept of adaptive capacity. The numbers indicate positive feedback loops, corresponding to the cornerstones of adaptation: 1: Reduce exposure, 2: Increase resilience, 3: Reduce sensitivity. Source: Own illustration. Based on Gallopín (2006); Adger et al., (2005); IPCC (2014) and Engle (2011).

Since adaptive capacity is a latent system variable, it only becomes apparent after a system has reacted to a stressor (Engle, 2011). Thus, to make conclusions about adaptive capacity regarding future climate change it has been suggested to use past coping and adaptation

strategies as indicators (Elasha et al., 2005; Engle, 2011). Here, adaptation strategies are defined as “*adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates, harms, or exploits beneficial opportunities*”. This definition is similar to the one presented above for adaptive capacity. However, adaptive capacity is a system characteristic, while adaptation can be seen as one manifestation of the systems’ adaptive capacity (Smit and Wandel, 2006). Adaptation measures provide a useful entry point to establish an indicator of adaptive capacity.

Adaptation measures can be divided into autonomous and planned adaptation measures (Engle, 2011). The first one describes adaptation measures initiated and realized by the decision-maker him- or herself (Engle, 2011). Planned adaptation on the other hand, includes actions initiated by adaptation planners, such as development organizations or extension officers. This distinction is important, as in many cases autonomous adaptation is considered as reactive and less effective, while planned adaptation is associated with anticipatory and more effective adaptation actions (Engle, 2011).

There are also other approaches to measure adaptive capacity, for example by considering resources, market access and institutional support as an indicator for adaptive capacity (Cooper et al., 2008; Dixon et al., 2014; Keshavarz et al., 2014). In such an approach it is hypothesized that the higher and more diverse the resource base of a household, the higher is its adaptive capacity to climate change (Cooper et al., 2008). The concept of sustainable rural livelihoods is commonly used to conceptualize the resource base of a household (Cooper et al., 2008).

This thesis follows the first approach by considering adaptation measures as an indicator of adaptive capacity and focusses thus mainly on technological and farm management options. Such an approach allows for system specific conclusions, that are relevant and comprehensible for household decision-makers, as well as external adaptation planners. A more detailed description of agricultural adaptation strategies is provided in the following section.

6. Dependent variables: adaptation measures

Agricultural adaptation options can be classified into four main categories: (1) technological developments, (2) government programs and insurance, (3) farm production practices and (4) farm financial management (Smit and Skinner, 2002). While the first two categories are principally the responsibility of public agencies as they require changes at macro-scale, the third and fourth category mainly involve farm-level decision-making by smallholder farmers (Smit and Skinner, 2002). However, there are interdependencies between all of the groups that have to be considered if the adaptation context is to be understood.

In the following this thesis focuses on farm production practices, since it is mainly smallholder farmers’ decision-making that shapes this dimension. Measures include

changes in farm operational practices and can be grouped into the classes *farm production, land use, land topography, irrigation, and timing of operations* (Smit and Skinner, 2002). A detailed description with adaptation measures frequently mentioned in the literature is found in Table II-1. The enumerated measures in this table provide the basis for the list of adaptation measures used during the survey.

Changes of farm production reduces sensitivity to climate-related risks and increases the flexibility of the farm to climate variability (Smit and Skinner, 2002). It includes the diversification of crop and livestock types and varieties, as well as intensification through application of fertilizer and agro-chemicals (Smit and Skinner, 2002). Changes of land use practices include changes in the location of crop and livestock production, as well as crop-rotation, mixed-cropping and alternative fallow and tillage practices (e.g. conservation tillage) (Smit and Skinner, 2002). Land topography changes include land contouring and terracing, as well as the construction of water storage facilities (dams, reservoirs, ponds). Changes of water management practices include the introduction or the enhancement of irrigation systems, such as piped irrigation, sprinkler irrigation or drip irrigation and of water harvesting systems (run-off catchment facilities on the roof, pipes, tanks). Changing the timing of farm operations includes changes of planting, spraying or harvesting dates to take advantage of the changing duration of the growing season (Smit and Skinner, 2002). In adaptation literature, early and late planting are the most mentioned strategies in this group. Most of the adaptation measures aim at improving soil moisture and nutrient retention by reducing water run-off, evaporation rates and increasing water up-take (Smit and Skinner, 2002). In more general terms these adaptation measures include mainly responses, that reduce vulnerability to climatic stresses, such as drought events and climate variability (Feenstra et al., 1998). In the following paragraphs adaptation measures addressed in this thesis are discussed in more detail:

Change crop variety: Using stress-tolerant varieties can improve yields and agricultural productivity in light of drought (Smit and Skinner, 2002). In particular in the maize seed sector farmers have the choice between different drought-resistant or early-maturing varieties (KEPHIS, 2015). Regarding vegetables fewer stress-tolerant varieties are available, making water availability and access to agro-chemicals a precondition for the cultivation. Although the production of certified seed has increased in Kenya over the past decade the use has remained low due to poor distribution systems and high prices (GoK, 2009). Furthermore, the lack of control mechanisms promotes misuse in the seed market and further exacerbates access to good quality seeds.

Fertilizer usage and application of animal manure: Appropriate application of mineral fertilizer and animal manure can increase yields and improve soil fertility (Tittonell et al.,

2008). Average application in Kenya is 52.5 kg/ha, but for smallholder farmers in SSA the rate is as low as 10 kg/ha (FAO, 2015; Tittonell et al., 2008). High input costs and unclear labeling lead to fewer application of artificial fertilizer among smallholder farmers (GoK, 2009). Moreover, decisions on purchasing fertilizers are made before planting, that is at a time of year when farmers have already sold their harvest from the previous season and risky investments are avoided (Tittonell et al., 2008). Applying animal manure as a natural fertilizer is only used by 24.3% of farmers in Kenya (GoK, 2009), indicating that there is a huge potential to improve soil conditions.

Application of agro-chemicals: Altered weather patterns can increase crop vulnerability to infections, pests and weeds (Rosenzweig et al., 2001). At the same time, most analyses show that pest organisms might become more active in warmer climates and changed precipitation patterns (Rosenzweig et al., 2001). Pesticides are widely used among smallholder farmers and inappropriate application of pesticides regarding timing, protection clothing and type of pesticide has led to negative consequences for humans and the environment in Kenya (Nyakundi et al., 2012). Thus, although this strategy can be considered as a reaction to climate change consequences, it has to be carefully considered whether it should be termed “adaptation” or “maladaptation”. Especially in the smallholder context cases prevail in which negative consequences resulting from wrong application are dramatic. Access to information, spraying teams or trainings are not common among smallholder farmers. Unfortunately, agrochemicals are at present the cheapest and most effective way for pest control in the short run and are readily available in local agro-vet stores (Nyakundi et al., 2012).

Livestock adaptation practices: Switching to animals that are more tolerant to drought or diseases can improve productivity and drought resilience of livestock production (Bernier et al., 2015). Especially local breeds are already adapted to harsh climate conditions (Silvestri et al., 2012). Furthermore, small species such as rabbits or chicken with less water requirement can increase adaptive capacity. Livestock feed management can be improved by storing animal feeds, e.g. as napier grass, which has positive side effects on soil erosion (Bernier et al., 2015). Rotating production between crops and livestock can reduce soil erosion and improve soil moisture and nutrient content (Smit and Skinner, 2002).

Mixed cropping, inter-cropping and crop rotation: Planting of two or more crops simultaneously in the same field can increase soil biodiversity and fertility, help to conserve water and increases returns per hectare (Pearson et al., 1995). Spreading the risk on different crops on one plot is a typical trait of smallholder farming systems and has been practiced for a long time (Pearson et al., 1995). Inter-cropping describes the same as mixed-cropping, the only difference being that crops are planted in a geometric pattern, e.g. in rows (Pearson et

al., 1995). Maize planted in interchanging rows with other crops can serve as a windshield. Not only spatial but also temporal distribution of crops can be applied to improve soil fertility and adapt the cropping pattern optimally to different conditions during the year. Crop rotation describes planting crops sequentially in the course of the year, thereby enhancing soil fertility and reducing sensitivity to pests and diseases (Thierfelder and Wall 2015).

Agroforestry: Interplanting of woody species among or in proximity to the main crops delivers multiple benefits to farmers including food provision, supplementary income and environmental services (Lasco et al., 2014). Fruit, fodder and fuel wood production can be increased, while runoff or erosion are decreased and soil fertility is enhanced (Bernier et al., 2015). Trees provide shade, shelter and protection from wind (Lasco et al., 2014). Furthermore, carbon dioxide is deprived from the atmosphere, making this measure particularly interesting for mitigation purposes. However, benefits differ strongly depending on planted species. Afforestation is a practice that has been employed by farmers in Kenya for a long time (Marenya and Barrett, 2007). It requires financial investment and labor force for buying seedlings and planting trees (Marenya and Barrett, 2007).

Conservation tillage³: Conservation farming practices lead to improved on-farm water productivity and increased yields (Rockström et al., 2009). Most important methods in this group are minimum-, zero-tillage and mulch-tillage (Rockström et al., 2009). The soil is only opened where the seeds are placed, with as little disturbance as possible to avoid transpiration losses through soil cracks (Ali, 2010). Furthermore, crop material is left on the fields after harvesting to improve soil moisture retention and nutrient uptake (Ali, 2010; Bernier et al., 2015). The practices are poorly adopted among smallholder farmers in SSA (Giller et al., 2009). Major constraints are competing uses for crop residues, increased labor demand for weeding and lack of access to external inputs (Giller et al., 2009). Conservation tillage is easiest to apply on mono-cultivated, large fields, e.g. for maize.

In-field water conservation: Building terraces and bunds or changing the slope of the field can slow the speed of water and increase thus infiltration close to the crops' roots to improve irrigation efficiency (Ali, 2010; Bernier et al., 2015).

Water harvesting and storage: Water harvesting structures includes a number of topographical measures that are used for collecting rainwater from a surface area (Bernier et al., 2015). With structures like ridges, bunds and dams rainwater is diverted, stored and used for irrigation at a later point in time (Chritchley and Siegert, 1991; Ali, 2010). Harvested

³ Conservation tillage is used here synonymously to conservation farming and conservation agriculture.

water can be used for supplemental irrigation during dryspells to increase yield stability or for planting off-season cash crops to increase household income (Fox et al., 2005). However, high investment costs and knowledge requirements restrict widespread up-take by smallholder farmers in SSA (Fox et al., 2005).

Table II-1: Classification of adaptation strategies (based on Smit and Skinner (2002)).

Group	Description	Adaptation measures
Farm Production	Diversification of crop types and varieties, including crop substitution. Diversification of livestock types and varieties. Changes of production intensification.	Change to drought resistant variety Change to early maturing variety Artificial fertilizer Animal manure Agro-chemicals (Pesticides/Herbicides/Fungicides) Improved/ drought resistant livestock breed Change livestock feed management
Land Use	Changes in the location of crop and livestock production. Use alternative fallow and tillage practices.	Mixed cropping and inter-cropping Crop rotation Agroforestry Conservation tillage (mulch-tillage (leave crop residue), reduced tillage, minimum tillage, no tillage)
Topography	Change land topography to address the moisture deficiencies	In-field water conservation (terraces, furrows, trenches, windbreaks) Water-harvesting and storage (dams/reservoirs/ponds)
Water management	Implement irrigation practices to address the moisture deficiencies	Introducing/Improving irrigation system Water resource exploitation (boreholes/wells/water pumps to access river water)
Timing	Change timing of farm operations to address the changing duration of growing seasons and associated changes in temperature and moisture.	Early planting Late planting

Irrigation: This type of adaptation improves farm productivity, enables diversification of production (e.g. to horticultural products) by increasing moisture retention in the soil and increasing water availability (Smit and Skinner, 2002). Limited access to water, low rain-fall efficiency and limited access to technologies and institutional support prevent widespread application of irrigation in sub-Saharan Africa (Ngigi et al., 2009). The most common irrigation scheme among smallholder farmers in SSA is surface irrigation, meaning that river water is diverted or pumped to the cropped area. More efficient technologies such as sprinkler or drip irrigation are largely unexploited (Ngigi et al., 2009).

Water resources exploitation: Not only stored rainwater, but also groundwater, rivers and lakes are potential sources for irrigation water. Accessing these sources by using pumps and pipelines or constructing boreholes can improve irrigation water access.

Changing planting dates: This measure has the potential to maximize farm productivity during the growing season and reduce heat stress and moisture deficiencies (Smit and Skinner, 2002). It is a frequently applied adaptation strategy in SSA (Bryan et al., 2013; Gbetibouo, 2009; Kristjanson et al., 2012). Late planting minimizes the risk of being surprised by a late onset of the rains. Early planting is practiced in order to enable replanting in case the crops do not germinate. The decision to change planting dates is based on the farmers' observations of the rainy season during the past few years and is particularly relevant for rain fed agriculture.

The way in which adaptation measures are assessed in this thesis has some limitations that have to be born in mind. The data reflects only reported changes and not if a change was of adaptive nature. Although enumerators had the task to only register practices that were adopted in expectation of future drought events, this procedure was probably not communicated comprehensibly to all smallholder farmers. Rather, general changes of farming practice during the past few years were registered. The underlying assumption is that every of these recently introduced strategies brings benefit to the farmer and increases adaptive capacity (see also Wood et al., 2014). Furthermore, maladaptation has not been considered in this thesis, meaning that inefficiently applied measures with overall negative effects on adaptive capacity were not detected. It is assumed that all of these measures have positive effects on the ability of the farm to cope with climatic challenges.

7. Explanatory variables: determinants of adaptation

7.1. Cognitive and resource factors

One of the aims of this thesis is to test the influence of socio-economic and of cognitive factors on climate change adaptation actions from smallholder farmers. For this purpose the protection-motivation theory of Grothmann and Patt (2005) was used to integrate available resources and climate change perception into one framework for explaining determinants of climate change adaptation. Furthermore, the sustainable rural livelihood concept by Scoones (1998) was used to classify and justify available resources (see Fig. II-2).

The *Socio-cognitive model of proactive private adaptation* (PMT model) developed by Grothmann and Patt (2003) serves as a solid background for explaining psychological factors regarding climate change adaptation. Although rooted in health science, the model has been adapted to climate change research and tested in a number of case studies (Gebrehiwot and van der Veen, 2014; Grothmann and Reusswig, 2006; Le Dang et al., 2014). In the PMT model adaptation is understood as a socio-cognitive-behavioral process, whereas adaptive behavior can only happen if a person exhibits on one hand the motivation to adapt (*adaptation motivation*) and on the other hand, if the necessary resources are available

(*objective adaptive capacity*) (Grothmann and Patt, 2005). Adaptation motivation consists further of two major cognitive factors influencing the decision to adapt, namely *climate change risk perception* and *perceived adaptive capacity* (Grothmann and Patt, 2005). The first factor consists of two sub-variables, *perceived risk probability* and *perceived risk severity*. *Perceived risk probability* refers to a person's expectancy of being exposed to the threat, while *perceived risk severity* describes a person's appraisal of how harmful the consequences of the threat would be to things he or she values.

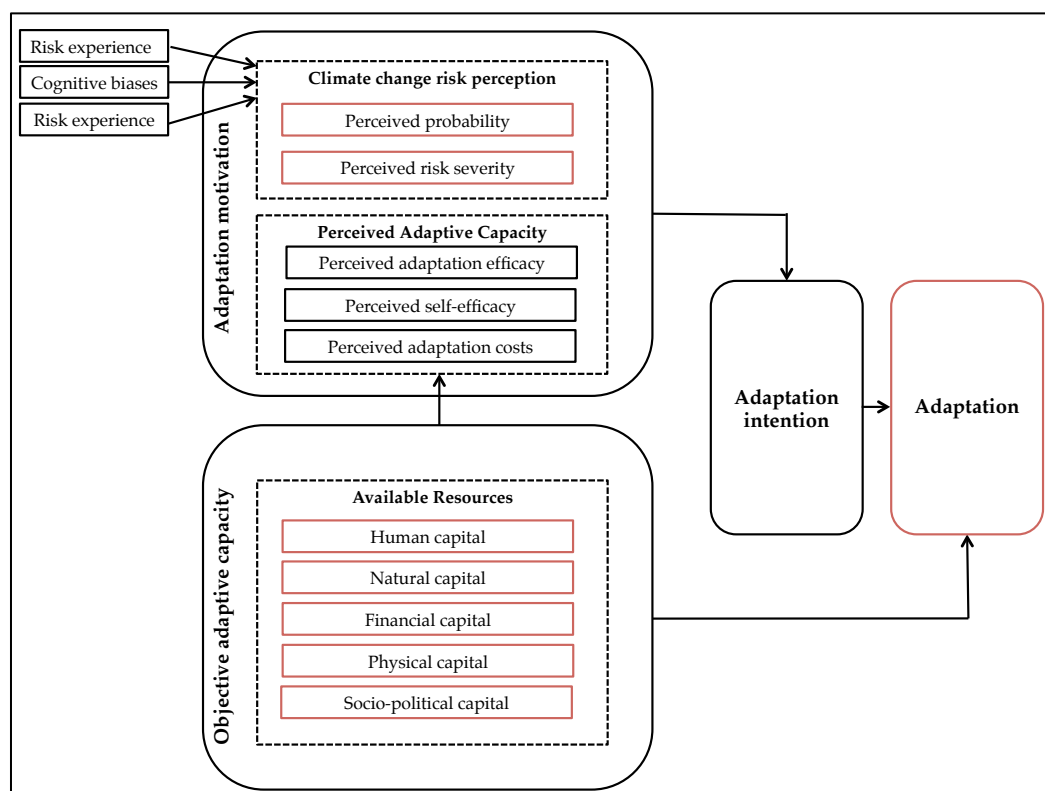


Fig. II-2 Theoretical framework to integrate cognitive factors and factors from the concept of sustainable livelihood for adaptation research. Adapted from the socio-cognitive model of private proactive adaptation by Grothmann and Patt (2005). Red boxes indicate the focus of the study.

A number of additional factors influence climate change risk appraisal, such as *risk experience*, *reliance on public adaptation* and *cognitive biases*, the latter describing over- or underestimation of the likelihood of a risk due to time distance to the last event. Only few studies have tried to assess the influence of perceived risk probability or risk severity on climate change adaptation in sub-Saharan Africa. Findings from Comoé and Siegrist (2015) indicated that farmers' decision to adapt occurred when farmers link climate change to its negative impacts on crop productivity, but not when just perceiving a change in climate without negative impacts. To enlighten this issue, the thesis will include the sub-variables belonging to climate change risk appraisal as cognitive variables in the analysis.

The second cognitive factor, *perceived adaptive capacity*, consists of three sub-variables *perceived adaptation efficacy*, *perceived self-efficacy* and *perceived adaptation costs*. Results indicated that smallholder farmers generally had a low perceived adaptive capacity; meaning that they did not believe that their actions can actually protect them from harm (Grothmann and Patt, 2005). Perceived adaptive capacity relates to the question, what a farmer thinks he *can* do (Grothmann and Patt, 2003). Factors related to *perceived adaptive capacity* will not be considered in this thesis, due to time and financial limitations. However, perceived adaptive capacity has to be kept in mind for the interpretation of the results.

The outcome of the perception process is a person's decision on how to behave. However, even if the person chooses to adapt (termed as *adaptation intention*), *objective adaptive capacity* (referring to available resources) will determine if adaptation is occurring. This last factor refers to available resources, such as financial and human capital, institutional support and environmental resources, all of which are often mentioned triggers of adaptation in sub-Saharan Africa (Below et al., 2014, 2012; Bryan et al., 2009; Deressa et al., 2009; Hassan et al., 2008). In this thesis, objective adaptive capacity is conceptualized and operationalized using the sustainable rural livelihood concept by Scoones (1998). The core assumption of this concept is that sustainable rural livelihoods build on five types of capitals, which are used for livelihood activities, without compromising livelihood options of others, either now or in the future (Cooper et al., 2008; Elasha et al., 2005). The five types of livelihood assets are: (1) Natural capital (e.g. land, water, trees, pasture, biodiversity), (2) Social-political capital (e.g. farmers associations, political claims/rights), (3) Human capital (e.g. household size, education, skills, health), (4) Physical capital (e.g. infrastructure, equipment) and (5) Financial capital (income level and variability over time, access to credit, debts) (Scoones, 1998.). The capitals are defined as the means of production available to a household and are used to generate livelihoods, through which the capitals can either become depleted or accumulated (Cooper et al., 2008). The livelihood concept can help understanding how people respond to climatic variability and how they adapt to change (Cooper et al., 2008). The major assumption of the concept is that a strong and varied asset base increases adaptive capacity (Cooper et al., 2008). Variables belonging to objective adaptive capacity were deduced from literature findings and grouped according to the capitals of the sustainable rural livelihood concept.

The direction of influence is positive for both cognitive and resource variables. *Climate change risk perception* and *objective adaptive capacity* are positively correlated with adaptation. Thus, the general assumption is that higher climate change risk appraisal and greater access to resources and institutional support is associated with increased application of adaptation measures.

The proposed model here is limited in two ways, which should be born in mind for the interpretation of the results. Firstly, the decision to adapt can either lead to maladaptation or

adaptation depending on the effectiveness of applied measures to prevent damage and increase benefits. Maladaptation refers to strategies that increase vulnerability in the long term by having high opportunity costs, creating dependencies and reducing incentives to adapt (Barnett and O'Neill, 2010). Maladaptation is a complex topic itself and addressing the issue would be beyond the scope of this thesis. Secondly, for the analysis there will be no distinction between *adaptation intention* and actual *adaptation*. Considering the temporal component of adaptation would be beyond the scope of this thesis. Therefore, the influence of *climate change risk perception* is measured directly on *adaptation* and *adaptation intention* is considered as a previously completed process.

7.2. Hypotheses

A summary of all variables is presented in Table II-2. Besides the cognitive and resource-related factors introduced above, gender was also identified as an influential factor to climate change adaptation in sub-Saharan Africa (Deressa et al., 2009). However, this factor was not assigned to one of the livelihood capitals but rather considered as a personal characteristic. In the following, the full list of determinants of adaptation are described. The chapter concludes with the formulation of the hypotheses:

Gender (Personal characteristic): Empirical evidence shows that agricultural work in general and adoption of agricultural practices is of gendered nature (Bernier et al., 2015). Men and women tend to have different levels of decision-making authority in different spheres of agricultural life and different access to assets and resources, which influences if and how specific agricultural practices are adopted (Bernier et al., 2015). Results showed that in some cases male headed-households were more likely to adapt to climate change than women (Deressa et al., 2009).

Age (Human capital): Age of the household head can be directly related to farming experience, which is associated with higher knowledge of agricultural strategies useful in the case of natural hazards. Older farmers were found more likely to adapt than younger farmers (Deressa et al., 2009).

Education (Human capital): Educated farmers were found to have a higher access to information on adaptation strategies and a higher likelihood to adapt to climate change (Deressa et al., 2009). In particular, there was a positive influence observed on soil conservation practices, changes in planting dates (Deressa et al., 2009).

Available workforce (Human capital): As many adaptation strategies are labor-intensive and require additional investment of time, a higher number of people working on the farm

was found to be positively associated with certain adaptation measures (Deressa et al., 2009).

Table II-2: Hypothesized determinants of adaptation.

No.	Variable	Classification according to sustainable rural livelihood concept or PMT-model	Description	Level of measurement
I	Gender	Personal characteristics	Gender of respondent (0=Female; 1=Male)	Dichotomous
II	Age	Human capital	Age of respondent (1=0-24; 2=25-34; 3=35-44; 4=45 – 64; 5 =>65)	Ordinal
III	Education		Highest degree of education (0 = no schooling; 1 = primary school, 2 = secondary school, 3 = college, 4 = University).	Ordinal
IV	Available workforce		Number of casual employees during the last 12 months	Continuous
V	Total income	Financial capital	Total household income in KES from crop and livestock activities during the year 2014 (1= <50k ; 2= 50k-100k; 3= 100k-150k; 4= 150k – 250k; 5 = >250k). Classification adapted from Ulrich, 2012 by considering inflation rates.	Ordinal
VI	Farm size	Physical capital/Natural capital	Total arable land in Laikipia (number of acres)	Continuous
VII	Access to extension services	Social-political capital	Access to extension service during the last 12 months. Binary variable (1 = yes, 0 = no)	Dichotomous
VIII	Access to farmers group and cooperatives		Access to farmers group or cooperatives during the last 12 months. Binary variable (1 = yes, 0 = no)	Dichotomous
IX	Significance of non-agricultural income		Percentage of non-agricultural income on total income (those who didn't have any income in 2014 were set 100 % for non-agricultural income) (1 = 0-10%; 2 = 11-20%; 3 = 21-30%; 4 = 31-40%; 5 = 41-50%; 6 = 51-60%; 7= 61-70%; 8 = 71-80%; 9 = 81-90%; 10 = 91-100%)	Ordinal
X	Perceived risk probability	Climate change risk appraisal	Self-assessed probability of the climate becoming better or worse in the future on a scale from 1 – 5 (1 = Highly beneficial; 2 = Average beneficial; 3 = Neither /Nor; 4 = average risk 5 = High risk).	Ordinal
XI	Perceived risk severity		Self assessed impacts of drought on crop productivity on a scale from 1-5. 1 = No impact; 2 = Small impact; 3 = Medium impact; 4 = High impact; 5 = Very high impact.	Ordinal
XII	Location	Control variable	1 = Laikipia East, 2 = Laikipia Central, 3 = Laikipia West Laikipia North was added to Laikipia Central due to little sample size.	Nominal

Farm income (Financial capital): Financial capital was found to be highly influential on adaptation (Bryan et al., 2013, 2009; Deressa et al., 2009). Financial liquidity enables decision makers to take short-term decisions in case of emergencies (coping). Regarding adaptation strategies, the relationship is less clear. However, most adaptation strategies require a certain amount of initial investment, which represents a high risk to a farmer with low

income (Cooper et al., 2008). Thus, higher income is associated with a more likely adoption of adaptation strategies.

Farm size (Physical/natural capital): Larger cultivated land allows for flexibility regarding changes in farming practices (Tongruksawattana, 2013). Furthermore, larger farm size is associated with greater wealth. Thus, larger amount of cultivated land is hypothesized to have a positive effect on adaptation practices. In this thesis, farm size is also associated with access to fertile land and therefore considered an indicator of natural capital. Due to temporal and financial limitations no additional data could be gathered to describe natural capital, such as soil or water quality.

Access to extension services (social-political capital): Access to extension services is one of the most often mentioned determinants of adaptation (Below et al., 2012; Bryan et al., 2013, 2009; Hassan et al., 2008). Agricultural extension provides informal, agriculturally relevant adult education for the purpose of agricultural development, community resource development, group promotion and cooperative development (Oakley and Garforth, 1985). As lack of information was found to be a major barrier to adaptation (Ofuoku, 2013). Thus, agricultural extension is expected to be positively associated with climate change adaptation strategies.

Access to farmers groups and cooperatives (social-political capital): Local rural organizations were declared to improve livelihood security in arid areas with disengagement of governmental services and limited access to income-generating activities (Washington-Ottombre and Pijanowski, 2013). Farmers groups and cooperatives play a significant role regarding access to micro-credit, exchange of information and resources among farmers and strengthen in that sense adaptive capacity.

Non-agricultural income (social-political capital): In general, access to non-agricultural income was associated with higher adaptation, as it represents an additional source of income. However, Deressa et al. (2009) found negative relationships with soil conservation practices and changes of planting dates. Farmers with a high non-agricultural income can afford expensive practices such as irrigation, application of fertilizer and afforestation and need less to depend on agronomic practices, such as the above-mentioned.

Perceived risk probability (Climate change risk appraisal): A persons' expectancy of being affected by the threat in the future is an important factor regarding the motivation to act (Grothmann and Patt, 2003). Besides objective factors and subjective adaptive capacity motivation is the other major determinant of adaptation (Grothmann and Patt, 2003). It relates to the question, what a farmer *wants* to do. Thus, farmers with future expectations of a threat are expected to be more likely to adapt (Grothmann and Patt, 2003).

Perceived risk severity (Climate change risk appraisal): A persons' appraisal of how harmful the consequences would be is the second important factor contributing to the motivation to adapt. As suggested by Grothmann and Patt (2003) perceived risk severity can also be described by using risk experience as an indicator, the latter being easier to measure and more understandable to smallholder farmers. Therefore, perceived risk severity was measured in terms of perceived impacts from climate change on crop productivity. The underlying assumption is that if past climatic events had severe impacts, a person will have a higher motivation to adapt to future events. Results show that perceived impacts had a positive influence on adaptation practices (Comoé and Siegrist, 2015).

From the above-described issues the following hypotheses are deduced:

H1: Older farmers are more likely to adapt

H2: Educated farmers are more likely to adapt

H3: Households with more employed casual workers are more likely to adapt

H4: Households with a higher income are more likely to adapt

H5: Households with access to more land are more likely to adapt

H6: Households with access to extension services are more likely to adapt

H7: Households with access to farmers groups and cooperatives are more likely to adapt

H8: Farmers with a higher non-agricultural income are more likely to adapt

H9: Gender has an influence on the adoption of adaptation strategies

H10: Farmers perceiving a high risk probability are more likely to adapt

H11: Farmers perceiving a high risk severity are more likely to adapt

8. Boundaries and definitions

The most common indicator for smallholder farmers is land-holding size but there exist also a number of multi-criteria definitions that include income, market orientation or labor input (Calcaterra, 2013). In this thesis, landholding size was used as an indicator to define smallholder-farming systems. Both cultivated (cropped) area and grazing land used for livestock only were included. This rather simple approach is limited as it misses some of the complexity of smallholder farming systems. However, it allows for fast classification and eases comparison with other studies. In semi-arid areas smallholders can cultivate up to 10 ha of land and manage 10 heads of livestock (Dixon et al., 2003). Lewis and Ndungu (2006) reported that farm size in Laikipia County varies between 1 to 22 acres (8.9 ha), with an average farm size of 5 acres (2 ha). In this study farmers having up to 24 acres (10 ha) of agriculturally used land for both crops and livestock were included in the analysis.

Secondly, farming households had to be assigned to one of the farming systems used for comparison in the analysis, namely the food crop and the horticultural farming system. The indicator was based on average area under cultivation of corresponding crop types (see Table II-3). Farmers using on average more than 30% of their arable land for growing vegetables, fruits or flowers/spices during the past five cropping seasons (long rains 2015; short and long rains 2014; short and long rains 2013) were classified as horticultural farmers. Farmers using on average at least 70% of their arable land for growing maize, common beans, potatoes or wheat were classified food crop farmers. The reasoning behind this classification is that horticultural crops are usually grown on smaller plots compared to food crops, due to their high labour intensity and irrigation requirements. Furthermore, as the majority of farmers are self-sufficient they can't afford to depend only on horticultural crops, but still use a substantial amount of their plots for food crops cultivation. The classification was verified by comparing it to the farmers personal perception about their major crops and to examples from literature. In 85% of the cases farmers' self-perception corresponded to the assigned farming system. Furthermore, in a classification developed by van de Steeg et al. (2010) for farming systems in the Kenyan highlands, cash crop farmers used on average 30% of their area for planting cash crops.

Table II-3: Major crops of the food crops and the horticultural farming system in Laikipia County.

Food crops	Horticulture		
	<i>Vegetables</i>	<i>Fruits</i>	<i>Flowers, spices</i>
Maize, common beans, potatoes, wheat	French beans, kale, onions, spinach, cabbage, garden peas, snow peas, tomatoes, capsicums, sugar snaps, carrots, crougette	Water melon, thorn melon, passion fruit, thorn melon, tree tomatoe	Sunflower, green pepper

III. Methods

In this chapter methods of data collection and analysis are presented. The first part describes methods of data collection in Laikipia County are described in more detail (section 9). Thereafter, methods of climate data analysis (section 10) and comparative methods, as well as the binary logistic regression are outlined (section 11 and 12).

9. Data collection in Laikipia County

Data was collected during an 11-day quantitative household survey between 13th and 27th of May 2015. A total of 271 smallholder farmers were participating in the survey. To collect data about climate change perception and adaptation a structured questionnaire was developed (see Appendix G for the full questionnaire). To gain more in-depth qualitative information about climate change issues two focus group discussions were conducted after the survey.

9.1. Questionnaire development, format and structure

The structured questionnaire entailed primarily closed-ended and a number of open-ended questions. Open-ended questions were chosen to address bias-prone issues in a sensitive way (farmers' perception of climate change). Closed-ended questions were used to assess monthly climate change, explanatory variables (household variables, risk perception) and dependent variables (climate change adaptation strategies) for the regression analysis. Climate change perception was related to a period of the past 5 years, while adaptation strategies were related to changes in on-farm practices during the past 10 years. In order to ease comprehension and translation of the questions, emphasis was put on a logical order of questions and clear and specific wording. Questionnaire length was not to exceed 1 hour. As described in Mayer (2008) an interviewees' concentration and willingness to answer questions usually starts to decrease after 40 minutes to one hour. Furthermore, farmers are often time constrained due to time-consuming farm labor, which they only reluctantly postpone. The final questionnaire version was compared to other available questionnaires from relevant study fields and validated with expert knowledge. During pretest the questionnaire was tested on comprehensibility, relevance to farmers and reliability.

The questionnaire was structured in the following way: Section A entailed questions on personal, household and farm variables. Although it is often stated that household variables should be put at the end of a questionnaire (Mayer, 2008), it was considered more suitable talking about farming activities and household features in the beginning to build up trust

and a familiar atmosphere with the smallholder farmers. Section B covered questions on general climate change perception and monthly temperature and precipitation changes. Section C covered questions about perceived drought impacts and respective coping strategies. Finally, Section D entailed questions about long-term adaptation strategies to reoccurring drought events. The interview ended with a few questions about access to institutional help.

Household variables and barriers to adaptation were assessed using closed-ended questions with coded answer-categories. For most of the questions “other, please specify” was included as an option to cover all possible answers by farmers. Furthermore, “don’t know”/“don’t remember” categories were put in places where it was likely that some farmers would not be able to answer the question. However, enumerators were instructed to avoid this answer category where possible to force farmers giving answers. Risk perception was measured using a 10-point Likert scale (Likert, 1937), which is a common tool to measure attitudes and perceptions. During data preparation for the statistical analysis the scale was summarized to a 5-point Likert scale.

Regarding adaptation strategies, the enumerator was instructed to first note down strategies mentioned by the farmer and to check afterwards a list together with the farmer on possibly forgotten strategies. This way, on-farm activities were captured that farmers didn’t link directly to climate but would still increase their adaptive capacity. This procedure was also successfully used in a study conducted by Keshavarz et al. (2014). Climate change perception was an open-ended question, where farmers could mention up to 7 different changes linked to climate change they’ve noticed during the past 5 years. Secondly, closed questions were used to assess monthly precipitation and temperature changes, as well as drought years remembered.

9.2. Survey methods

The paper-pencil questionnaires were filled out by nine enumerators that were familiar to the area and fluent in the local languages (English, Swahili and Kikuyu). Absence of the researcher during the interview was considered necessary to avoid answer bias and to build up an atmosphere in which farmers would answer freely and honestly. This procedure leads to a loss of control over data collection for the researcher. A good preparatory training was therefor considered crucial to avoid enumerator bias and ambivalent question posing.

The 3-day training prior to data collection included introduction to the questionnaire, translation of sensitive questions, role games and a pretest with 15 farmers. Smallholder farmers that participated in the pretest were excluded from the actual sample and further analysis. Furthermore, questionnaires were always checked on consistency right after data collection in the field and open issues or difficulties were discussed.

As farmers were not always readily available for interviews it was necessary to make appointments with the farmers in advance. For each of the targeted Sub-locations a facilitator, to whom smallholder farmers had trust, was contacted a few days prior to the survey and helped to establish contact between the research team and the smallholder farmers. Each of the enumerators was assigned to three or four different farmers during one data collection day. Interviews were conducted inside or in front of the homestead and whenever possible enumerators were moving from one farm to the other by foot. If distances were too long two cars were available for transportation. The enumerators were instructed to complete the questionnaire with the agricultural decision-maker of the household. However, in cases of absence of the corresponding person, another adult person living in the household was interviewed, e.g. the spouse or a grown-up son or daughter.

9.3. Sampling strategy and sample size

During data collection a non-probability sampling strategy, namely the quota sampling, was applied (Bird, 2009). Participants that were thought to be relevant for the research were purposively chosen according to crop types cultivated and location in Laikipia County.

The target was to reach equal sample size of horticultural and food crops smallholder farmers, as well as a sample distribution that is more or less proportionate to number of farming households in the targeted areas. The disadvantage of quota sampling is that it does not allow for statistical generalizations (Bird, 2009). The non-random choice leads to a bias that inhibits the calculation of standard errors. However, this strategy was considered suitable since characteristics of the study population were known. Furthermore, limited time and financial resources for this study asked for an efficient sampling strategy in a short time. For the planned statistical analysis, a binary logistic regression, Peduzzi et al. (1996) stated that minimal sample size (N) should be calculated with the following formula:

$$N = \frac{10 * k}{p}$$

with k = the number of independent variables and p = proportion of positive cases. With the applied 12 independent variables and an assumed 0.5 (0.4, 0.6) proportion of adaptation strategies minimal sample size is 240 (300, 200). After data collection in May 2015 and exclusion of unsuitable cases during data preparation, sample size resulted in 267 cases included in the analysis. The reached number is within the required range to enable solid statistical analysis.

9.4. Focus Group Discussions

After the actual survey, two focus group discussions were conducted, with food crops and horticultural farmers separately. Focus Group Discussions are a useful instrument of gaining qualitative, in-depth information about a topic and can be used to complement quantitatively gained information (Häder, 2006). The discussions took place after data collection in the city center of Nanyuki. A translator led the discussion using a flipchart to note down major statements. The researcher was present to guide the translator and to document gathered information. Each discussion lasted about two 1 hour and 40 minutes. Addressed topics corresponded to those in the structured questionnaire and followed same order. The discussion allowed for further questions by the researcher and for a broader exploration of the research topics. Data generated from the group discussions was not statistically analyzed. Qualitative information about climate change and adaptation issues was required for the interpretation of the results and is included in the discussion of this thesis. The complete guideline for the focus group discussion can be viewed in Appendix F.

10. Establishment of climatic trends

Farmers' perception of climate change was compared with measured temperature and precipitation data from two meteorological stations in Laikipia County, located in the Sub-locations Kalalu (0°04'54.24" N 37°09'49.71" E) and Matanya (0°03'54.41" S 36°57'19.77" E) in Laikipia East. Daily minimum and maximum temperatures as well as total daily precipitation was available from January 1986 until April 2015. Data gaps exist during the years 2006 – 2009 in Matanya and 2006 in Kalalu (for a complete list of all missing values see Table C-1 in Appendix C). For the climate data analysis plotting of trend lines was applied. The quality of the data was considered as sufficient for this purpose.

For the comparison of perceived and measured climate change a number of descriptive indices were calculated, which would help to assess if the amount or characteristics of precipitation have changed (see also Schmocker, 2013). These included total rainfall and average temperature trends, timing of rainy season, duration of dry spells and number of heavy precipitation days. They were considered to represent best the climatic stimuli relevant to agricultural adaptation: long-term changes in means, inter-annual or decadal variability, and isolated extreme events (such as floods, droughts and storms) (Smit et al., 1999).

Regarding long-term changes indices included total rainfall and average temperature trends on annual, seasonal and monthly basis (see Table III-1). Although smallholder farmers in sub-Saharan Africa often perceive lack of rainfall as a major cause for decrease in crop productivity, temperature effects shouldn't be underestimated. Increased temperatures lead to higher evapotranspiration, which could be mistakenly taken as a decrease in rainfall by

farmers (Coe and Stern, 2011; Osbahr et al., 2011). Therefore temperature effects are important to consider, when validating farmers perception of climate change.

Inter-annual variability was represented by calculating trends for onset and cessation dates of the long and short rainy season. Underlying assumptions were adopted from Berger (1989) who developed them for the Mt. Kenya region. This agro-climatological definition is based on daily rainfall data and was used by Schmocker, 2013 for the same area. The definition is related to crop production, since it considers that single days with precipitation are not relevant for crop production, if they are followed by a series of dry days (Schmocker, 2013). For the exact definition see Table III-1.

Indices representing extreme events included maximum precipitation events and consecutive dry days (CCD) - an index for dry spells during the growing seasons. CCD describe days where precipitation is <1mm, while number of heavy precipitation days includes days where precipitation is ≥ 10 mm and ≥ 20 mm respectively.

For all indices time series were plotted together with a linear trendline, which was then tested on significance (pearson correlation, confidence level 0.95). Average trends per decade were calculated by multiplying the slope of the regression line times 10. The statistical software R (RStudio, Inc. 2015, Version 0.98.1091) was used for all calculations.

Table III-1: Description of climate indices. Long rains: Mar, Apr, May (MAM). Short rains: Oct, Nov, Dec (OND).

Indices	Definition
Total rainfall	Yearly total rainfall, seasonal total rainfall (MAM and OND), monthly total rainfall (Jan – Dec) [mm]
Average temperature	Yearly, seasonal and monthly average, average maximum and average minimum temperatures [°C]
Length of rainy seasons	<p>1. Within at least 5-consecutive days from the earliest possible onset date of the season, 20 mm of rainfall must be recorded, at least 3 mm on the first of these days. 2. If another 20 mm of rainfall are received within the following 10 days, the first day of the period under 1.) marks the beginning of a wet period.</p> <p>3. The end of a wet period is defined by the last day of a 10-day period without rainfall. If such a period doesn't occur the latest cessation date is set as the end of the season.</p> <p>Earliest on-set date: MAM: 1st of March OND: 15th of September</p> <p>Latest cessation: MAM: 15th of September OND: 31st of December</p>
Max. Precipitation events during rainy season	Number of days during rainy season with a precipitation above ≥ 10 mm / ≥ 20 mm
Dry spells during rainy season	Max. consecutive dry days during rainy season < 1mm

11. Analytical methods

Assessed data was digitalized using the software CSPro (Census and Survey processing system, Version 6.1). It allowed for double data entry to minimize data entry mistakes. In the

following the statistical software SPSS (IBM SPSS Statistics for Windows, Version 21.0) was used for analysis of climate change adaptation and in particular the regression. Statements from open questions were grouped and frequencies were analyzed using Excel (Microsoft Excel for Mac 2011, Version 14.4.4 (140807)). The following subsection describes the statistical methods and procedures.

11.1. Comparing meteorological evidence with farmers' perception

An analytical framework by Simelton et al. (2013) was adapted to compare descriptively climate change perception with measured climate data. The framework follows a two-step procedure: Firstly, perceived changes of climatic parameters were assessed. These included on one hand generally mentioned climatic changes and on the other hand rainfall as well as temperature changes related to agriculturally relevant periods of the year (onset, duration and cessation of rainy seasons). The reasoning behind this approach is that rain-fed agriculture is sensitive to changes in rainfall pattern during times of the year when crops are in their critical growth-stage. As the success of crop production of most crops depends on conditions during rainy seasons, farmers are expected to put particular attention on them. Secondly, farmers' perception was validated with calculated climatic indices. This step included on one hand the comparison of the calculated climatic indices to generally mentioned changes and on the other hand, comparing measured temperature and precipitation trends for onset, duration and cessation of rainy seasons with mentioned changes for the corresponding months of the year. For this particular step analysis data from both farming systems were pooled together. A descriptive comparison of both farming systems regarding their monthly climate change perception indicated that nothing contradicts the pooling (see Fig. B-2 in Appendix B). Lastly, drought years during the past 30 years remembered by farmers were compared to total annual precipitation developments.

11.2. Frequency of adaptation measures

The frequency of different adaptation measures was separately analyzed for each farming system. First, the measures were summarized to adaptation classes based on Smit and Skinner (2002). Secondly, the frequency of single adaptation measures was displayed. For this it was differentiated between autonomous and planned adaptation. Autonomous adaptation describes self-initiated adaptive measures. Planned adaptation stands for adaptive measures realized with external support from governmental or private organizations. The average share of autonomous adaptation measures was calculated and statistically compared between both farming systems. For this step a Mann-Whitney-U test for continuous but not normally distributed variables was used. Significance level was set at $\alpha = 0.05$ (two-sided).

11.3. Binary logistic regression

Influence of personal characteristics, available resources and climate change perception on the adoption of single adaptation measures was tested with a binary logistic regression analysis. Binary logistic regression is a suitable method used to predict the probability of a person adopting a certain adaptation strategy based on the selected independent variables (Field, 2009). It has been applied in previous analyses regarding a similar research questions (see Comoé and Siegrist, 2015).

The dependent variable (Y) is a dichotomous variable that takes the value 1 if a person has adopted a particular adaptation measure and takes the value 0 if a person did not adopt the adaptation measure. Logistic regression expresses the probability of Y occurring given known logarithmic values of one or several predictor variables (X_z), which are either continuous or categorical:

$$P(Y) = \frac{1}{1 + e^{-(b_0 + b_1 X_1 + \dots)}}$$

The regression coefficient b is calculated with a maximum-likelihood estimation. This implies that coefficients are selected, which make the observed values most likely to have occurred (Field, 2009). Since the relationship between predictors and the dependent variable is of logistic nature, b cannot be directly interpreted. The results were transformed to Odds ratio (OR), which is an indicator of the change in the odds of an event occurring resulting from a unit change of the predictor (Field, 2009).

Binary logistic regression included the calculation of the Wald statistic's (z-statistic), which indicates whether a variable is a significant predictor of the outcome. Hypotheses in this thesis were accepted if the level of significance was <0.05 . Nagelkerke's R-square is an indicator of model quality and shows how much of variance in the model is explained with the predictor variables. Any further statistical calculations and verifications linked to the binary logistic regression are explained in Chapter 15.

IV. Results

In this chapter results from the survey as well as climate data analysis are presented. Section 12 describes demographic and agronomic characteristics of the sample population. Section 13 outlines first the results for research question 1 and 2 (climate change perception) and second, compares farmers' perception to meteorological evidence (research question 3). In section 14 both farming systems are compared regarding the application of different adaptation measures (research question 4). Section 15 identifies factors influencing the application of a few chosen adaptation strategies (research question 5).

12. Characteristics of the sample population

12.1. Sample distribution and major crops in Laikipia County

In total 113 horticultural and 154 food crop farmers participated in the survey. Distribution of sampled farming household corresponded to the distribution of major agricultural activities. Due to logistic reasons there was a slight prevalence of farmers from areas close to Nanyuki, namely from the Sub-locations Ngenia and Matanya (see Fig. A-1 in Appendix A). In third place was the Location Ngobit in the South of Laikipia, which is an area not so densely populated, but with high agricultural activity due to fertile soils and water access. The lowest share of farmers held the Sub-location Segera, which can be attributed to the arid climate and its Northern location on the boarder to pastoral lands. Given access to river water and irrigation horticultural farmers dominated in Segera and Ngobit. Food crops farmer dominated especially in areas located in Laikipia West (Sub-locations Melwa and Kinamba), but also in the Sub-location Nyariginu in Laikipia East.

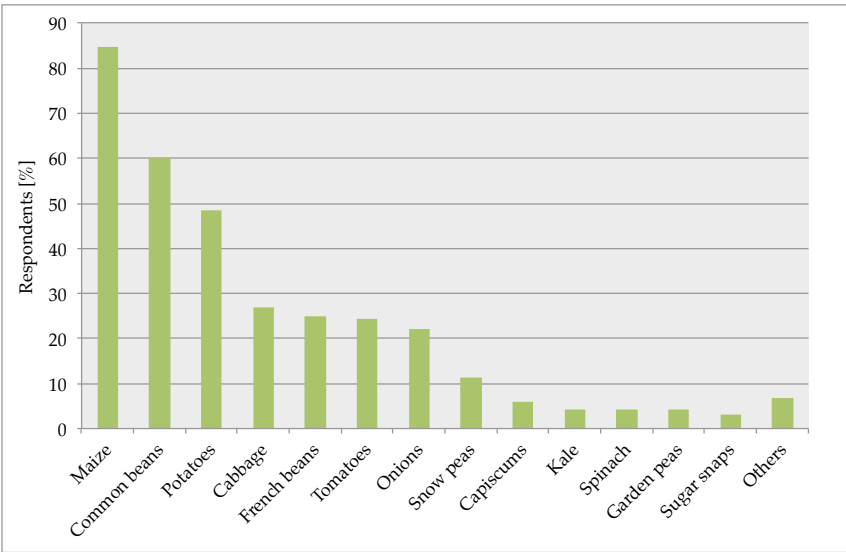


Fig. IV-1: Major crops grown in Laikipia County (n = 267). The numbers indicate percentage of farmers that mentioned to grow this crop on their farm. *Others* include: Fruits (Tree tomatoe, thorn melon, water melon, passion fruit): 1.9%; Carrots: 1.5%; Wheat 1.5%; Courghette 1.1%; Sunflower 0.4%; Green pepper 0.4%.

Most commonly grown crops in Laikipia County are presented in Fig. IV-1. Almost all of the surveyed farmers indicated growing maize on their plots, which is the major staple crop in Kenya, besides potatoes and common beans. Common vegetables in Laikipia County included cabbage, French beans, tomatoes and onions. Only few farmers were cultivating fruits, spices or flowers.

12.2. Demographic attributes

Gender distribution revealed that horticulture is clearly a male dominated business (see Table IV-1). 75.4% of interviewed horticultural farmers were male, while in the food crop farming system gender distribution was more balanced with only 46.8% of surveyed farmers being male. During the survey farmers were also asked to name gender of the household decision-maker. In the food crop farming system this corresponded to a male household member in 56.5% of the cases. The disparity between gender of respondent and gender of household decision-maker in the food crop farming system showed that in some cases farm labor is under responsibility of the women, while male household members (husband/father) take the final decision.

Average age of respondent was high for both farming systems, with 52.5 years for food crop farmers and 46.0 years for horticultural farmers. Usually older family members were the decision-makers in the household and corresponded therefore to the targeted survey respondents. Secondly, farming was becoming increasingly unattractive to younger people, which, instead of investing in agricultural business development, rather migrated to cities decoyed by more lucrative and less risky job opportunities. This was reflected in the high share of respondents in the age group of 45–64 years in the food crop farming system (see Table IV-1). Horticultural farmers on the other hand, exhibited a higher share of young farmers between 25 and 44 years of age. Horticultural farming has evolved recently in Laikipia County and the result implied that mostly young, innovative and risk-taking farmers practice it.

Almost all the farmers have received primary education, about half has completed secondary school, and only few have completed college, the majority of them being horticultural farmers.

12.3. Agronomic attributes

Mean area under crop production was generally very low for both farming systems, with 3.1 acres on average. Food crop farmers exhibited a slightly larger land size compared to horticultural farmers. Both horticulture and food crop farmers grew a variety of crops, which is a major characteristic of smallholder systems, since crop diversification minimizes the risk of total crop failure due to climatic and economic shocks (see Fig. IV-2). Only 7.8% of farmers

in this sample were growing exclusively horticultural crops. Most commonly grown vegetables among horticultural farmers included tomatoes, French beans, onions, cabbage and snow peas. However, food crops still occupied on average almost one third of the farm plots in the horticultural farming system. They were probably used to meet household consumptive needs and served as a backup in case of cash crop failure.

Table IV-1: Characteristics of the survey population.

	Food crops	Horticulture
Sample size (%)	55.8	42.2
Gender of respondent		
<i>Female (%)</i>	53.2	24.8
<i>Male (%)</i>	46.8	75.2
Age		
<i>Average age (years)</i>	52.50	46.00
<i>Age <24 (%)</i>	0.00	0.90
<i>Age 25-34 (%)</i>	5.20	15.00
<i>Age 35-44 (%)</i>	24.00	31.90
<i>Age 45-64 (%)</i>	51.90	44.20
<i>Age >65 (%)</i>	18.20	8.00
Educational level		
<i>No school (%)</i>	1.90	0.00
<i>Primary school (%)</i>	98.10	100.00
<i>Secondary school (%)</i>	43.50	54.00
<i>College (%)</i>	7.80	12.40
<i>University (%)</i>	0.60	0.00
Acreage		
<i>Mean area under crop production (acres)</i>	3.3	2.8
<i>Mean grazing land (acres)</i>	1.3	1.1
Livestock activities		
<i>Livestock owner (%)</i>	98.7	87.6
<i>Dairy cattle owner (%)</i>	82.9	74.7
Fertilizer		
<i>Farmers using manure (%)</i>	86.4	85.1
<i>Farmers using chemical fertilizer (%)</i>	76.6	94.7
Farmers practicing irrigation (%)	35.7	94.7
Average share of household consumption for major crops types (%)	72.6	23.7
Access to extension services (%)	48.1	64.0
Access to non-agricultural income (%)	34.4	29.2

Food crop farm plots on the other hand were cultivated much more homogenously. 37.8% of farmers in this sample were growing exclusively food crops. They relied largely on the production of maize, beans and potatoes with only minor share of vegetable plots.

Almost every household owned livestock and had a small share of grazing land on the farm. Farmers growing food crops had more livestock compared to horticultural farmers. Especially keeping of dairy cattle was more spread among food crop farmers compared to horticultural farmers. Farmers owning dairy cattle had an additional income from selling milk and other dairy products and could apply manure to their fields as natural fertilizer.

Livestock keeping in Laikipia County was mentioned by Ulrich et al. (2012) “as important as crop production for the generation of cash income and a strategy to bridge food deficit periods”. Although food crops farmer possessed more livestock, applying manure to the fields was an equally common practice in both farming systems. The application of artificial fertilizer was more spread among horticultural farmers compared to farmers growing food crops.

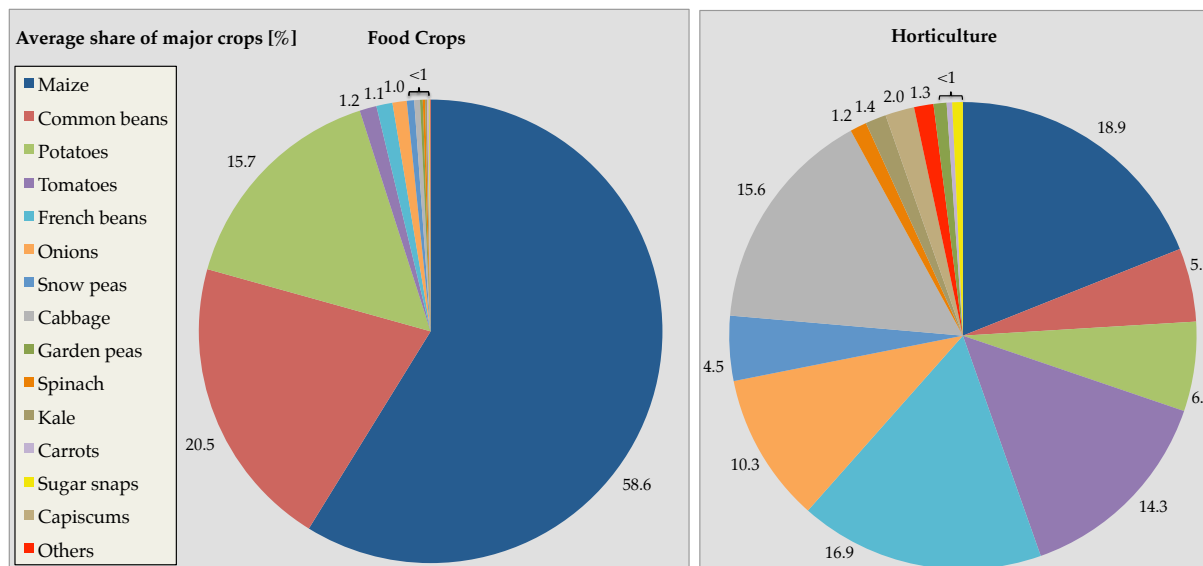


Fig. IV-2: Average area for each crop during past 5 farming seasons (long rains 2013 - long rains 2015) (n = 267).

In addition, the proportion of horticultural farmers irrigating their crops was much higher (94.7 %) compared to farmers growing food crops (35.7 %). Vegetables have high water requirements and irrigation access is a precondition for their cultivation. Consequently, horticultural farmers had the ability to plant and harvest all year round and were less dependent on rainfall compared to the rain-fed food crop farming system. The drought year 2014 can be taken as an example, when crop failure was more abundant among non-irrigated crops such as maize and beans (~30%) compared to irrigated vegetables (~10%) (see Fig. A-2 in Appendix A). However, irrigation requires access to water sources, which were in Laikipia County most often rivers and streams, more seldom also reservoirs or tapped water. Depending on their size and type of coverage these reservoirs are themselves sensitive to dry periods. Rivers are often seasonal and unprofessionally constructed dams and ponds suffer from high evaporation rates (GoL, 2013). Therefore, despite irrigation activities horticultural farmers are not to be considered as completely independent of rainfall.

Irrigation technologies were low in both farming systems. Surface irrigation with pipes, cans and canisters was practiced in 60.8% of the cases. 20.7% of the farmers mentioned to practice flood irrigation. Surprisingly, one quarter of food crop farmers with irrigation access mentioned to use sprinkler irrigation, most of them located in the Sub-location Ngenia. Institutional support and programs might have spread this particular technology in this area.

12.4. Market access and financial attributes

Farmers growing food crops were more subsistence-oriented, while horticultural farmers appeared to be market-oriented. Food crop farmers consumed on average 72.6% of harvested crops by themselves, while horticultural farmers only consumed on average 23.7% of harvested crops. From a crop perspective, vegetables are considered high value or cash crops, meaning that they render higher revenue from selling compared to food crops (see also Fig. A-3 in Appendix A). Food crops are mainly cultivated for household consumption and are only sold if produced in excess (Bühlmann, 2012). Since 2014 was a drought year, the share of sold food crops appeared very low in this study and was likely to be higher in more productive years. While food crop farmers mainly had access to local, more rarely also to regional or national markets, horticultural farmers sold on local, regional, national and even international markets (see Fig. A-4 in Appendix A). Consequently, income from selling crops was much higher in the horticultural farming system compared to the food crop farming system, despite additional livestock activities (see Fig. IV-3).

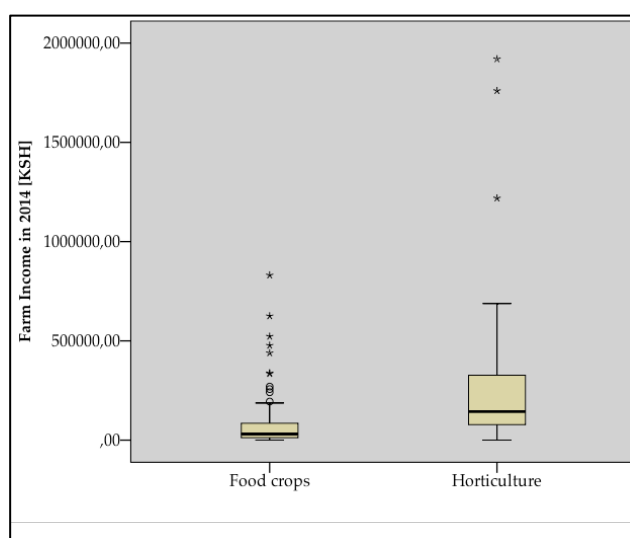


Fig. IV-3: Distribution of farm income (income from crop and livestock activities) in 2014 (n = 267).

There was an enormous variability regarding income levels for the year 2014 in both farming systems. Differences in income can be explained either with drought impacts due to differences in irrigation access (among food crop farmers) or with differences in land size (among horticultural farmers). In general, share of farmers earning below the international poverty line of less than 1\$ per day was higher among food crop farmers (14.1%) compared to horticultural farmers (2.7%). During the survey it has become evident that many farmers with no income during the drought year 2014 have mentioned receiving financial support from neighbors and/or relatives living in the cities. Furthermore, farmers have also mentioned to rely on non-agricultural income in case of crop failure. This seems to be of particular importance among food crop farmers, of which more than one third had to rely on

non-agricultural income during the year 2014. Thus, informal networks and non-agricultural businesses were important sources of money and risk-reducing factors in Laikipia County.

12.5. Institutional support

Horticultural farmers had a higher participation in farmers groups and cooperatives as well as in extension programs compared to food crop farmers. Laikipia County is an area where in recent years private as well as governmental organizations have maintained programs for smallholder farmers. Mentioned institutions in this survey included the Ol Pejeta Conservancy, Syngenta foundation for sustainable agriculture, CARITAS and the Kenyan Ministry of Agriculture. Not all smallholder farmers have perceived these programs as useful. Farmers participating in the focus group discussion have mentioned missing follow-ups after the program has ended and insufficient availability of extension officers, as major critique points.

The results presented in this section showed that differences between both farming systems were significant regarding system characteristics and agronomic strategies. The food crop farming system can be described as a traditional subsistence-oriented system, relying on the cultivation of staple crops and with a long history in Kenya. Farming consisted mainly of mono-cropping of maize and/or beans on larger plots, complemented with livestock husbandry. Access to informational sources was rather limited and low input and irrigation access made this system particularly vulnerable to drought events. This was also reflected in higher reliance on non-agricultural income, an indicator of livelihood diversification.

Horticultural farmers in contrast formed a more innovative and business-oriented system. Farming was practiced on smaller, but intensely managed plots. Farmers in this system experienced less drought impacts due to irrigation access, had a better connection to input and output markets and generated a significantly higher income from their farming activities.

13. Climate change perception

13.1. Farmers' perception of climate change

Research question 1 asked for climatic changes perceived by smallholder farmers and research question 2 for differences in perception between the food crops and the horticultural farming system. In the following section the perception of climate change is described for both food crops and horticultural farmers in Laikipia. Firstly, general climate changes perceived by farmers are described and the frequency of mentioned changes is compared between the farming systems. Secondly, results are presented regarding changes

in temperature and precipitation during single months of the year. Lastly, drought years that farmers remember since they've started farming are outlined.

Generally mentioned changes: During the survey farmers were asked if they had perceived any climatic changes over the past few years and if yes, to specify those changes. All of the interviewees have stated at least one aspect of climate or weather that has changed. The frequency of different changes was quite similar between the farming systems. 97.3% of all horticultural farmers and 98.1% of all food crop farmers mentioned changes linked to rainfall (see Fig. IV-4). Regarding temperature, 73.5% of horticultural farmers stated that temperatures have increased while in the food crop farming system 55.8% stated the same. Temperature as a climatic parameter is more difficult to directly perceive. It is possible that horticultural farmers were more aware of the problem due to information access or due to irrigation practices, which made them more sensitive to evapotranspiration and changes in temperature.

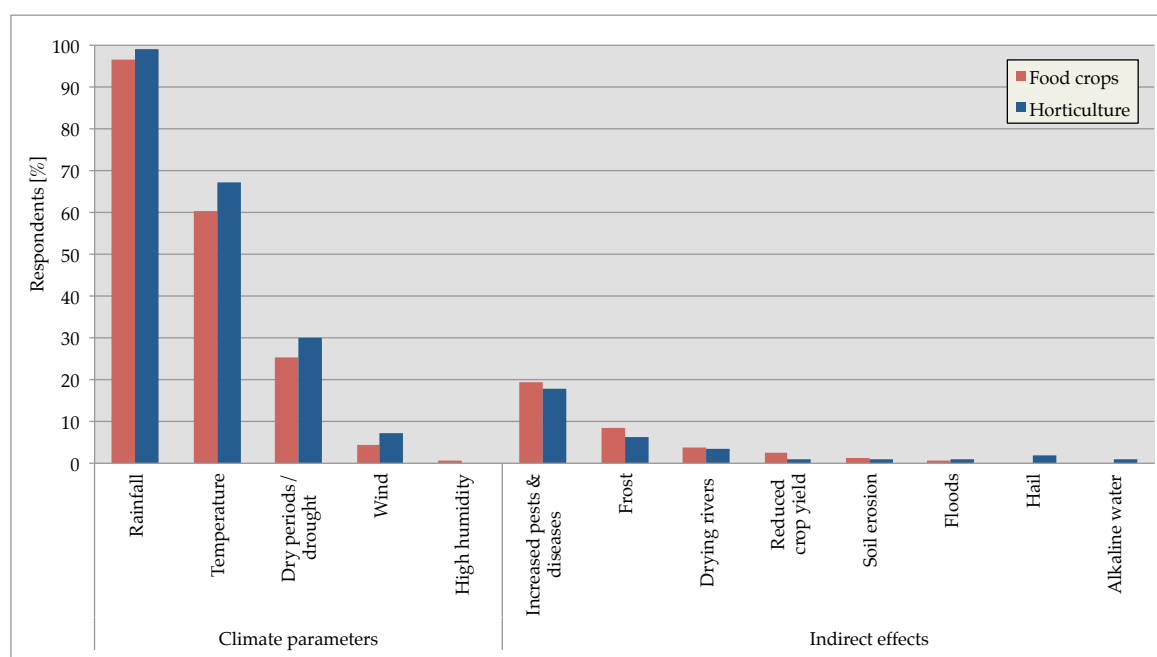


Fig. IV-4: Summarized climatic and indirect changes mentioned during the survey (n=267).

29.9% of food crop farmers and 23.9% of horticultural farmers mentioned changes in the frequency or intensity of dry periods. This could be explained again by the higher amount of irrigation horticultural farmers had, which makes them less vulnerable to drought. Changes of wind speed were mentioned mostly by horticultural farmers (8.8 %).

Some of the changes mentioned by the farmers were indirect effects of climate change, such as crop pests and diseases or reduced crop yield. Although indirectly linked to climate, these factors gave important insights on impacts of climate change in the region and on challenges farmers were facing. It pointed at the fact that farmers' perception of climate is strongly

linked to crop performance and that farmers confused climatic and non-climatic factors (Coe and Stern, 2011). Increased pests and diseases were often mentioned in both systems, followed by increased frost, drying rivers and reduced crop yield.

The mentioned climatic changes are further itemized in Fig. IV-5. In each group only the most often mentioned changes are displayed (for a complete list see Table B-1 in Appendix B). Statements linked to rainfall were grouped into rainfall quantity, timing of rainfall and characteristics of single rain events. Differences between both farming systems were only marginal. More than half of the farmers in both farming systems mentioned decreasing rainfall amounts. Very few farmers perceived an increase. Furthermore, later onset of rainy season and more erratic and unpredictable rainfall were often mentioned. Few farmers mentioned changes in rainfall intensity. It seemed that there is considerable disagreement about whether rainfall intensity showed an increase or a decrease.

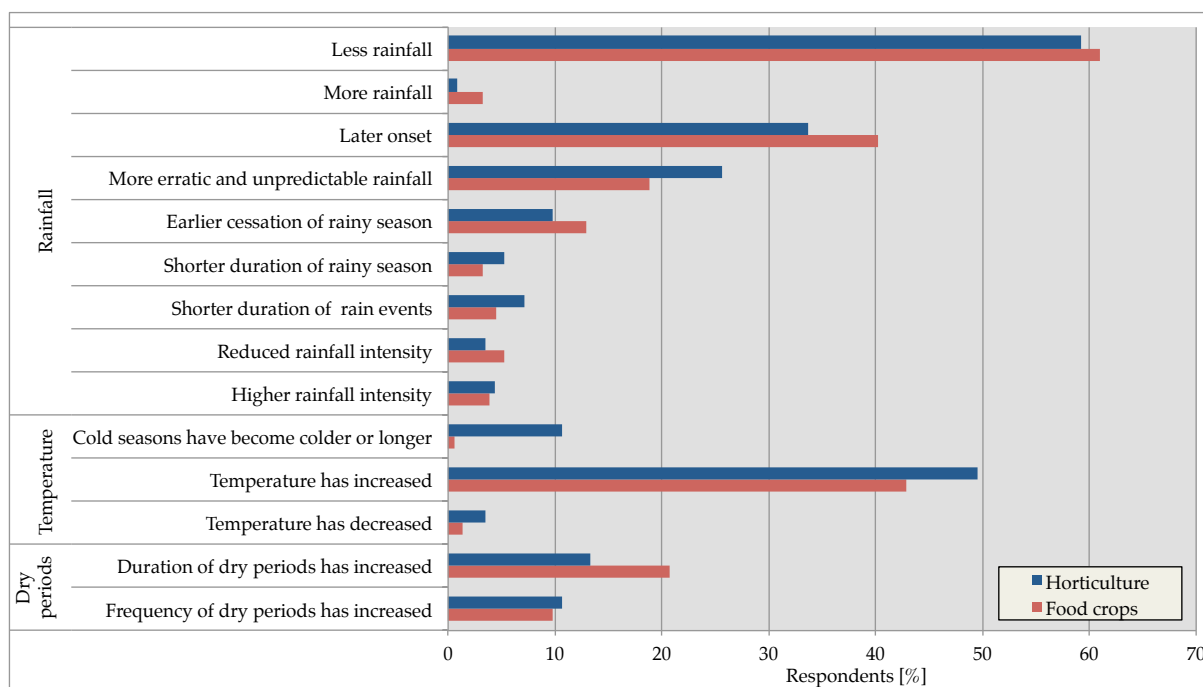


Fig. IV-5: Climatic changes mentioned during the survey (n=267).

Some geographical differences were found for the frequency of mentioned changes (see table B-2 in Appendix B). However the results should be interpreted with care as sample size differs strongly between different Sub-locations. It appeared that in particular for the Sub-locations Nyariginu and Ngenia rainfall decrease and increased erratic rainfall was perceived the least, while in the Sub-locations Lamuria and Segera these factors were mentioned most often. Furthermore, later onset of rainy season was in most locations mentioned by more than 35 % of surveyed farmers, with Lamuria and Segera again being the exception with a lower frequency of this factor. Statements from Laikipia West (Kinamba and Melwa) were dominated by less rainfall and more erratic rainfall.

Statements linked to temperature were mostly referring to average conditions. In both farming systems almost 50% of farmers stated to have perceived an increase of temperatures. Higher temperatures were mentioned frequently in all Sub-locations, particularly in Matanya, Ngobit, Lamuria and Segera. Among the horticultural farmers 10.6% mentioned decreasing temperatures during the cold season (June, July). Decreasing temperatures during cold seasons were mentioned most often in Ngenia and Matanya, but in Ngobit and Kinamba.

Statements linked to drought events or dry periods were referring to either the duration or the frequency of dry periods. Especially food crop farmers perceived an increase of the duration of dry periods. Again, this could be attributed to the fact that farmers without irrigation have difficulties bridging dry periods, which made them particularly aware of this factor. An increase in frequency was mentioned less often and about the same often in both farming systems. Factors related to dry periods were often mentioned in Laikipia West (Melwa, Kinamba), where food crops were the predominant farming system.

Temperature and precipitation changes during onset, duration and cessation of rainy seasons: During the survey farmers were specifically asked if they had perceived temperature or precipitation changes during the months of the year. Frequencies of mentioned trends are displayed in Fig. IV-6. Perceptions from horticultural and food crop farmers were pooled together as only minor differences in their perception of the different months were found (see Fig. B-2 in Appendix B). In the following, the focus lies on months linked to onset, duration or cessation of rainy seasons. This includes the months March, April, May (MAM) for long rains and October, November, December (OND) for the short rains.

Regarding precipitation most changes have been noticed during MAM and OND months, which is attributable to the fact that these months are the most critical ones for crop cultivation. However, statements were often of ambivalent nature. Especially concerning April and May, farmers gave opposite statements. More than half of farmers have mentioned decreasing rainfall for March and April and almost half of farmers have stated an increase of rainfall during May. For March, October, November and December most farmers stated that rainfall was decreasing during the past few years.

Regarding temperature, an increase was often mentioned regarding the hottest and driest time of the year, namely January until March. Furthermore, temperature increases were also mentioned for September. In correspondence to this most farmers stated that dry periods most often occur during January, February and September (see Fig. B-1 Appendix B). Decreasing temperatures were mentioned for the rainy season (April-May) and the subsequent months (June – July), which correspond to the coldest of the year. However, the proportion of farmers stating “no change” was quite large between April and December.

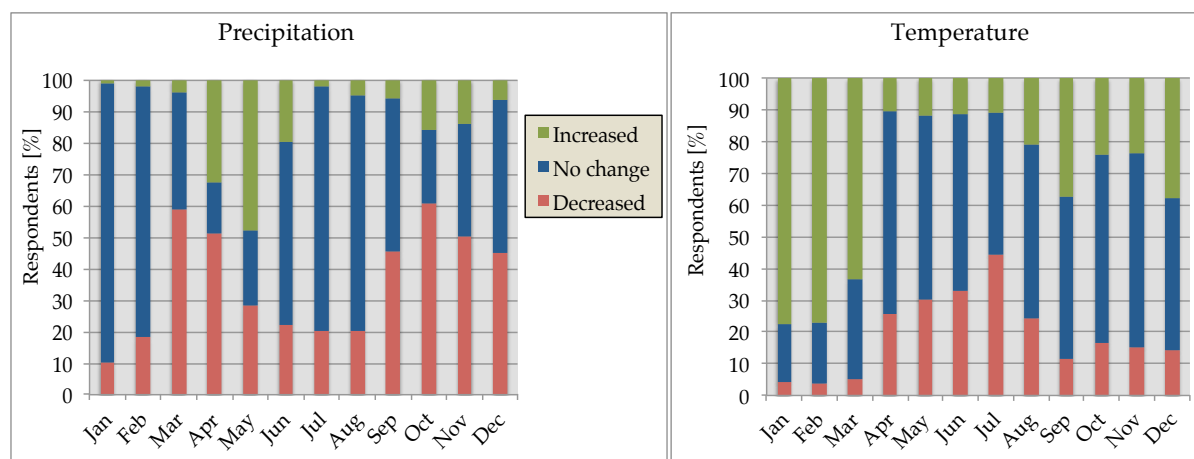


Fig. IV-6: Frequency of farmers mentioning increase, decrease or no change for each month of the year regarding precipitation and temperature (n = 267).

To sum up, the results showed that farmers' perception is clearly influenced by their agricultural activities during the year. Most precipitation changes were associated with months during the agricultural high season. Statements were sometimes contradictory which might be related to Laikipia's topographical heterogeneity and climatic alterations between different locations. Temperature statements were less contradictory and seemed to indicate that farmers perceive an increase of extreme temperatures. Hot and dry periods of the year, such as the months right before the rainy season, were perceived to become hotter, while cold periods of the year were perceived to become colder and longer (such as June and July).

Drought history: Farmers were asked to list drought events they remember during their lifetime. Results are displayed in Fig. IV-7. More than 60% of food crop farmers mentioned 1984 being a major drought year. Horticultural farmers mentioned this year slightly less often, which is attributable to their lower average age. The years 1984 – 1985 were indeed subject to a severe large-scale drought, with severe impacts in the Horn of Africa and Ethiopia. This result implies that 1984 has become part of the collective memory and was often mentioned because farmers *knew* it happened. During the 1990's only few droughts have been mentioned, including '92 and '96. Recent drought years mentioned by many farmers were the years 2000, 2009 and 2014. Horticultural farmers have emphasized recent drought events more often compared to food crop farmers. A possible explanation for this behavior is that food crop farmers, due to longer farming experience, had more possibilities of comparison regarding the severity of drought events. What was a severe drought to a horticultural farmer might have been only a minor dry spell in the eyes of an experienced food crops farmer, who took 1984 as a benchmark.

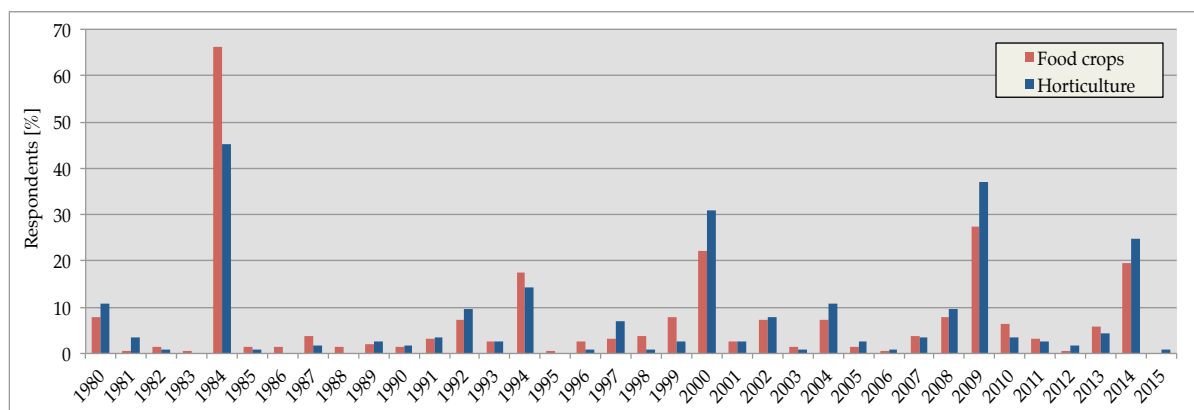


Fig. IV-7: Drought years remembered by food crops and horticultural farmers in Laikipia County (n = 267).

13.2. Meteorological evidence

Research question 3 asked for a comparison between perceived climate change and measured climatic developments. In the following section results of climate data are presented and compared to the results outlined in the previous subsection (13.1). After describing general temperature and precipitation trends, indices are used to verify farmers' perception of precipitation and drought events. Finally, monthly temperature and precipitation trends are presented in subsection 13.2 and compared to the farmers' statements of monthly precipitation and temperature changes from Fig. IV-6.

General temperature and precipitation trends: A summary of average temperature and precipitation trends for both stations can be viewed in Table IV-2. For annual and seasonal values, time series were calculated until the year 2014, since records for the year 2015 could only be obtained from January until March. For the calculation of monthly average values (total precipitation, average temperatures) only months with a complete record were included.

The temperature increase mentioned by farmers was clearly reflected in the temperature trends of both stations. Results showed that average temperature increased significantly over the past 29 years in both Kalalu and Matanya. The increase was around 1.3 °C (on average 0.45 °C/decade) for Kalalu and 1.74 °C for Matanya (0.6 °C/decade). This was also true for maximum and minimum temperatures. Especially maximum temperatures in Matanya increased more strongly compared to minimum temperatures. The coefficient of variation was rather low but slightly higher in Matanya compared to Kalalu.

Regarding precipitation the situation was more complex. Average annual precipitation was similar for both stations but appeared rather high for a semi-arid region. When looking at the coefficient of variation it became evident that the area experienced extreme climate variability. During the past 29 years, annual total rainfall spanned from below 400mm to

more than 1200mm (see Fig. IV-8). No significant trends were determined regarding annual total precipitation. Moreover, trends were opposite for Kalalu and Matanya meteorological station. Total annual rainfall increased on average by 65 mm/decade in Kalalu, while it decreased on average by 40 mm/decade in Matanya. This result pointed out again the climatic heterogeneity in Laikipia, which made it difficult establishing precipitation trends valid for the whole County.

Table IV-2: Temperature and precipitation trends for Kalalu and Matanya meteorological stations. Significant trends are indicated with * if $p < 0.05$ and ** if $p < 0.01$. Corresponding plots can be viewed Fig. C-1 and Fig. C-2 in Appendix C.

		Kalalu	Matanya
Coordinates		0°04'54.24" N 37°09'49.71" E	0°03'54.41" S 36°57'19.77" E
Elevation		2034 m.a.s.l	1843 m.a.s.l
Time series		1986-2015	1986-2015
Major Gaps		P/T: Jan – 11 Aug 06	T: 05 Jul 06 – 11 Feb 09 P: Sep 06 – 11 Feb 09
Temperature	Annual average temperature (max, min) [°C]	16.94 (24.31, 9.57)	18.58 (26.07, 11.08)
	Trend annual average temperature (average max, average min) [°C/decade]	+0.45** (+0.43**, +0.47**)	+0.06** (+0.92**, +0.29*)
	Coefficient of variation [%]	3.0	3.5
Precipitation	Annual mean rainfall [mm]	760.6	754.4
	Trend annual total rainfall [mm/decade]	+65	-40
	Coefficient of variation [%]	35	24
	Seasonal mean rainfall [mm]	MAM: 282.3 OND: 206.9	MAM: 250.1 OND: 271.7
Precipitation <i>seasonal</i>	Trend seasonal total rainfall [mm/decade]	MAM: +15.7 OND: +32	MAM: -2.6 OND: -62.5*
	Coefficient of variation [%]	MAM: 43 OND: 63	MAM: 33 OND: 33

As already pointed out above, farmers from Nyariginu and Ngenia – two areas closely located to Kalalu - had the least number of farmers perceiving a rainfall decrease. This could be attributed to the precipitation increase recorded in Kalalu. Farmers from locations close to Matanya meteorological station, in particular Lamuria and Matanya, mentioned decreasing rainfall more often, which corresponded to the recorded precipitation decrease. Regarding seasonal total precipitation it became evident that changes during the short rainy season (OND) were stronger compared to changes during the long rains (MAM). Precipitation decrease for the short rains in Matanya was significant at a level of < 0.05 . Thus, on a very local level, farmers' perception of climate change was reflected in recorded meteorological data. On regional level no final conclusion about farmers' perception of precipitation trends could be made with the available meteorological data. However, the strong temperature rising possibly led to increased evapotranspiration and diminished positive effects of

precipitation increase. This could be another reason for the majority of farmers perceiving decreasing rainfall.

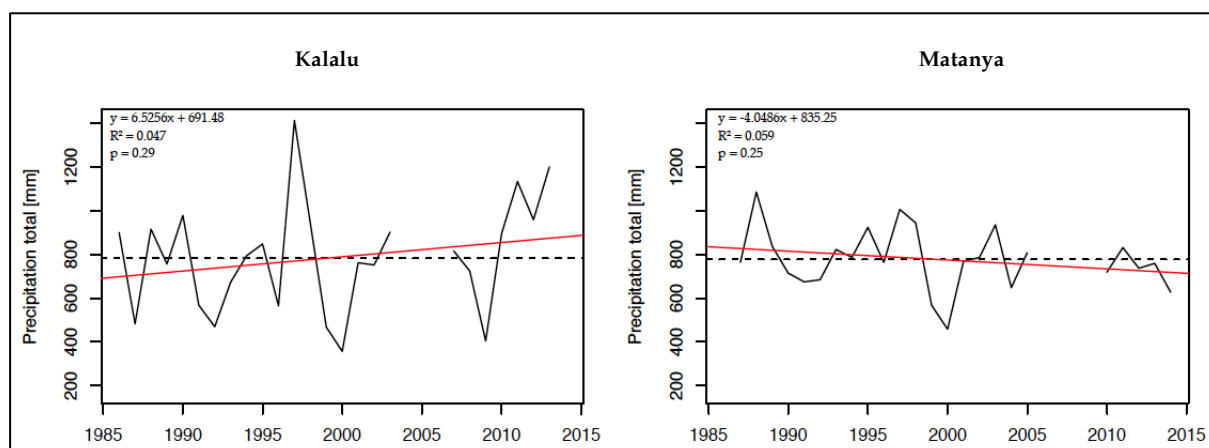


Fig. IV-8: Annual total precipitation for Kalalu (left) and Matanya (right) meteorological stations. Red line: linear regression line. Dashed line: mean of the past 29 years.

Consecutive dry days: For further verification of farmers' statements about dry spells and dry periods, consecutive dry days (CCD) during long and short rains were calculated. No significant results could be established. However, both locations seemed to have experienced a slight increase of dry spell duration during long rains and Kalalu station also during the short rains (see Fig. C-3 in Appendix C). This confirmed farmers' statements about an increase of dry period duration. However, the question was open-ended and farmers often did not specify whether they are referring to dry spells during seasons or dry periods during the year. Thus, farmers' statements could not be conclusively validated with the recorded meteorological data.

Heavy precipitation days: No significant results were established regarding the number of days with >10mm or >20mm during long and short rains (see Fig. C-4 in Appendix C). The pattern showed that changes were much more distinct for the short rains compared to the long rains. Number of days with a precipitation >10 mm during the short rains was increasing for Matanya, while Kalalu experienced a decrease. For the long rains no specific trend became evident. The number of days with a precipitation >20 mm showed similar but weaker trends compared to number of days with a precipitation > 10 mm. Farmers stating an increase of rainfall intensity were about equally abundant like farmers stating a decrease of rainfall intensity. As measured climate trends showed, this might be explained again due to regional differences in precipitation patterns.

Timing of rainy seasons: Many farmers mentioned a later onset of the rainy season and to a lesser extent also an earlier cessation. Results from the climate data analysis showed no significant trends regarding onset or cessation of long and short rains (see Fig. C-5 in

Appendix C). For Matanya station the trend indicated an earlier cessation of short and long rains, while in Kalalu an earlier onset of the long rains was recorded. Before the survey period in May 2015 farmers have experienced a late onset of the long rains, which might have increased farmers' awareness of a later onset of the rainy season. The late onset 2015 was also reflected in the measured data from Matanya and Kalalu meteorological station. In general, the results for the time series 1986 - 2014 indicated an earlier onset and earlier cessation of long and short rains. The rainy seasons seemed to have shifted to an earlier time of the year.

However, calculating onset and cessation for a time series from 1995-2014 (19 years time series) revealed a reverse trend for the long rains onset in Matanya. Long rains seemed to have experienced a delay during the past 20 years, while cessation has stayed the same. For Kalalu trends from 1995-2015 stayed similar to those calculated using the long time series.

Thus, it can be concluded that statements from farmers were not reflected in the long-term trends over 29 years. Nevertheless, when looking at short-term trends at least one of the meteorological stations confirmed farmers' perception of a later onset of the rainy season. A possible explanation for this is that farmers were able to perceive short-term trends better than long-term trends.

Temperature and precipitation changes for each month of the year: Average Temperature and precipitation trends were calculated for each month of the year from 1986–2014. Results are displayed in Table IV-3. Regarding precipitation, results differed between months and stations. No significant trends were established, while for temperature almost all of the months experienced significant increase.

The majority of farmers have mentioned a decrease of rainfall in April and an increase in May, which was reflected in measured climate data displayed in the table below. Both stations recorded in April a strong decrease and in May a strong increase of precipitation. In Matanya station a decrease was measured for March. This might be another reason why later onset of the rainy season was an often-mentioned climate change. March and April are months associated with the beginning of the long rains.

Recorded rainfall decrease was particularly distinct during June, December and January, and November in Matanya station. The majority of farmers mentioned a decrease of rainfall in November and December, but for January and June most of the farmers have not perceived any changes. This result confirms once more that farmers were inclined to put more weight to changes concerning months during the growing season compared to off-season months.

Temperature significantly increased almost for all months of the year. However, farmers seemed to be much less attentive to these changes compared to changes in rainfall. Temperature increases were strongest in December, February and March. This corresponds partly to farmers' perception of increased temperature during dry periods. The mentioned

temperature decrease for the period between April and July could not be confirmed. Nevertheless, temperature increase was lowest for May and June.

Table IV-3: Recorded monthly temperature and precipitation trends. Trends are indicated with the average increase or decrease per decade. Significant trends are marked with * if $p < 0.05$ and with ** if $p < 0.01$.

Month	Precipitation		Temperature	
	Average trend (mm/decade)		Average trend (°C/decade)	
	Kalalu	Matanya	Kalalu	Matanya
January	-9.9	-8.2	0.31*	0.52*
February	-3.2	1.8	0.57**	0.74**
March	7.4	-1.6	0.41**	0.69**
April	-6.7	-6.4	0.37**	0.61**
May	15	5.4	0.55**	0.56**
June	-7.5	-17	0.5**	0.49**
July	16.9	-13	0.61**	0.57**
August	4.9	10.4	0.58**	0.45**
September	11.2	8.3	0.61**	0.53*
October	19	-0.3	0.29**	0.59**
November	16	-18	0.33**	0.65**
December	-7.9	-17.7	0.26	0.75**

Drought events: Very low annual total precipitation was recorded during the years 1988, 1992, 1997, 2000 and 2009 (see Fig. IV-8). While farmers' observations corresponded well to measurements of rainfall during the past decade, there was a discrepancy regarding the droughts during the 1990's. Drought events during the 1990's were rarely mentioned, even though widespread droughts have been recorded during the year '91/'92 and '95/'96 also by international observers (UNDP, 2015). These events might have been already too distant for a significant part of farmers remembering it.

14. Adaptation strategies

Research question 4 asked what type of adaptation strategies farmers applied in the food crops and the horticultural farming system. During the survey farmers were asked specifically about their actions against drought events and additionally the enumerators were required to go through a list of possible adaptation measures with the respondents. Obtained results are presented in this section. Farmers mentioned some practices in addition to those from the list, particularly regarding livestock practices, e.g. migration or zero grazing. Because this thesis focuses mainly on crop and not livestock production and to avoid bias, they were not included in the analysis. First, results are presented for grouped adaptation measures in both farming systems (subsection 14.1). Second, results are outlined for the different types of adaptation strategies (subsection 14.2). Additional focus is placed on the difference between autonomous and planned adaptation strategies.

14.1. Grouped adaptation measures

Fig. IV-9 shows the frequency of farmers having adaptation measures in the groups based on Smit and Skinner (2002) (see also Table II-1). Farm production was separated into crop and livestock production. A farmer was associated with a group if he had at least one adaptation measure in the corresponding group. As number of possible adaptation measures differed between groups, frequencies should be interpreted with care. Differences between farming systems on the other hand can be interpreted as presented here.

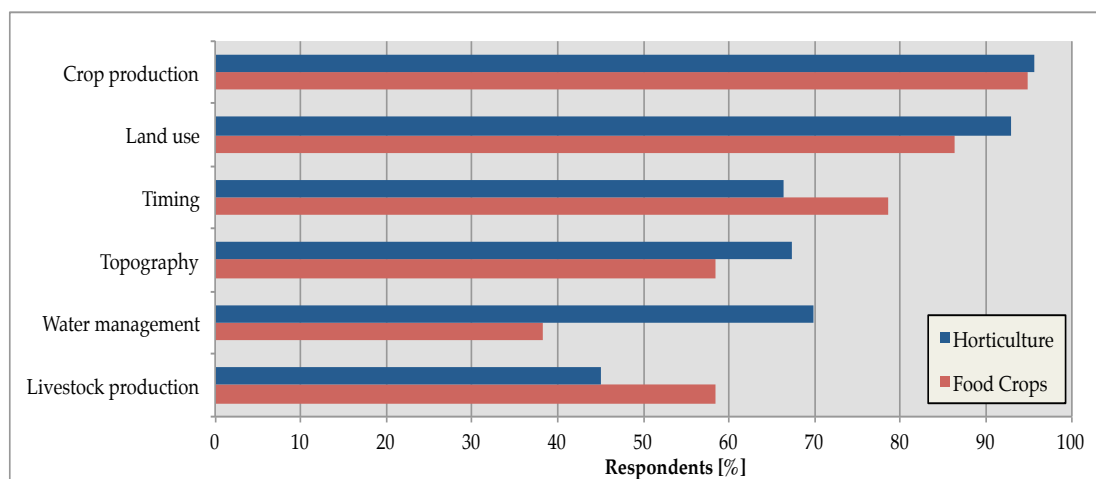


Fig. IV-9: Frequency of summarized adaptation groups (based on Smit and Skinner (2002)) (n=267).

Respondents from both systems had most often mentioned strategies associated with crop production and land use. Differences between farming systems were minor regarding these two groups of adaptation measures. Concerning timing of planting, food crop farmers exhibited a slightly higher application. This could be attributed to the lack of irrigation, that forced food crop farmers to adjust to seasonal variations. Food crop farmers also had a higher proportion of livestock production measures, indicating that dairy production was an important livelihood strategy. Horticultural farmers on the other hand had a much higher adoption of water management strategies. Unlike the cultivation of maize and beans, growing vegetables requires irrigation, which explained the difference regarding water management between farming systems.

14.2. Single adaptation measures

Fig. IV-10 and Fig. IV-11 show the frequency of the itemized adaptation measures and share of autonomous and planned adaptation for both farming systems. Measures were classified as planned, if support from a local, national or international institution was provided to the farmer, including information on the measure or resources for its implementation. Measures that farmers have realized without any external institutional help were classified as

autonomous. In general farmers have stated to apply surprisingly many adaptation strategies. On average (median) farmers mentioned to apply 9 of the 17 adaptation strategies. 65.5% of farmers applied 10 or fewer strategies, and 23.5% of farmers applied 5 or fewer strategies. This could be partly explained by the fact that both autonomous and planned adaptations were considered. For many adaptation strategies up to 50% of farmers applying it, were supported by external organizations for its realization.

Food crop farming system: Major adaptation strategies for food crop farmers were mixed- and inter-cropping, planting of early maturing varieties, conservation tillage, application of agro-chemicals and early planting.

Mixed- and inter-cropping was mostly autonomous adaptation. It is one of the most important risk reducing strategies among smallholder farmers and has been a typical trait of farming systems in Laikipia County for a very long time (Ogalleh et al., 2012). Farmers mix long- and short-cycle crops to maximize the probability of harvest during different times of the year. Knowledge about this practice is passed on between generations and requires rarely support from external sources. Planting of early maturing varieties was also predominantly autonomous adaptation. This was to be expected for the food crop farming system, since especially for maize different seeds are available (e.g. Variety type 614 and 513) (Ogalleh et al., 2012). During the survey many farmers mentioned the need to improve seed quality.

Conservation tillage was in more than 50% of cases externally supported, indicating that this particular adaptation strategy was rather new to the region and required information and training. Application of agro-chemicals was only in 30% of the cases externally supported, which should be alarming regarding the danger of negative consequences for humans and natural systems when pesticides are incorrectly applied. However, farmers had access to chemicals in local agro-vet stores, a fact that involves the danger of farmers buying cheap and uncertified products and applying it to their fields without prior instruction.

Early planting was more often mentioned compared to late planting despite the fact that many farmers mentioned a later onset of rainy season. However, as described above early planting allows for replanting and is thus a risk-reducing way of coping with increased rainfall variability. The frequent application of late planting points out that farmers were insecure when to expect the onset of the rainy season.

Measures related to water management were less frequently mentioned compared to other strategies. This might be attributed to the higher cost, material and knowledge such measures require and to the fact that maize and beans can be cultivated in rain-fed agriculture.

Horticultural farming system: Major adaptation strategies among horticultural farmers were crop rotation, conservation tillage, planting of early maturing varieties, application of agro-chemicals, animal manure and artificial fertilizer and introducing irrigation systems.

In the horticultural farming system crop rotation was enabled because farmers cultivate a diversity of crops and were able to grow continuously during the year due to irrigation. This enabled planting of crops during different times of the year on different plots, increasing thereby soil fertility and maximizing production on small land-size.

Conservation tillage is a rather atypical strategy for horticultural farmers, since it requires high labor input and effort if applied on small vegetable plots. The high abundance of this strategy among horticultural farmers could only be explained by the fact that maize and beans still took a significant space on horticultural farms. It is most likely, that conservation tillage was applied on these plots and not on vegetable plots. Similarly to this, the use of early maturing varieties referred most likely to maize varieties used on horticultural farms, since such seeds are not available for vegetables.

Horticultural farmers applied more often agro-chemicals, animal manure and artificial fertilizer to their fields compared to food crop farmers. The results implied that horticultural farmers invested much more in intensifying production and improving soil fertility compared to food crop farmers. Thus, it was possible that willingness and ability to invest in inputs was higher in the horticultural farming system, as benefits from selling cash crops were greater.

Introduction or improving irrigation systems was expected to be frequently mentioned by horticultural farmers, since it is a precondition of vegetable cultivation. It could be argued, that in such a case introducing an irrigation system is not an adaptation strategy to climate change in the narrower sense. During focus group discussions it was mentioned that farmers often relied on low-cost construction of water storage and irrigation systems. Coupled with farmers' misjudgment of water storage capacities, this sometimes led to a quick exhaust of water resources when dry spells occurred. Thus, irrigation systems too, have to be constantly adapted to changing climate conditions and there is considerable room for improving efficiency of these systems in the horticultural farming system.

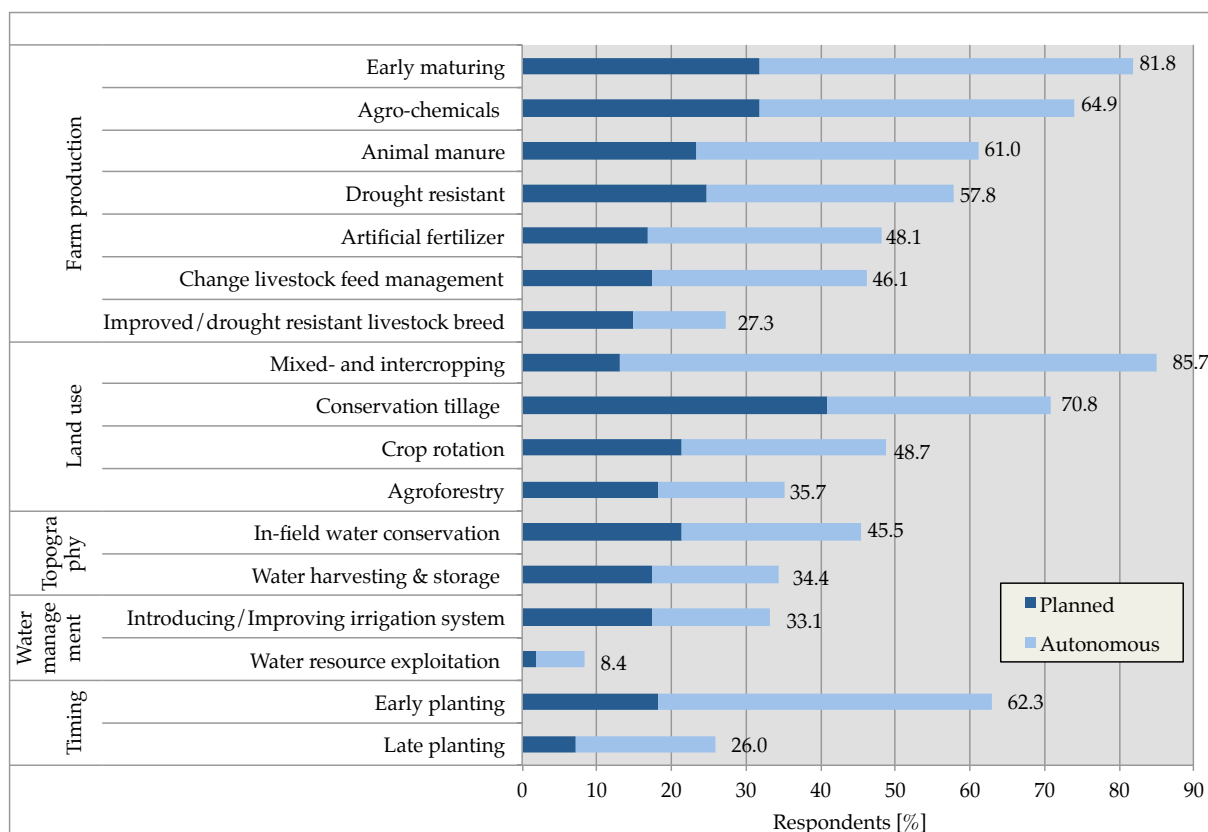


Fig. IV-10: Frequency of adaptation measures in the food crop farming system (n=154).

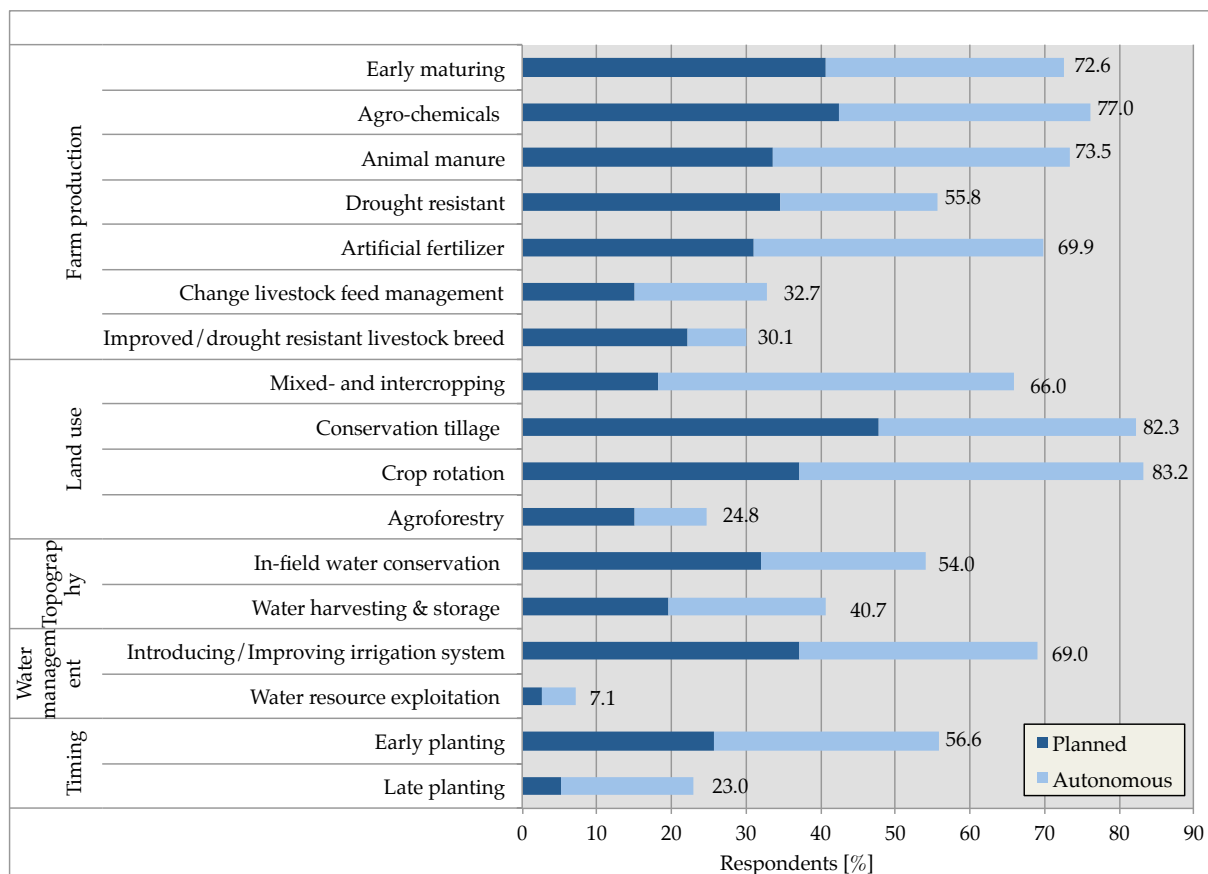


Fig. IV-11: Frequency of adaptation measures in the horticultural farming system (n=113).

In general, adopted strategies by horticultural farmers were more often planned measures, while strategies adopted by food crop farmers were more likely to be autonomous measures (see Table IV-4). This result reflected the fact that horticultural farmers had more access to informational sources and extension services compared to food crop farmers.

It is probable that access to institutional help led to a higher awareness of adaptation strategies among horticultural farmers, increasing thereby also the application of adaptive measures. However, it also involves the danger of having received biased answers, as during the survey farmers with information access were more likely to have indicated what they *knew* and what they think was *wished-for* by the enumerator, rather than what they actually *did* on the farm. This bias has to be kept in mind when interpreting frequencies of adaptation measures.

Furthermore, regarding the horticultural farming system mentioned strategies indicated that farmers probably referred to all the crops cultivated on their farm, not only the major ones. It was concluded that horticultural farmers had an interest in increasing productivity of all their crops and not only regarding the cash crops. For example, farmers obtaining an irrigation system due to vegetable cultivation might have also irrigated plots with maize or beans, increasing thereby adaptive capacity of their farm as a whole. This was also reflected in mean productivity for maize, which was around 1035 kg/ha for food crop and 1885 kg/ha for horticultural farmers.

Table IV-4: Average share of autonomous adaptation strategies in the food crops and the horticultural farming system. A Mann-Whitney-U test was used to test the difference. Significant results are indicated with * if $p < 0.05$.

	Food crops	Horticulture
Share of autonomous adaptation strategies		
Mean	67.67*	52.51*
Median	80.00	66.66

15. Factors influencing adaptation and perception

Research question 5 addressed the issue of which factors influence the adoption of adaptation measure in the food crops and the horticultural farming system. In the first part (subsection 15.1 and 15.2) statistical proceedings and model quality are outlined. In the second part (subsection 15.3), results from the binary logistic regression analysis for single adaptation measures are presented. Emphasis is put on influential factors, which are discussed one-by-one, considering results from both farming systems together. Corresponding hypothesis are accepted and declined at the end of this section (subsection 15.4).

15.1. Statistical proceedings

A binary logistic regression was performed to ascertain the effects of the hypothesized independent variables on single adaptation measures. For each adaptation measure a single regression was performed. Only those regressions with sufficiently high model quality are presented and discussed in this thesis. This approach was chosen because detailed information on single adaptation measures is more useful than aggregated data, for adaptation planners and smallholder farmers. They are the ones meant to make use of the gained knowledge. Furthermore, pooling different adaptation measures together to one index, demands for weighting of single strategies according to their effectiveness (for an example see Below et al. (2012)). This analytical process needs further data collection (such as focus groups and expert interviews) and was not realizable within the scope of this thesis.

15.2. Model quality

The binary logistic regressions were performed separately for both farming systems. Collinearity was checked with VIF and tolerance values by performing a linear regression as suggested by Field (2009). A correlation matrix of all independent variables can be found in Table D-1 in Appendix D. VIF values were all below 5 and tolerance values all above 0.25, as recommended by Urban and Mayerl (2008).

Standardized residuals were checked to detect outliers. For most of adaptation strategies 100% of cases were in a range between -3.29 and +3.29 as recommended by Field (2009). Standard errors were carefully observed to check for incomplete information from the predictor. All values were below 2 and thus considered satisfactory (Field, 2009).

A categorical control variable was added for location but summarized to districts, with Nyariginu and Ngenia assigned to Laikipia East; Matanya, Lamuria, Ngobit and Segera assigned to Laikipia Central; Melwa and Kinamba assigned to Laikipia West. This classification is not entirely politically correct, but reflects different agro-ecological zones of Laikipia.

Four strategies were analyzed for each farming system. Two of these had both systems in common and were chosen on purpose to allow for a system comparison. They included the application of animal manure and planting of trees (agroforestry). The third and fourth of analyzed strategies were different between farming systems and included late planting and irrigation for food crop farmers and in-field water conservation and application of artificial fertilizer for horticultural farmers respectively.

Table IV-4 and Table IV-5 present the results from the binary regression analysis for the food crops and the horticultural farming system respectively. All the regression models were significant and had Nagelkerke R-square values between 0.297 and 0.592, which means they

could explain 29.7 to 59.2% of the variance in the data. This was comparable to results from other adaptation studies. Comoé and Siegrist (2015) reached Nagelkerke R-square values between 0.27 and 0.38 when identifying influential factors regarding specific adaptation actions in Côte d'Ivoire. Below et al. (2012) reached a corrected R-square value of 0.28 for the weighted adaptation index in Tanzania. Such results are typical when studying multifactorial social systems. Nevertheless, the large amount of unexplained variability points out that important predictors were missing from the models. Some of these factors were probably not measurable or have not been captured during data collection due to biased questions and way of operationalization.

15.3. Factors influencing adaptation

For each of the explanatory variables the odds ratio (e^{β}) and the regression coefficient (β) were interpreted to identify extent and direction of influence respectively. The p-value indicated the level of significance for each variable.

Gender had only a weak influence on the application of artificial fertilizer among horticultural farmers. Surprisingly, female farmers were more likely to apply artificial fertilizer than male farmers.

Age was a triggering factor for late planting and on a less significant level also for the application of animal manure among food crop farmers. It was positively associated with agroforestry in the horticultural farming system. All of these measures belong to those with a longer history in the region as compared to the application of artificial fertilizer or irrigation, which are recently introduced technologies. Thus, it can be concluded that older farmers were more likely to cling to traditional practices and were being less innovative, compared to younger ones.

Level of education was only relevant in the food crop farming system, where it was weakly associated with agroforestry. Among horticultural farmers education was not significant for any adaptation strategies.

Available workforce was found to be positively influencing the application of animal manure in both farming systems, the application of artificial fertilizer in the horticultural farming system and adoption of agroforestry, late planting and less significantly also irrigation in the food crop farming system. The results indicated that available workforce is a critical factor regarding labor-intensive practices such as the planting of trees and also the application of fertilizer and manure. Most farm labor is done manually and it is thus an advantage of being able to employ people on a casual basis during times when labor force is

needed. Furthermore, it is the wealthier households being able to employ workers, which means they were also more likely to adopt expensive adaptation measures, such as irrigation and the application of artificial fertilizer.

Surprisingly, **total income** and **total arable land**, both indicators of wealth and liquidity were not found to have a positive influence on the adoption of adaptive measures. Total arable land had a slight influence on in-field water conservation, but not significantly. Furthermore, total arable land was negatively associated with the application of artificial fertilizer among horticultural farmers and with late planting among food crop farmers. These results were in contrast to all those studies identifying financial and physical capital as a major influential factor (Bryan et al., 2013, 2009; Deressa et al., 2009; Hassan et al., 2008).

Access to extension services was found to be most influential on the adoption of analyzed adaptation strategies. Extremely high odds-ratio values were reached in particular for the horticultural farming system. Horticultural farmers with access to extension services were 18.4 times more likely to practice in-field water conservation, 17.6 times more likely to apply artificial fertilizer and 6.9 times more likely to apply animal manure to their fields.

Regarding the food crop farming system farmers with access to extension services were 3.2 times more likely to apply animal manure to their fields and 2.7 times more likely to adopt agroforestry. Also the adoption of irrigation systems was positively influenced by access to extension services, though less significantly. Horticultural farmers had higher access to extension services and the results here showed that this factor is of major importance in the horticultural farming system.

Access to a farmers group or cooperative was positively associated with the application of animal manure and adoption of irrigation systems among food crop farmers. Less significantly also with late planting. In this study access to farmers groups and cooperatives was associated with credit access (Pearson correlation of 0.47, Sig. <0.001). Furthermore, in groups and cooperatives farmers had the possibility to step into contact with each other, to exchange information and resources. This made this factor particularly meaningful for low-income, resource-poor producers.

Among horticultural farmers this factor was only relevant in the case of agroforestry but with a low significance. Interestingly, for in-field water conservation access to farmers groups and cooperatives was negatively associated with the application. No explanation could be found for this peculiar pattern.

Share of non-agricultural income had a negative influence on adaptation measures in the food crop farming system. Food crop farmers with a higher share of non-agricultural income

were less likely to apply animal manure on their fields, adopt irrigation measures and practice late planting. In the horticultural farming system share non-agricultural income was associated positively with in-field water conservation. In other studies off-farm employment was found to be positively correlating with animal feed management (Gbetibouo, 2009), agroforestry and late planting (Deressa et al., 2009). However, these studies have taken absolute values of non-agricultural income, while in this thesis the variable was operationalized with the relative percentage of non-agricultural income on total income. This approach brought in a new view on livelihood diversification: for the case of food crop farmers in Laikipia livelihood diversification seemed to have negative consequences for their agricultural engagement. Farmers with a non-agricultural income didn't depend as much on their agricultural productivity - in case of crop failure they could still rely on the non-agricultural income - and seemed to be less motivated to invest in innovative technologies.

At an early stage of livelihood diversification, additional income might have a positive impact on agricultural innovation. The results here showed that the more the process advances agriculture got partly abandoned and fulfilled in the best case the role of an additional food source, but not of a foundation for a rural livelihood. As already discussed above horticultural farmers had much more revenue from their farming activities and a lower share of non-agricultural income compared to food crop farmers. Consequently, among horticultural farmers non-agricultural income was more likely to be invested in agronomic strategies.

Risk perception was positively associated with a number of adaptation measures, in particular among horticultural farmers. Horticultural farmers perceiving a high probability of being negatively affected by future climate change (**risk probability**) were more likely to apply animal manure and artificial fertilizer to their fields and to adopt agroforestry. In the food crop farming system risk probability was only positively associated with agroforestry. It was negatively associated with late planting.

In the case of agroforestry the strong influence of cognitive factors showed that the adoption of this measure was associated with a certain attitude towards climate change. During survey some farmers have mentioned to be aware of positive impacts of tree planting on the microclimate on their farms, as well as the global climate. Thus, cognitive factors were in fact relevant for the application of measures that were associated with long-term planning. Farmers being aware of future negative impacts from climate change might have been more likely to invest in practices with long-term benefits, such as agroforestry. Building up soil fertility is also a process that takes several years. Therefore the application of animal manure and artificial fertilizer was associated with farmers planning ahead and willing to improve their agricultural productivity in the long-term. Late planting on the other hand is an

adaptation measure that doesn't require long-term planning and was most probably applied by farmers being less aware of future climate change.

Risk severity, the degree to which farmers were experiencing impacts from climate change, was positively associated with late planting in the food crop farming system. It was negatively associated with the application of artificial fertilizer in the horticultural farming system. Interestingly risk severity always had negative signs for horticultural adaptation strategies, though the influence is in most cases not significant. Among food crop farmers risk severity had more positive than negative signs. This issue indicated that horticultural farmers were already in an advanced state of climate change adaptation where a higher climate change adaptation was associated with fewer impacts from climate change. The food crop farming system could be described as being in a *pre-adaptation* state, where farmers, that were aware of climate change impacts on their crop productivity, were more likely to adapt.

The control variable **Location** was found relevant in the case of irrigation, indicating farmers in Laikipia Central are more likely to adopt irrigation compared to farmers from Laikipia East. This points out that local water availability – a variable that has not been captured in this survey – might be a crucial factor regarding irrigation among food crop farmers. Furthermore, farmers in Laikipia Central have participated in water harvesting programs by CARITAS and the Ol Pajeta Conservancy during the last 12 months, which has probably lead to an increased application of irrigation practices. Horticultural farmers in Laikipia West were more likely to apply in-field water conservation methods. Since access to extension services reached extremely high odd ratio values for this adaptation strategy, it is possible that programs promoting such techniques have taken place predominantly in Laikipia West.

The results were compared to mentioned barriers of adaptation perceived by smallholder farmers (see Fig. IV-12). High initial cost turned out to be by far the most mentioned limiting factor to adaptation. This contradicts findings from the regression analysis, where financial and physical capital were not very influential factors. A possible explanation would be that in many cases farmers mentioned to be applying strategies, while it was rather the case, that they have just heard of it from extension officers or fellow farmers. This would also explain the strong explanatory power of informational sources in the regression analysis, such as access to extension services and access to farmers groups and cooperatives. Both seemed to increase farmers' awareness of innovative agronomic practices. Since the data in this study relied on farmers' statements only, there is no proof if they were in fact successfully applying these measures on their farm. Thus, the results in this study might have underestimated the importance of income for the adoption of adaptation measures.

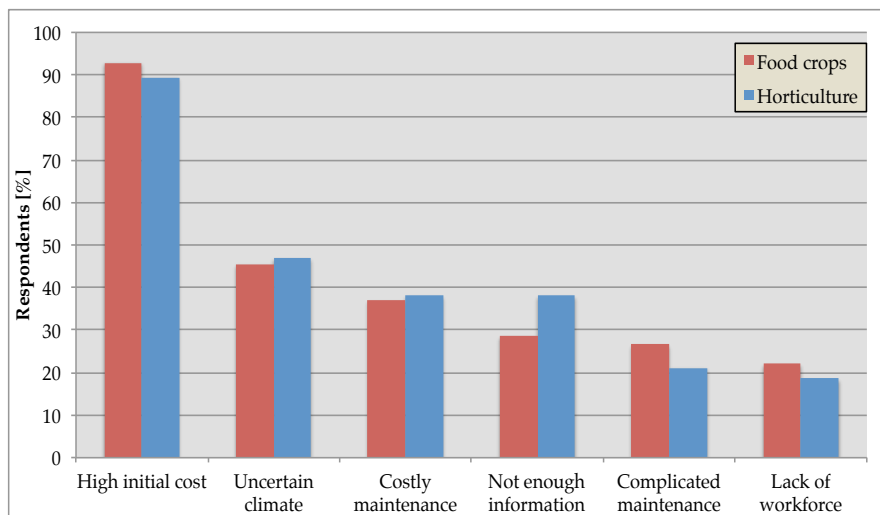


Fig. IV-12: Mentioned barriers to adaptation by smallholder farmers (n = 267).

15.4. Hypotheses

The result showed that in particular access to extension services had positive impacts on agricultural adaptation. The hypothesis for *Access to extension services* (H6) was accepted for most of tested adaptation strategies, with the exception of agroforestry in the horticultural farming system and the case of late planting and irrigation in the food crop farming system. Overall access to extension services had a stronger influence on adaptation among horticultural farmers compared to food crop farmers.

Available workforce, a measure for human but also financial capital, was particularly important in the food crop farming system and in the case of measures that require labor force. *Available workforce* (H3) was proven to have a significant positive influence on adaptation in the case of artificial fertilizer and animal manure among horticultural farmers and in the case of late planting, agroforestry and the application of animal manure in the food crop farming system.

The hypothesis for *Access to farmers groups and cooperatives* (H7) was accepted in the case of irrigation and application of animal manure in the food crop farming system. The hypothesis is rejected for all adaptation strategies in the horticultural farming system.

Furthermore, perceived risk probability was found to be of particular importance in the horticultural farming system and associated with adaptation strategies that require long-term planning. In the horticultural farming system *perceived risk probability* (H10) was a significant factor in the case of artificial fertilizer, agroforestry and application of animal manure. For the food crop farming system the hypothesis could only be accepted in the case of agroforestry.

Risk severity (H11) was a significantly triggering factor for late planting in the food crop farming system. For all other adaptation measures the hypothesis had to be rejected. Especially in the horticultural farming system risk severity was often negatively associated with adaptation, indicating that farmers with more adaptation measures experienced less impacts from climate change.

The hypothesis for *Share of non-agricultural income* (H8) was rejected for all cases. The factor was found to be negatively influencing adaptation in the case application of animal manure among food crop farmers and with a lower significance level also irrigation and late planting. Among horticultural farmers share of non-agricultural income had a positive influence on in-field water conservation, but with a low significance level.

Age (H1) was significantly fostering adaptation in the case of late planting in the food crop farming system and in the case of agroforestry in the horticultural farming system.

Regarding *gender* (H10) the hypothesis had to be rejected in all cases. However, a weak influence on the application of artificial fertilizer was found for the horticultural farming system. Surprisingly, women were more likely to adopt this measure than men. The hypothesis for *total income* (H4) was rejected in all of the cases. On the contrary a higher income was even negatively associated with a higher application of artificial fertilizer among horticultural farmers.

Education (H2) was rejected as a significant trigger of adaptation in both farming systems. There is only a weak positive influence on agroforestry among horticultural farmers.

Land size (H5) didn't lead to any positive and significant results in this study and the hypothesis has to be fully rejected. A weak positive influence was found for the case of in-field water conservation among horticultural farmers.

Table IV-5: Factors influencing adaptation measures of farmers growing food crops. ***, **, * = significant at 1%, 5%, and 10% probability level, respectively. β = regression coefficient, SE = Standard error, p = significance, e^β = odds ratio.

Animal manure	Predictor	β	SE	p	e^β
I	Gender	-0.186	0.449	0.678	0.83
II	Age*	0.621	0.32	0.052	1.861
III	Education	0.377	0.35	0.281	1.458
IV	Available workforce**	0.168	0.066	0.011	1.182
V	Total income	0.05	0.186	0.788	1.051
VI	Total arable land	-0.063	0.1	0.527	0.939
VII	Extension services***	1.162	0.434	0.007	3.197
VIII	Farmers group or farmers cooperative**	1.196	0.487	0.014	3.308
IX	Share of non-agricultural income**	-0.164	0.075	0.028	0.848
X	Risk probability	0.215	0.194	0.269	1.24
XI	Risk severity	-0.093	0.226	0.68	0.911
XII	Location			0.608	
	<i>Laikipia Central</i>	-0.382	0.547	0.485	0.682
	<i>Laikipia West</i>	-0.595	0.616	0.335	0.552
	Constant	-3.512	1.994	0.078	0.03
Model: N = 153. $\chi^2 = 53.601$. $p = 0.000$. Nagelkerke $R^2 = 0.401$.					
Agroforestry	Predictor	β	SE	p	e^β
I	Gender	0.432	0.435	0.321	1.54
II	Age	0.301	0.287	0.295	1.351
III	Education*	0.607	0.327	0.063	1.834
IV	Available workforce**	0.099	0.039	0.012	1.104
V	Total income	-0.109	0.176	0.536	0.897
VI	Total arable land	-0.068	0.099	0.488	0.934
VII	Extension services**	0.985	0.424	0.02	2.678
VIII	Farmers group or farmers cooperative	-0.375	0.451	0.405	0.687
IX	Share of non-agricultural income	-0.098	0.076	0.197	0.906
X	Risk probability***	0.62	0.197	0.002	1.859
XI	Risk severity	0.153	0.224	0.494	1.165
XII	Location			0.415	
	<i>Laikipia Central</i>	-0.554	0.501	0.269	0.575
	<i>Laikipia West</i>	-0.703	0.613	0.251	0.495
	Constant	-5.405	1.929	0.005	0.004
Model: N = 153. $\chi^2 = 37.293$. $p = 0.000$. Nagelkerke $R^2 = 0.297$.					
Late planting	Predictor	β	SE	p	e^β
I	Gender	-0.347	0.529	0.512	0.707
II	Age**	0.952	0.39	0.015	2.591
III	Education	-0.157	0.391	0.687	0.854
IV	Available workforce***	0.181	0.047	0.000	1.199
V	Total income	0.031	0.227	0.89	1.032
VI	Total arable land*	-0.231	0.13	0.075	0.794
VII	Extension services	0.642	0.495	0.194	1.901
VIII	Farmers group or farmers cooperative*	0.848	0.513	0.098	2.336
IX	Share of non-agricultural income*	-0.193	0.107	0.072	0.825
X	Risk probability**	-0.521	0.224	0.02	0.594
XI	Risk severity***	0.919	0.329	0.005	2.507
XII	Location			0.885	
	<i>Laikipia Central</i>	-0.051	0.574	0.929	0.95
	<i>Laikipia West</i>	0.278	0.7	0.692	1.32
	Constant	-7.136	2.547	0.005	0.001
Model: N = 153. $\chi^2 = 50.512$. $p = 0.000$. Nagelkerke $R^2 = 0.412$.					
Irrigation	Predictor	β	SE	p	e^β
I	Gender	-0.067	0.476	0.888	0.935
II	Age	0.4	0.321	0.212	1.492
III	Education	-0.193	0.345	0.575	0.824
IV	Available workforce*	0.079	0.046	0.084	1.082
V	Total income	0.295	0.182	0.105	1.343
VI	Total arable land	0.054	0.099	0.586	1.055
VII	Extension services*	0.749	0.438	0.087	2.115
VIII	Farmers group or farmers cooperative***	1.343	0.478	0.005	3.83
IX	Share of non-agricultural income*	-0.178	0.091	0.052	0.837
X	Risk probability	0.189	0.198	0.339	1.208
XI	Risk severity	0.075	0.246	0.76	1.078
XII	Location***			0.005	
	<i>Laikipia Central***</i>	1.575	0.534	0.003	4.83
	<i>Laikipia West</i>	0.073	0.686	0.915	1.076
	Constant	-5.34	2.021	0.008	0.005
Model: N = 153. $\chi^2 = 47.628$. $p = 0.000$. Nagelkerke $R^2 = 0.373$.					

Table IV-6: Factors influencing adaptation measures of horticultural farmers. ***, **, * = significant at 1%, 5%, and 10% probability level, respectively. β = regression coefficient, SE = Standard error, p = significance, e^β = odds ratio.

Animal manure	Predictor	β	SE	p	e^β
I	Gender	0.091	0.66	0.89	1.096
II	Age	-0.101	0.327	0.757	0.904
III	Education	0.039	0.421	0.927	1.039
IV	Available workforce**	0.224	0.093	0.015	1.252
V	Total income	-0.32	0.222	0.15	0.726
VI	Total arable land	-0.223	0.168	0.184	0.8
VII	Extension services**	1.926	0.6	0.001	6.863
VIII	Farmers group or farmers cooperative	0.554	0.583	0.342	1.74
IX	Share of non-agricultural income	0.143	0.12	0.23	1.154
X	Risk probability**	0.567	0.25	0.023	1.763
XI	Risk severity	-0.12	0.255	0.639	0.887
XII	Location			0.751	
	<i>Laikipia Central</i>	-0.478	0.752	0.525	0.62
	<i>Laikipia West</i>	-0.81	1.167	0.488	0.445
	Constant	-0.747	2.307	0.746	0.474

Model: N = 153. $\chi^2 = 53.601$. $p = 0.000$. Nagelkerke $R^2 = 0.401$.

Agroforestry	Predictor	β	SE	p	e^β
I	Gender	0.089	0.686	0.897	1.093
II	Age**	0.882	0.387	0.023	2.415
III	Education	-0.44	0.452	0.33	0.644
IV	Available workforce	0.016	0.052	0.758	1.016
V	Total income	0.329	0.252	0.192	1.389
VI	Total arable land	-0.278	0.184	0.13	0.758
VII	Extension services	0.971	0.66	0.142	2.64
VIII	Farmers group or farmers cooperative*	1.37	0.704	0.052	3.936
IX	Share of non-agricultural income	0.135	0.126	0.285	1.145
X	Risk probability***	1.389	0.372	0.000	4.011
XI	Risk severity	-0.314	0.262	0.231	0.73
XII	Location			0.316	
	<i>Laikipia Central</i>	-0.817	0.729	0.263	0.442
	<i>Laikipia West</i>	0.372	1.059	0.725	1.45
	Constant	-9.446	2.798	0.001	0.000

Model: N = 153. $\chi^2 = 37.293$. $p = 0.000$. Nagelkerke $R^2 = 0.297$.

In-field water conservation	Predictor	β	SE	p	e^β
I	Gender	-0.477	0.55	0.386	0.621
II	Age	-0.106	0.27	0.695	0.9
III	Education	0.381	0.364	0.296	1.464
IV	Available workforce	-0.014	0.044	0.75	0.986
V	Total income	-0.04	0.183	0.826	0.961
VI	Total arable land*	0.251	0.152	0.099	1.285
VII	Extension services***	2.915	0.678	0.000	18.44
VIII	Farmers group or farmers cooperative**	-1.434	0.637	0.024	0.238
IX	Share of non-agricultural income*	0.195	0.113	0.085	1.216
X	Risk probability	0.286	0.199	0.151	1.331
XI	Risk severity	-0.209	0.235	0.375	0.812
XII	Location**			0.014	
	<i>Laikipia Central</i>	0.786	0.616	0.202	2.195
	<i>Laikipia West*</i>	-1.843	1.019	0.07	0.158
	Constant	-2.18	1.949	0.263	0.113

Model: N = 153. $\chi^2 = 50.512$. $p = 0.000$. Nagelkerke $R^2 = 0.412$.

Artificial fertilizer	Predictor	β	SE	p	e^β
I	Gender*	-1.56	0.827	0.059	0.21
II	Age	-0.049	0.391	0.901	0.952
III	Education	-0.785	0.527	0.137	0.456
IV	Available workforce**	0.619	0.183	0.001	1.857
V	Total income	-0.187	0.261	0.474	0.83
VI	Total arable land**	-0.593	0.229	0.01	0.553
VII	Extension services***	2.869	0.797	0.000	17.627
VIII	Farmers group or farmers cooperative	-0.856	0.765	0.263	0.425
IX	Share of non-agricultural income	0.148	0.138	0.283	1.16
X	Risk probability***	0.92	0.323	0.004	2.509
XI	Risk severity**	-0.717	0.315	0.023	0.488
XII	Location			0.257	
	<i>Laikipia Central</i>	0.046	0.776	0.952	1.048
	<i>Laikipia West</i>	2.848	1.792	0.112	17.26
	Constant	1.257	2.701	0.642	3.514

Model: N = 153. $\chi^2 = 47.628$. $p = 0.000$. Nagelkerke $R^2 = 0.373$.

V. Discussion

In the following chapter, results are discussed in light of the broader context and existing literature and with consideration to the limitations of this study. Climate change perception is addressed in section 15, adaptation measures in section 16 while results regarding the determinants of adaptation are addressed in section 17.

16. Climate change perception

The results showed that smallholder farmers perceived climate change as one of the most important risk factors to agricultural production. Farmers had a detailed and diversified view of weather patterns in their region and perceived a broad variety of factors involved, the most significant being decreasing rainfall, increasing temperatures and a later onset of the rainy season. All farmers mentioned at least one changing factor, indicating that climate change was a phenomenon with high significance across the farming community. Furthermore, the unpredictability of climate conditions was the second-most mentioned obstacle to adaptation (see Fig. IV-12).

In contrast, Mubaya et al. (2012) reported that, when facing a multiplicity of risks, farmers in Zimbabwe and Zambia were likely to attribute negative impacts on crop productivity solely to climate variability. Similarly, Rao et al. (2011) reported that smallholder farmers were likely to overestimate the occurrence of poor seasons, which indicated that farmers perceived a higher risk compared to recorded climate data. The same could be true for Laikipia County where farmers were facing a high number of economic and social risks and might therefore also give too much weight to climate factors.

Perceived changes should be understood in the context of recent climatic developments. Mentioned climatic changes were comparable to other studies conducted in East Africa. Ogalleh et al. (2012) reported that farmers from Laikipia County perceived decreasing rainfall, increasing temperature and less predictable rainfall. Bryan et al. (2009) reported the perception of increasing temperature and decreasing rainfall for Ethiopian farmers. Even though some of the mentioned changes were not reflected in measured climate data, farmers' perception was determined by incidences during the last 5 – 10 years (Rao et al., 2011). In Laikipia these incidences included a severe drought in 2014 with significant impacts on crop production and rural livelihoods, causing hunger and water shortage (NDMA, 2014). Furthermore, the survey was conducted in May 2015, two months after farmers had experienced a delayed onset of the long rainy season. This increased farmers' awareness of a changed rain pattern and could also explain the large amount of farmers mentioning a later onset of rainy seasons and irregular rainfall.

Certain limitations have to be considered when interpreting the results. Firstly, the question on climate change perception was asked straightforward (“Have you perceived any climatic changes over the past few years?”), assuming that all farmers know what climatic changes are. Posing a question in such a direct manner might have increased the likelihood of farmers mentioning changed climatic factors because it was suggestive. Nevertheless, for this thesis it was more important to define which factors farmers perceive as changing and in which way they have changed, rather than if farmers knew what climate change is. Secondly, what was described for adaptation is also valid for climate change perception: access to information and training increases likelihood of farmers mentioning what they *knew* and not what they actually *perceived*. Thirdly, a bias due to differences between enumerators when translating from Kikuyu or Swahili to English cannot be excluded.

Results showed that farmers’ perception of climate was linked to crop productivity. Almost 20% of the surveyed farmers mentioned indirect effects of climate change, such as increased frequency of pests and diseases and reduced crop yield, indicating that farmers were not always able to discern between climate factors and climate impacts on agriculture. Secondly, farmers perceived most changes during months related to the growing season, when crops are at a critical growth stage. These results confirmed that the perception of long-term trends is subjective and is developed indirectly over the crop type or other factors relevant to the farmers' livelihoods (Osbaahr et al., 2011; Rao et al., 2011).

Differences in perception between sampled Sub-locations have shown that farmers referred to climate change at their specific location. As for temperature, climate data analysis revealed similar trends for both Kalalu and Matanya meteorological station. Also farmers’ statements were quite homogeneous and mostly in line with the measurements. Regarding precipitation, measured trends as well as statements were more controversial and exhibited geographical differences. Laikipia’s heterogeneity regarding topography led to different precipitation patterns and trends already within small distances.

Perception differed between farmers with high and low livelihood vulnerability regarding specific climatic factors. In general, only minor differences between the food crops and the horticultural farming system were revealed in regard to climate change perception. However, farmers growing food crops mentioned more often erratic rainfall and increased drought length as a changing factor. Lack of irrigation led to higher vulnerability of food crop farmers regarding moisture deficits, which could be one of the reasons why they perceived changes of rainfall more intensely.

17. Adaptation measures

Overall, results showed that reactions to climate change were diverse. Farmers were observed to have invested in several strategies at the same time. Firstly, some of them are more effective if applied in combination with others, such as the application of animal manure and artificial fertilizer (see also Tifton et al., 2008). Secondly, investing in several measures at a time reduces the risk of crop loss, if one of the measures fails to have the desired effect. Some of these strategies were applied in expectation of future events (*ex-ante*), while others were more a reaction to past events (*ex-post*), but all of them increased adaptive capacity in the long- or medium run.

In general, farmers in Laikipia County mentioned surprisingly many adaptation strategies. Results from Deressa et al. (2009) in Ethiopia and Bryan et al. (2009) in South Africa and Ethiopia indicated that 42% and 37%, respectively, of farmers were not adapting to climate change. These studies all used open-ended questions when asking for climate change adaptation. In the survey for this master thesis, all farmers with the exception of one had applied at least one of the listed adaptation measures. Thus, bearing in mind the results from other studies, the findings in this study were likely to be biased due to closed-ended question posing. As already described in section 14.1 there is no proof which of the mentioned strategies were actually applied and which farmers were only aware of. Conservation agriculture for example, was mentioned frequently in both farming systems. Conservation agriculture was introduced to the area 20 years ago, but a master thesis study by Schaefer (2009) showed that utilization of conservation agriculture on visited plots in Kalalu and Matanya was only little. More than 40% of the surveyed farmers did not know about conservation agriculture at all. This stands in contrast with the results reported in this study, where 70.8% of food crop farmers and 83.2% of horticultural farmers responded positively to using conservation tillage methods.

On the other hand it is quite possible that farmers in Laikipia County exhibited a slightly higher adoption rate of adaptation strategies compared to SSA average. In a more recent study in Kenya, Bryan et al. (2013) found that only 19 % of all participating farm households did not adapt to climate change. Kenya is the strongest economy in East Africa and is able to boost and attract development activities. Many agricultural organizations have been active in the region of Laikipia offering extension services, including CARITAS, Syngenta Foundation for Sustainable Agriculture, different conservancies and foundations and the Kenyan Government. Such services are likely to have increased farmers' awareness of climate change and of possible adaptation measures, as well as the adoption of the corresponding strategies.

The occurrence of certain measures was linked to characteristics of Laikipia County. Water resource exploitation practices were surprisingly rarely mentioned, considering the fact that many farmers wished for irrigation. This could be explained with the pressure that high

populations impose on scarce resources such as groundwater and river water in Laikipia County (Ulrich et al., 2012). Furthermore, many farmers expressed the wish to invest in the construction of rain-water harvesting structures (see Fig. E-1 in Appendix E). Rainfall is a water source, for which farmers do not stand in direct competition with each other and which they could exploit much more efficiently.

Adopted agricultural adaptation strategies reflected livelihood strategies and properties of both farming systems. Results were comparable to what has been found by Bryan et al. (2013) for Kenya. Common strategies mentioned were changes of crop variety, changes of planting dates, changes of crop type, planting trees, destocking and other livestock related strategies, fertilizer application and soil conservation practices.

Differences between the farming systems can be understood by considering properties of the farming system and the properties of adaptation measures. For example, higher access to irrigation among horticultural farmers compared to food crop farmers led to more adaptation strategies regarding water management. Higher access to financial resources was a probable reason for higher application of artificial fertilizer and agro-chemicals among horticultural farmers. Furthermore, higher crop diversity on horticultural farms and continuous production throughout the year made crop rotation a popular adaptation strategy among horticultural farmers. On the other hand, early and drought resistant varieties were in particular available for maize, making this measure more likely for food crop farmers. Furthermore, the higher number of adaptation strategies linked to livestock management were attributable to the importance of animal husbandry in the food crop farming system. Hence, different strategies in farming systems reflected on one hand that systems had a different ability to adapt; on the other hand it reflected where farmers put their priorities, depending on crop type and livelihood strategy. The horticultural farming system was a market-oriented system, where farmers invested much more in crop production strategies, while food crop farming system exhibited more crop risk-reducing strategies, in particular mixed cropping, changes of planting dates and livestock strategies.

These results led to the conclusion that horticultural farmers had a higher adaptive capacity compared to food crop farmers. In total, food crops farmers cited fewer adaptation strategies compared to horticultural farmers. Moreover, while located in the same area and exposed to the same climate, horticultural farmers reported experiencing less severe impacts on productivity compared to food crop farmers, namely less cases of crop failure (see Fig. A-2 in Appendix A). Such a situation is reminiscent to what has been described by Holler (2014): Wealthy households benefit from adaptive actions, while more vulnerable households cannot afford costly and sustainable investments. Rather, unsustainable coping strategies keep them stuck in a poverty trap. In this context, some authors argue that adaptation to climate change is just reproducing social injustice and is not a contribution to social equity (Holler, 2014).

Thus, as climate change progresses, social differences between horticultural and food crop farmers are likely to further increase. By investing in measures that improved crop productivity and crop income, horticultural farmers increased their adaptive capacity to climate change. In contrast, food crop farmers were more inclined to neglect crop productivity and tended to divert to non-agricultural activities, especially during times of drought. This situation could be described as a vicious cycle, with the absence of more effective adaptive strategies leading to a lower crop income, while lower crop income restrained farmers from investing in more sustainable strategies.

Informal networks and reliance on financial help from more wealthy neighbors played a crucial role regarding the capabilities to cope with drought impacts, especially among food crop farmers. Many of the more vulnerable farmers mentioned reverting to casual farm labor or borrowing money from neighbors in case of severe drought impacts. This indicated that wealthier farms were part of a larger social safety net, with major implications for individual farmers struggling with crop failure.

The situation in the food crop farming system as encountered in this study in Laikipia County should be alarming and calls for action regarding increase of productivity and sustainability of livelihoods. After all, Kenya is still a net importer of staple crops, meaning that at present there is not enough national production of staple crops to satisfy the country's food requirements.

18. Determinants of adaptation

The set of hypothesis for adaptation determinants for each adaptation measure depended on characteristics of the particular measure, but also on characteristics of the farming systems. In the following subsection, influential factors are first discussed regarding different adaptation measures and secondly, differences are considered between farming systems.

18.1. Comparison between adaptation measures

Determinants of adaptation were revealed to be linked to characteristics of adaptation measures. Cognitive factors were especially important in the case of agroforestry. This makes sense as this strategy exhibits long-term benefits, such as the reduction of erosion and carbon sequestration, requiring more extensive long-term planning than just the next season. Available workforce was significant for labor-intensive strategies, such as the application of animal manure and artificial fertilizer and the planting of trees. Age was positively associated with measures that have been practiced for a long time in the area, such as the application of animal manure and agroforestry. Older farmers seemed to be inclined to cling to traditional practices. Although not significant, it is still noteworthy that more innovative

and recently introduced practices like crop rotation, in-field water conservation and the application of artificial fertilizer all exhibited negative relationships with age.

Findings in other studies often emphasized differences between expensive and low-cost adaptation measures. Bryan et al. (2013) and Deressa et al. (2009) found that expensive measures such as agroforestry, fertilizer application, irrigation and soil & water conservation methods are often fostered by access to non-farm income, access to credit and extension services and household wealth. Cheaper measures such as changes in planting date and changes in crop variety are influenced by having access to weather information, education and social safety nets (Bryan et al., 2013; Deressa et al., 2009).

Such a clear distinction could not be made from the above-presented results. Expensive measures such as irrigation, agroforestry and the application of artificial fertilizer were influenced by access to extension services, access to farmers groups and cooperatives, available workforce as well as also cognitive factors in the horticultural system. Cheaper measures such as application of animal manure, late planting and in-field water conservation were influenced by age, available workforce, access to extension services and farmers groups and risk probability and severity in the food crop farming system. Thus, a separation of influential factors for expensive and cheaper adaptation measures was not as clear as in the studies mentioned above. This could also be rooted in the separation of the data into two farming systems, one having a higher and the other a lower income, thus eliminating effects of financial capital and income in the regression. Since income levels were different between farming systems, farmers had a different approach to different adaptation strategies. For example, agroforestry might have been an expensive measure for food crop farmers, while for horticultural farmers it was not. Thus, interpreting the established determinants of adaptation had to be done considering specific farming system characteristics (see next subsection). Making general assumptions from the above-presented results that are valid for both systems did not seem justified.

18.2. Comparison between farming systems

The present comparison between farming systems revealed considerable differences regarding factors influencing adaptation. Access to information and cognitive factors seemed to be more important factors among horticultural farmers. Access to human capital (available workforce) and access to farmers groups – which eased access to credit and resources – , were influential factors particularly in the food crop farming system.

These findings were comparable to results from a study by Bryan et al. (2009). Access to agricultural extension services was shown to improve adaptation in low, middle and high income farming systems. The same study revealed that perception of climate risks had a

high influence on adaptation of high-income farmers, while available resources were more important among low-income farmers.

Thus, as farm income increases the limiting factors shifted from access to resources and financial capital to the farmer's personal attitude and knowledge of his adaptation possibilities. Surprisingly, financial and physical resources, such as total income and total arable land did not have a significant influence on adaptation in the food crop farming system in this survey. Rather, access to extension services, access to farmers groups and available workforce were decisive factors. However, these factors still underline the importance of resource-access for adaptation, as available workforce demands for certain financial liquidity or access to other forms of payment for casual labor. Furthermore, farmers groups are a platform for sharing financial or physical resources among poorer farmers and can also ease credit access. While horticultural farmers received strong adaptation incentives from extension services by increasing knowledge and changing attitudes, adaptation among food crop farmers was fostered by access to formal and informal networks, which guaranteed higher access to physical, financial and informational resources and access to human power. This result showed that adaptation planners have to approach different farming systems in a fundamentally different way in order to achieve successful project implementation.

The presented results are also limited in the following way: As mentioned above, closed-ended question posing might have led to a bias, meaning that farmers appeared to apply more adaptation strategies than they actually did. If a large enough percentage of farmers enumerated adaptation measures that they were aware of but have not necessarily applied, access to information might have turned out to have a greater influence in the regression analysis than financial or physical resources. Thus, it is likely that the results underestimated the influence of financial resources and overestimated the influence of information access and training to climate change adaptation.

While livelihood diversification might be an initial trigger of adaptation for very isolated and vulnerable farming systems, it was no longer true in the case of Laikipia County, where the process has been going on for decades. A higher share of non-agricultural income had a negative influence on irrigation, late planting and application of animal manure in the food crop farming system. As already described above, advanced livelihood diversification led to fewer investments in agricultural practices among food crop farmers. Low significance of crop revenue for household income, coupled with frequent cases of crop failure, rendered farmers risk averse and unwilling to invest in new agronomic strategies. Farmers experienced that relying on non-agricultural business was more lucrative and less risk-prone, thus spurring them to abandon full-time agricultural activities. This process could increase with proceeding climate change and demands for immediate action.

Adaptation is an evolutionary process and conducting adaptation research means capturing just one moment in the whole development. Much adaptation has already occurred in Laikipia County and some farmers have increased their adaptive capacity in various ways during the past decades. This was reflected in the negative influence of risk severity - that is climate change impacts - on adaptation measures. During analysis preparation it became apparent that most impact-variables correlated negatively with the adoption of adaptation measures, indicating that adapted farmers experience less impact from drought compared to non- or less adapted farmers. Thus, drought impacts on farm productivity (risk severity) correspond actually to what has been described above as residual impact (Vulnerability) in Fig. II-1. Consequently, risk severity is a system characteristic that describes an adaptation outcome, rather than a triggering factor to adaptation. Late planting in the food crop farming system remained an exception, as it was positively associated with risk severity. Farmers experiencing high impacts from climate change were more likely to apply it.

VI. Conclusion

This chapter will first give a summary of obtained results and outline the final conclusions (section 19). Secondly, conclusions on the methodological and empirical approach are presented and recommendations for future adaptation research are given (section 20). Lastly, recommendations for adaptation planners and an outlook on possible future developments are outlined (section 21).

19. Summary of study and final conclusions

This study aimed at describing climate change perception, agricultural adaptation strategies and factors influencing adaptation in two different smallholder-farming systems. For this purpose a survey was conducted with 267 farmers engaged in horticultural or food crop farming in Laikipia County (Kenya). Firstly, temperature and precipitation trends were described by analyzing a time series of recorded data from two meteorological stations located in the study region. The data was then used for comparison with the farmers' climate change perception. Secondly, technological and agronomic adaptation measures were compared between both farming systems. Lastly, a binary logistic regression was conducted for single adaptation measures to identify determinants of adaptation. Hypothesized influential factors included a number of household variables and two cognitive factors, namely future expectations of climate change (risk probability) and currently perceived impacts from drought on agricultural production (risk severity).

19.1. Climate change perception

Results showed that Laikipia has experienced a strong temperature increase, while precipitation trends vary depending on the location, but with most changes occurring during the short rainy season (OND). Farmers' perception of climate change matched well with recorded climate trends in the case of temperature. Their perception of precipitation statements was sometimes contradictory to measured data. The majority of farmers perceived decreasing rainfall, increasing temperatures and a later onset of the rainy season. In general, differences of perception between farming systems were only marginal, but were evident to a greater extent between sampled Sub-locations. This is probably due to Laikipia's topographical heterogeneity.

It can be concluded that farmers' perception was influenced by agricultural activities during the year, as most precipitation changes were associated with months during the long- or short rainy season, when crops are at their critical growth stage. Furthermore, farmers seemed to have difficulty distinguishing between climate factors and crop performance on

their farm. When asked to name perceived climatic changes, many farmers mentioned indirect effects of climate change linked to crop productivity, such as an increase of crop pests and diseases, as well as a decline of crop yield. Also, food crop farmers mentioned more often an increased frequency of dry periods, pointing to a higher crop-vulnerability to these events, due to limited irrigation access. Lastly, farmers' perception was also influenced by recent climatic events, such as droughts in 2013/2014 and the late onset of the long rainy season in 2015.

19.2. Climate change adaptation measures

Adopted agricultural adaptation strategies reflected livelihood strategies and properties of both farming systems. Adaptation strategies among food crop farmers were mainly risk-reducing or reactive in nature, such as mixed- and inter-cropping, planting of early maturing varieties, conservation tillage, application of agro-chemicals and early planting. Adaptation strategies among horticultural farmers aimed primarily at intensifying crop production and were more innovative, such as crop rotation, conservation tillage, planting of early maturing varieties, application of agro-chemicals, animal manure and artificial fertilizer and introducing irrigation systems. In total, horticultural farmers exhibited more adaptation strategies and received more institutional support for their realization, compared to food crop farmers. It was concluded that willingness and ability to invest in inputs and agronomic strategies was higher in the horticultural farming system, as benefits from selling cash crops were greater and necessary information was available. Thus, these results indicated that horticultural farmers have a higher adaptive capacity compared to food crop farmers regarding climate change. As climate change progresses, social differences between horticultural and food crop farmers are likely to further increase, which should be alarming regarding the fact that staple food production and food safety in Kenya are already below a desirable level.

19.3. Determinants of adaptation

The findings outlined above were further undermined by identified factors influencing adaptation. Measures analyzed included application of animal manure, agroforestry, late planting and irrigation for food crop farmers and application of animal manure, agroforestry, in-field water conservation and application of artificial fertilizer for horticultural farmers.

Results showed that determinants for each adaptation measure depended on characteristics of the particular measure, but also on characteristics of the farming system. Regarding farming system differences, results showed that access to information and cognitive factors were decisive for most adaptation strategies in the horticultural farming system, while

access to human capital and access to farmers groups had a particular influence on strategies in the food crop farming system. It was concluded that as farm income increases, limiting factors shift from access to resources and financial capital to the farmers' personal attitude (risk perception) and knowledge of their adaptation possibilities. Furthermore, share of non-agricultural income was found to negatively influence most adaptation measures in the food crop farming system, thus contradicting results from other adaptation studies. In this study, share of non-agricultural income was interpreted as a proxy for livelihood diversification. This result showed that food crop farmers with access to less risk-prone income sources than agriculture have little motivation to invest in crop production.

Regarding characteristics of single adaptation measures it was found that access to workforce was decisive in the context of labor-intensive adaptation measures. Future risk expectations (risk probability) were positively associated with strategies entailing long-term benefits, while perceived climate change impacts (risk severity) were positively associated with low-cost adaptation measures in the food crop farming system. The latter indicated that more adapted households experienced fewer impacts from climate change. As opposed to other studies, direct effects of income or physical capital on the adoption of more expensive measures could not be established in this study.

19.4. Final conclusions

The discussion above has shown that the adaptation context in Laikipia County was extremely complex and shaped by historical and present climatic, economic and livelihood trends. Effects of livelihood diversification, population pressure, climate change and actions of development agencies were factors shaping the farming systems and its adaptation possibilities during the history and present day Laikipia County. Capturing all factors relevant to the adaptation context was extremely difficult. The comparison between both farming systems revealed increasing social differences between the market-oriented horticultural farming system and the self-sufficiency oriented, and more vulnerable, food crop farming system. Farmers related to climate via their crop types and in turn, adaptation options depended on specific factors of the farming system. Different farming systems experienced different impacts from climate change and reacted differently to the stressor, even within small spatial distances at the micro-level.

Geographical characteristics such as degree of isolation, access to water, fertile soil and markets are also crucial factors. They were addressed only marginally in this study and could be further explored in future studies. The discussion on cognitive factors has shown that the decision making process was more than just resource dependent, but of complex nature and influenced by a multiplicity of factors. The farmers' personal attitude towards the risk and future expectations, as well as knowledge of adaptation measures were

extremely important factors to trigger adaptation among the more productive horticultural farmers.

20. Conclusions on theoretical and empirical approach

The farming system approach has proven to be suitable to address climate change perception and adaptation issues. Climate change perception and adaptation were both related to system specific properties, such as cultivated crop types and biophysical crop-specific vulnerability, available resources and adaptation options. The approach allowed for system-specific conclusions and has revealed that adaptation planners need to employ different strategies, depending on the type of farming system, in order to foster climate change adaptation.

The PMT model by Grothmann and Patt (2003) was a useful theoretical framework to describe risk perception, although in most of the cases the variable *risk severity* didn't exhibit the expected relationship with adaptation measures. Measuring risk severity by using impact variables led to negative relationships with adaptation, indicating that risk severity is rather a system characteristic similar to vulnerability and not an influential variable on adaptation.

Quality of the binary logistic regression models was satisfactory, but there is room for improvement. Not all the explanatory variables from the PMT model were considered in this study. Also, access to natural capital was insufficiently represented. Capturing the relevant factors for explaining adaptation of complex socio-economic-ecological systems is extremely difficult, especially when considering more than one farming system at a time.

A quantitative survey with a structured questionnaire was considered suitable for a description of perception and adaptation in Laikipia County. However, in some cases using closed-ended questions led to biased answers, especially regarding the application of adaptation measures. It is very likely that, in actuality, the farmers applied fewer adaptation strategies than what they have mentioned. As described above, this issue might have led to a bias in the regression analysis, where financial and physical capital were probably underestimated for the benefit of informational access (e.g. extension services).

Lastly, the study is limited in the sense that adaptation was restricted to on-farm production practices at smallholder household level. Smallholder farmers have more than just on-farm technological or managerial options for climate change adaptation. Also financial, nutritional and even migratory or more transformative adaptation options exist.

Furthermore, climate change adaptation is a multi-level process, that demands for simultaneous action at all levels and the cooperation between different parties relevant to the smallholder adaptation context. Although this study focused on the micro-level, generated information can also support other relevant parties, such as the government,

other market participants and private institutions, to create a conducive environment for smallholder climate change adaptation in Laikipia County.

21. Recommendations and outlook

21.1. Recommendations for future research

Firstly, more research is needed on cognitive factors regarding climate change adaptation in SSA. In this survey it was shown that farmers might overestimate climate impacts and underestimate their own ability to cope or adapt to external stressors. More information on how farmers perceive their own ability to adapt or the efficiency of different measures could deliver useful information for adaptation planners to better understand barriers to adaptation.

Secondly, there are a countless variety of smallholder farming systems in Kenya, all exhibiting different system characteristics and embeddedness in the adaptation context. In recent years there has been considerable development activities in certain areas making the adaptation context much more complex. Further system specific research could enable adaptation planners to develop targeted strategies for specific farming systems.

The farming systems approach is useful because it takes into account multiple factors specific to the farming system and reveals system-specific opportunities and barriers. Future research should try to investigate whether results for specific farming systems, such as horticulture and food crops are transferable to other similar farming systems in Kenya or even SSA. Such evidence could support the development of widely applicable, but still system-targeted, adaptation measures.

Thirdly, farmers' access to information and resources should be further explored. Information accessed through extension services and farmers groups was a major factor fostering adaptation, but as statements of farmers show, informal networks could also be important channels of information. Results will help adaptation planners to choose the right channels to transfer knowledge and recommendation to farmers.

Lastly, future research should put emphasis on farm visits and assessment of adaptation strategies per farm plot to gain reliable information about on-farm adaptation practices. When approaching an entirely unknown system, it is useful to verify adaptation measures with qualitative approaches (focus group discussions, farm mapping, etc.), before applying quantitative methodologies.

21.2. Recommendations for adaptation planners

Results from this survey suggested, that adaptation planners need to be aware of the fact that horticultural and food crop farmers have completely different preconditions regarding their adaptation options, even if located in the same area. What might be an easy-to-implement strategy for a horticultural farmer, might be much more difficult for a food crop farmer, and may be perceived from a different standpoint.

Particular attention should be paid to the food crop farming system, if national staple food production is not to collapse under climate change. The food crop farming system is operating far below its potential productivity and measures are needed to boost production and decrease cases of total crop failure. Growing staple food needs to become an attractive and livelihood-maintaining business again. The promotion of farmers' organizations and groups is certainly a good way of triggering adaptation among food crop farmers. Credit access, access to resources and legal rights can be improved for farmers participating in such institutions.

Secondly, since climate trends have pointed at a precipitation increase in one of the stations, rainfall is a potential water source, that could be exploited with water harvesting and storage structures. Negative impacts from unpredictable rainy seasons would have less impact on the food crop farming system, reduce pressure on river ecosystems and make crop production more profitable.

Furthermore, adaptation to climate change could also include a shift from maize-based to sorghum and millet-based farming systems, which are local crop varieties and much more drought resistant compared to maize. For such a step the traditionally grown crop varieties would have to be re-introduced to the Kenyan market and to everyday diet. Changing people's diet is an extremely sensitive and difficult issue, however by giving the right incentives the government and also private companies could ease such a shift.

Switching from food crops to horticulture is also regarded an adaptation measure among smallholder farmers, but requires access to irrigation. At larger scale such a transformation is not desirable since staple crops are the primary source of carbohydrates and the foundation of food security.

In conclusion, developing targeted strategies for food crop farming systems should be imperative for the coming decade. It would also counteract the social injustice in the region and the loss of a traditional cropping system. Furthermore, since access to extension services and farmers groups were important determinants in the regression analysis, adaptation planners should carefully consider how knowledge can be transferred through these channels to smallholder farmers.

21.3. Outlook

Although farmers in Laikipia County are aware of many of their adaptation options, the impact of climate change is substantial and is likely to increase. Climate change will bring considerable challenges to smallholder farmers in Laikipia County, especially regarding the food crop farming system, which is extremely vulnerable to drought events. Increasing climate change is also likely to result in higher irrigation requirements, what could trigger off conflicts about the already pressured water resources. Both farming systems have very different preconditions. The results have shown that providing more information from external sources, as well as enable knowledge and resource exchange through grassroots organizations, could be promising starting points for Kenyan adaptation planners.

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Appendix A – Characteristics of farming systems

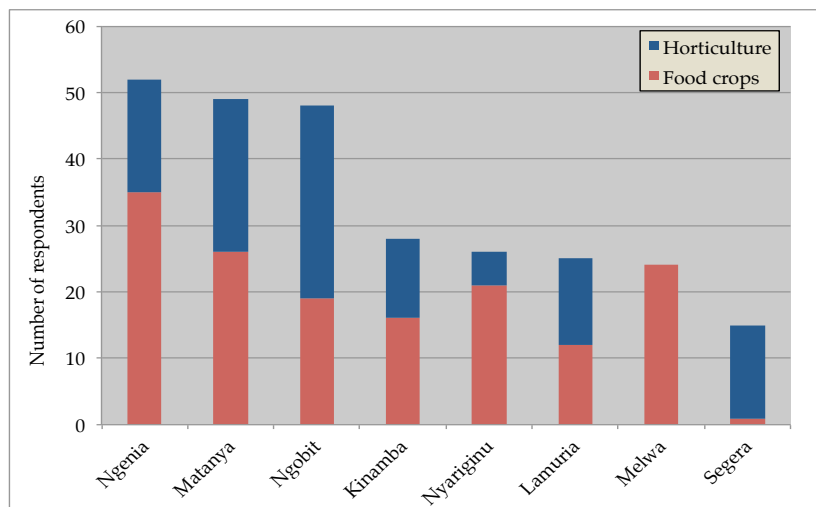


Fig. A-1 Distribution of sampled farmers in Laikipia County (n=267).

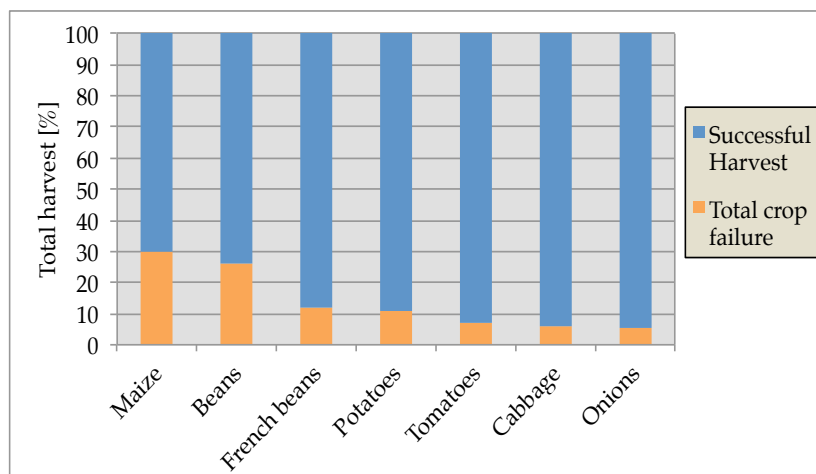


Fig. A-2: Average percentage of successful and unsuccessful harvesting (total crop failure) for most important crops (n=267)

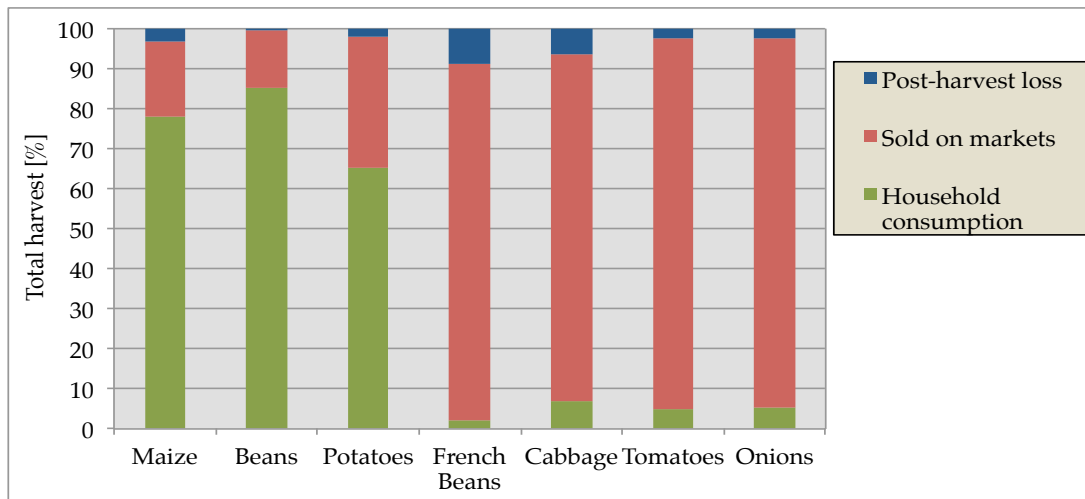


Fig. A-3: Fate of harvested crops. Percentage corresponds to average in 2014 (n=267)

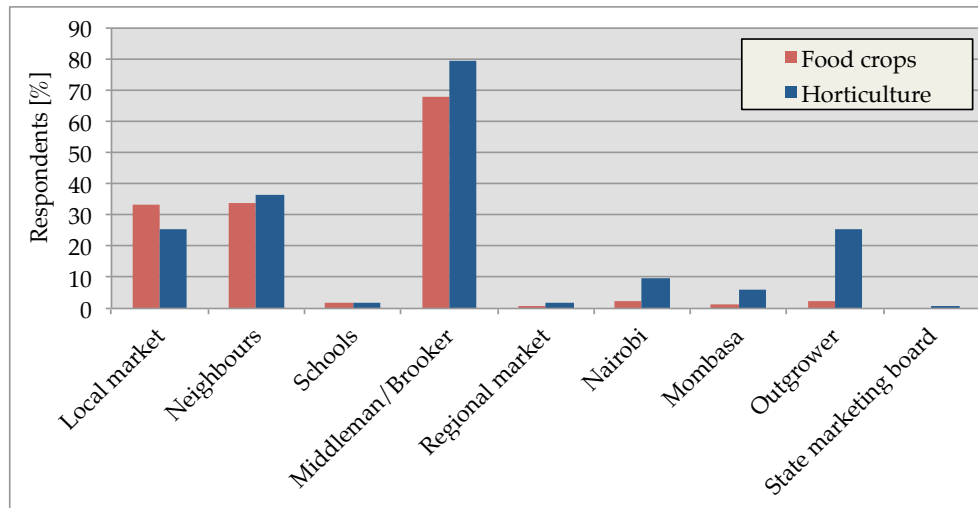


Fig. A-4: Accessed markets by food crops and horticultural farmers (n=267).

Appendix B – Climate change perception

Table B-1: Perceived climatic changes in Laikipia County. Total statements, percentage of farmers mentioned the change, percentage of food crops and horticultural farmers mentioned the changes.

Group	Statement	Total [%]	Food crops [%]	Horticulture [%]
Rainfall quantity	Less rainfall	60.30	61.04	59.29
	More rainfall	2.25	3.25	0.88
Timing of rainfall	Later onset	37.45	40.26	33.63
	More erratic and unpredictable rainfall	21.35	18.83	25.66
	Earlier cessation of rainy season	11.61	12.99	9.73
	Shorter duration of rainy season	4.12	3.25	5.31
	Earlier onset	1.87	2.60	0.88
	Longer duration of rainy season	0.37	0.00	0.88
	Later cessation of rainy season	0.37	0.65	0.00
Characteristics of single rain events	Shorter duration of rain events	5.62	4.55	7.08
	Reduced rainfall intensity	4.49	5.19	3.54
	Higher rainfall intensity	4.12	3.90	4.42
	Less frequent rain events during rainy season	4.12	6.49	0.88
Average temperatures	More frequent rain events during rainy season	0.37	0.65	0.00
	Temperature has decreased	2.25	1.30	3.54
	Temperature has changed (unspecified)	10.49	7.79	14.16
Seasonal temperatures	Temperature has increased	45.69	42.86	49.56
	Cold seasons have become colder	1.87	0.65	3.54
	Cold seasons have become longer	3.00	0.00	7.08
Inter-annual variability	Temperature variability has increased	3.00	4.55	0.88
Daily temperatures	Day temperatures have increased	0.37	0.65	0.00
	Frosty mornings	0.75	0.65	0.88
	Night temperatures have decreased	1.12	1.95	0.00
Dry periods	Frequency of dry periods has increased	10.11	9.74	10.62
	Duration of dry periods has increased	17.60	20.78	13.27

Table B-2: Percentage of mentioned changes per study site.

Sub-location	Less rainfall [%]	Later onset [%]	Higher temperature [%]	Longer dry periods [%]	More frequent dry periods [%]	Cold seasons have increased [%]	More erratic and unpredictable rain [%]
Nyariginu	38.5	42.3	42.3	23.1	3.8	0	11.5
Ngenia	48.1	42.3	34.6	13.5	7.7	5.8	7.7
Matanya	61.2	38.8	51	12.2	10.2	6.1	22.4
Ngobit	64.6	37.5	56.3	18.8	10.4	2.1	12.5
Lamuria	80	20	52	20	4	0	36
Kinamba	64.3	39.3	35.7	25	3.6	3.6	42.9
Melwa	67.2	41.5	45.7	17.9	29.3	0.0	26.5
Segera	73.3	26.7	53.3	13.3	20	0	33.3

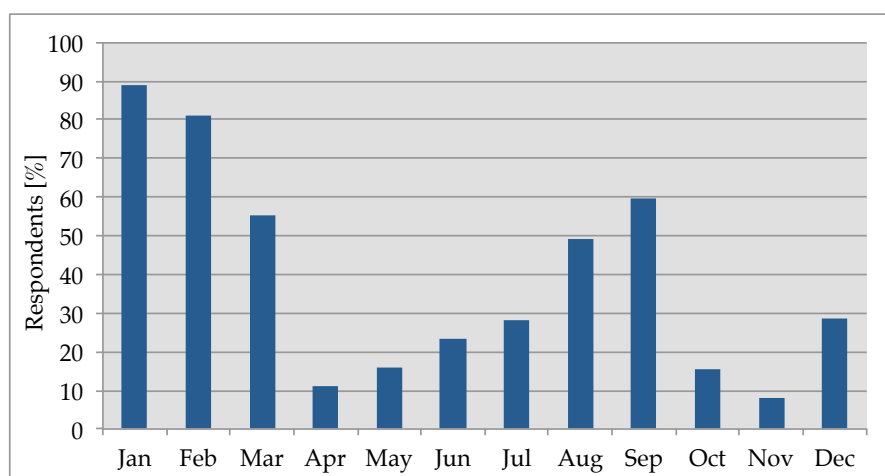


Fig. B-1: Perceived occurrence of dry spells during the year (n=267).

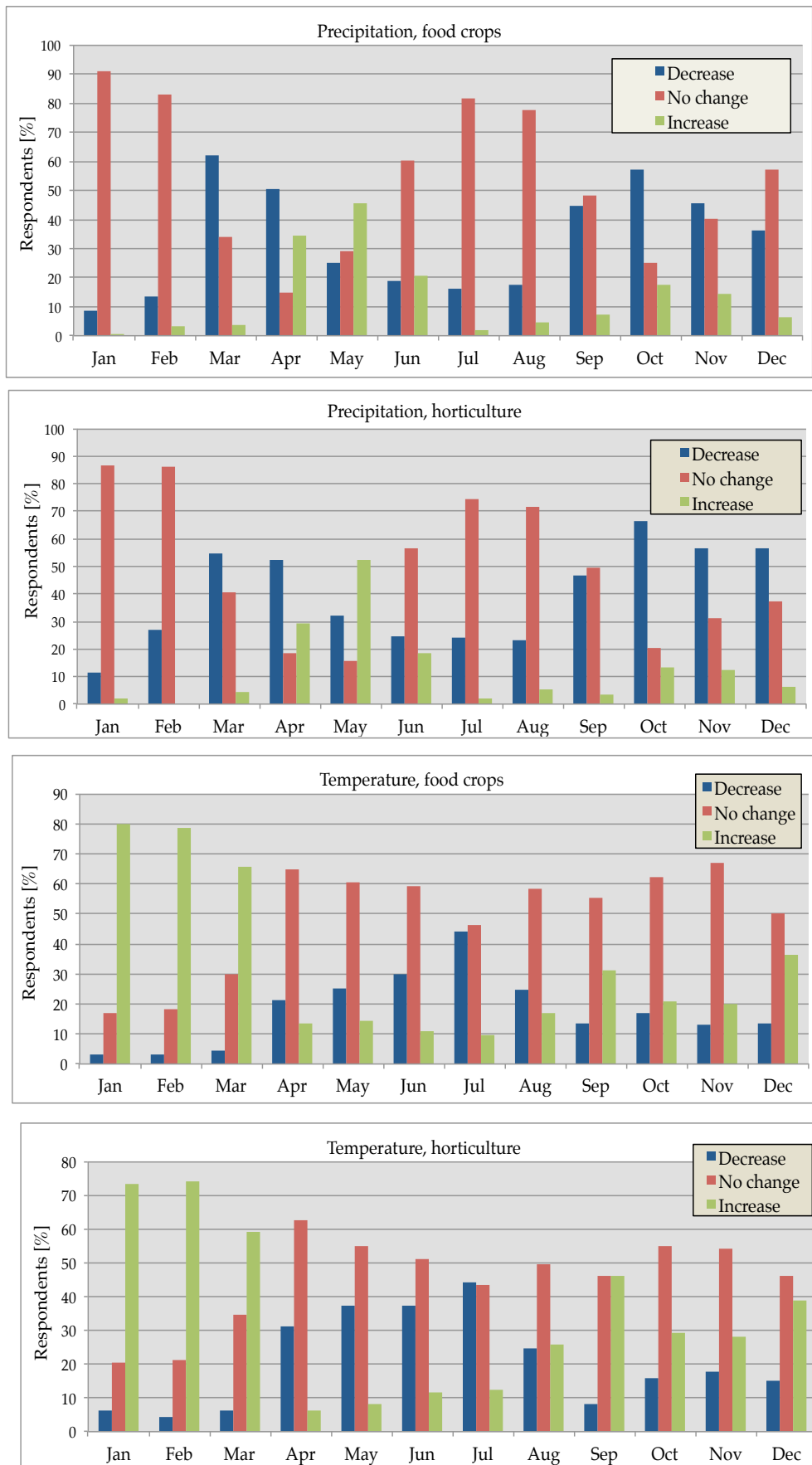


Fig. B-2: Perceived monthly temperature and precipitation changes (n=267).

Appendix C – Climate data plots

Table C-1: Gaps in the timeline of Matanya and Kalalu station for temperature and precipitation.

	Temperature	Precipitation
Kalalu	01 Jan – 14 Jan 86	
	01 – 04 Jun 01	
	12 Jun 03	Jan 04
	Jan – 10 Aug 06	Jan – 11 Aug 06
	01 Sep 06	27 Nov 14
	29 Sep 12	
Matanya	31 Dec 04	
	01 Jan – 17 Mar 86	01 Jan – 28 Feb 86
	10/11/17 Aug 87	10/11/17 Aug 87
	30/31 Dec 87	
	21/27/30 Apr 90	
	01 Apr – 31 May 98	
	06 Feb 01	
	1 – 4 Jun 01	
	01 Mar 03	
	05 Juli 06 – 11 Feb 09	01 Sep 06 – 11 Feb 09

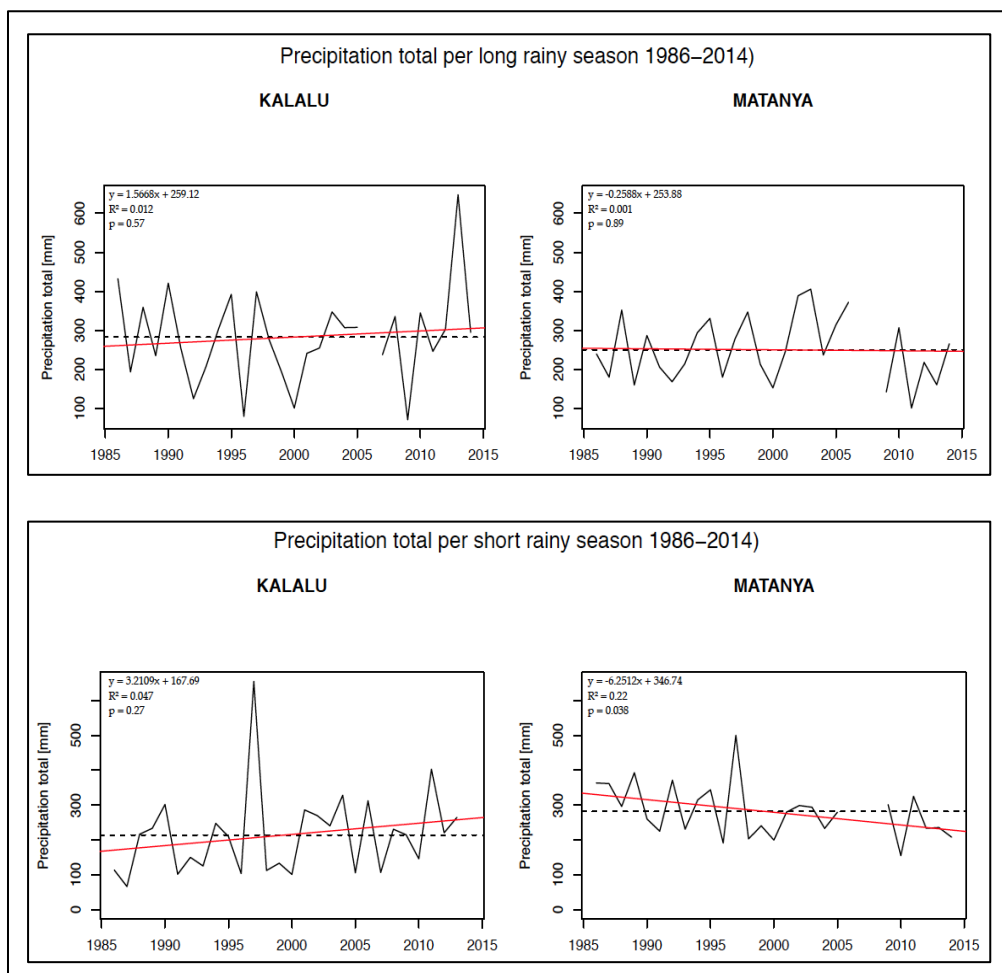


Fig. C-1: Total seasonal rainfall trends 1986 – 2014.

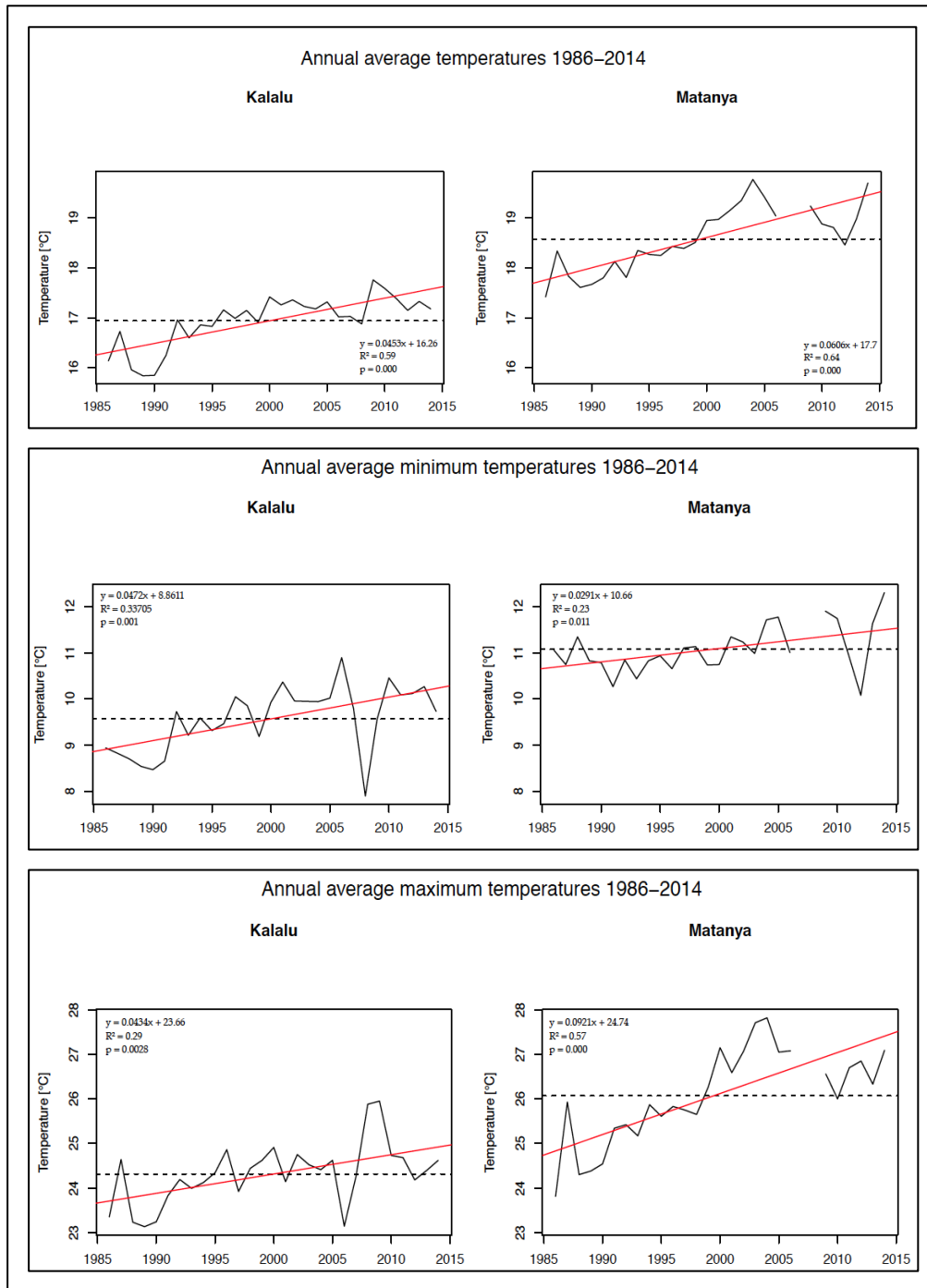


Fig. C-2: Average, average maximum and minimum temperature trends 1986 – 2014.

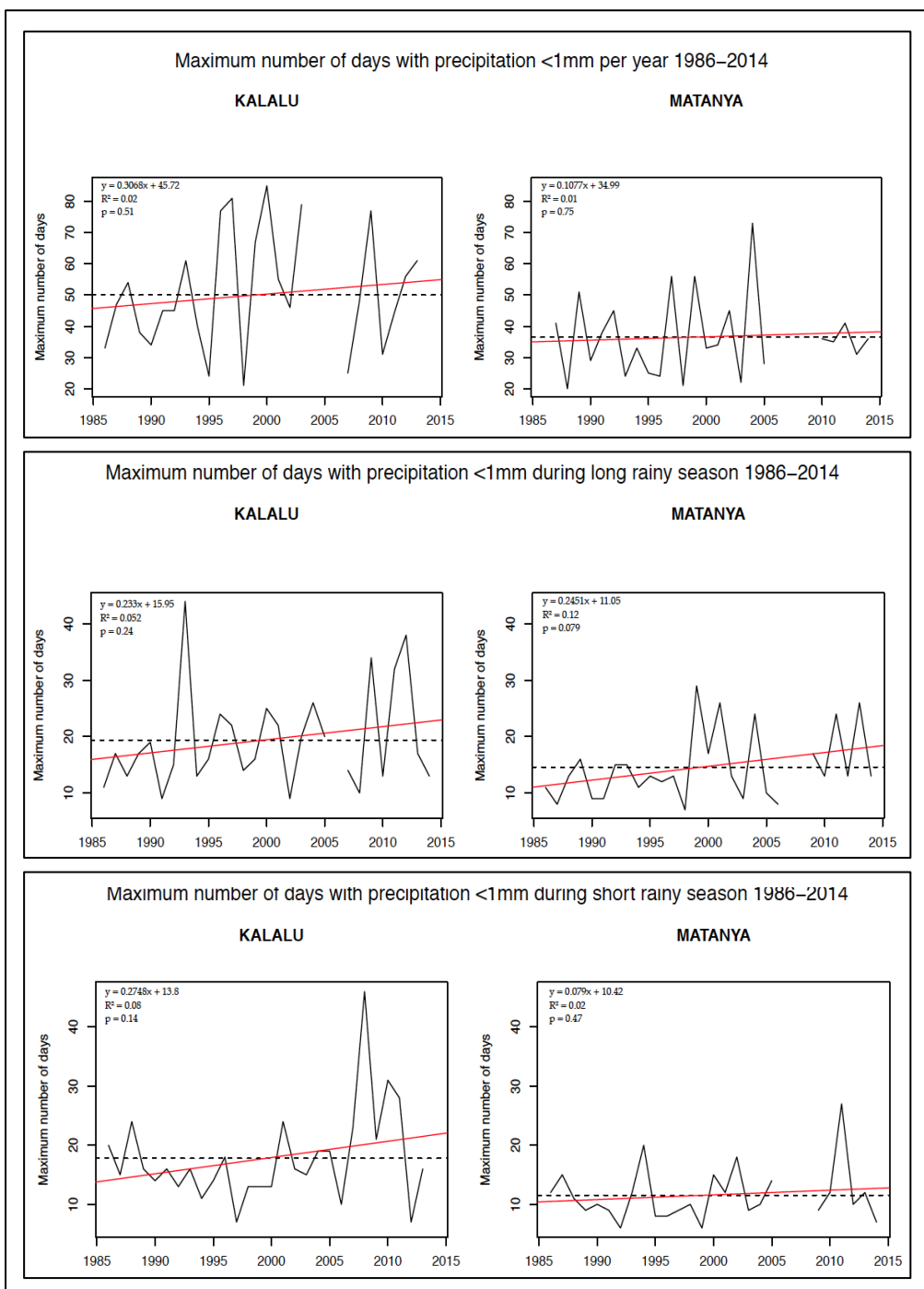


Fig. C-3: Consecutive dry days (CCD): annual and seasonal trends 1986 – 2014.

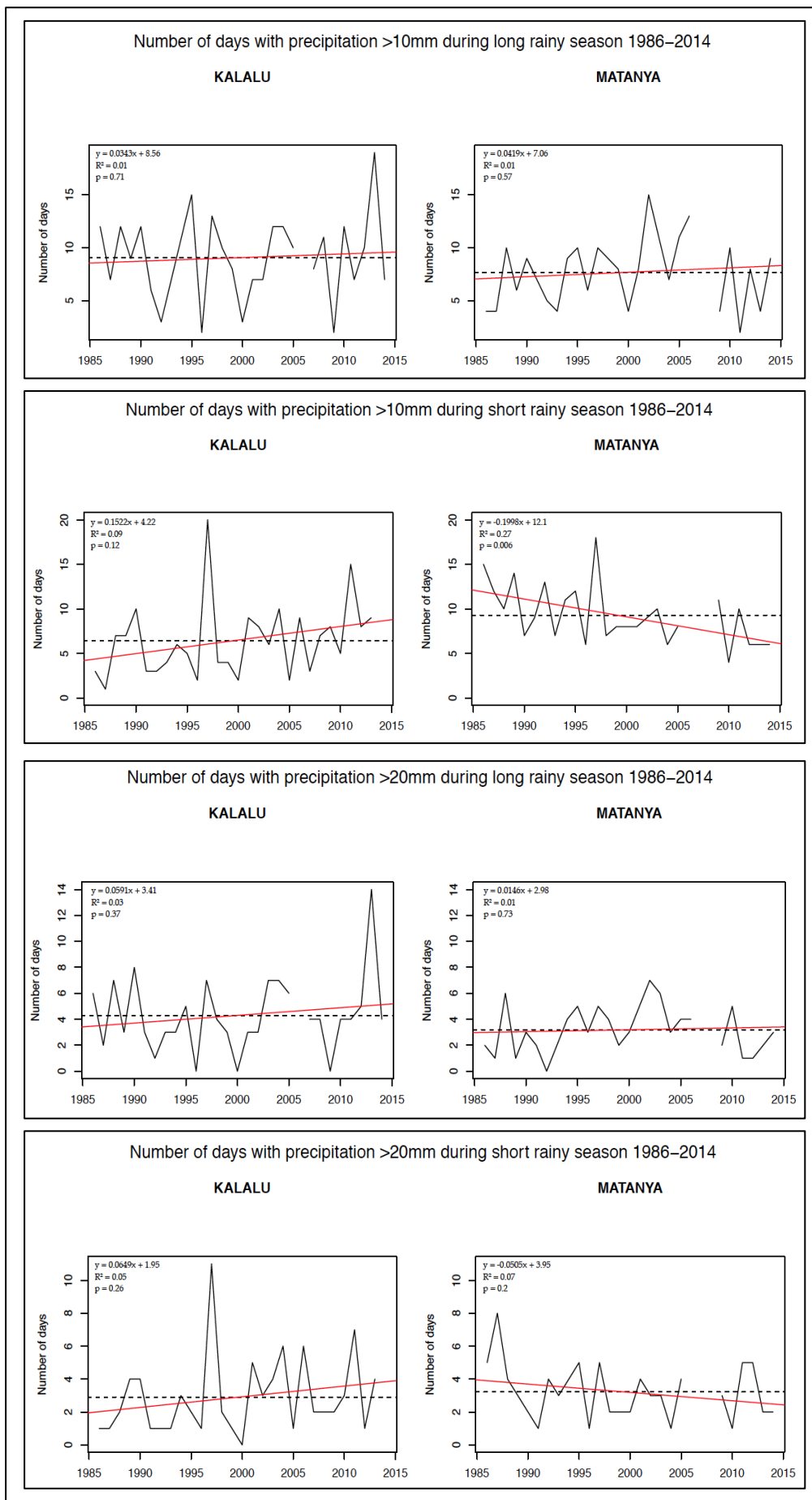


Fig. C-4: Number of heavy precipitation days >10 mm and >20 mm: seasonal trends 1986 – 2014.

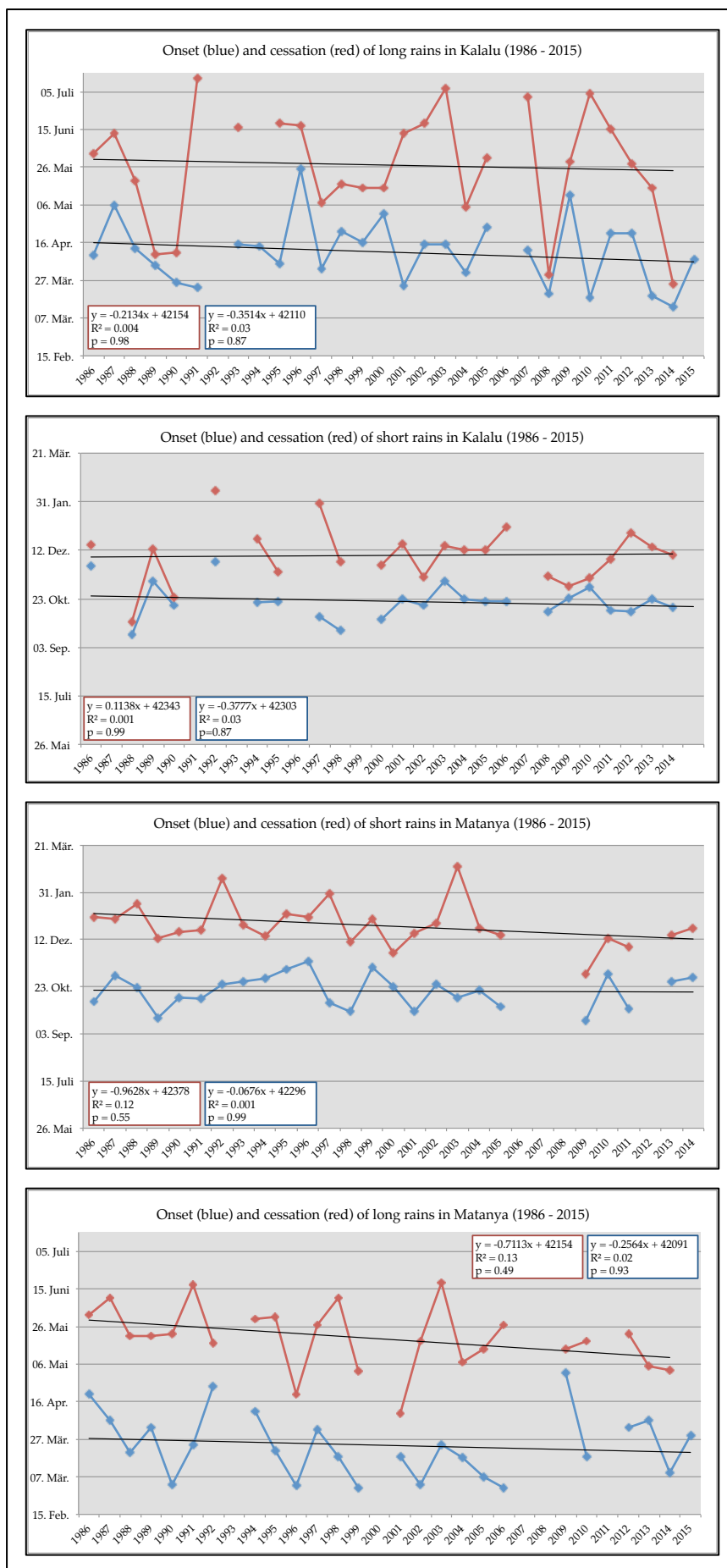


Fig. C-5: Onset and cessation of the rainy seasons in Kalalu and Matanya 1986-2015

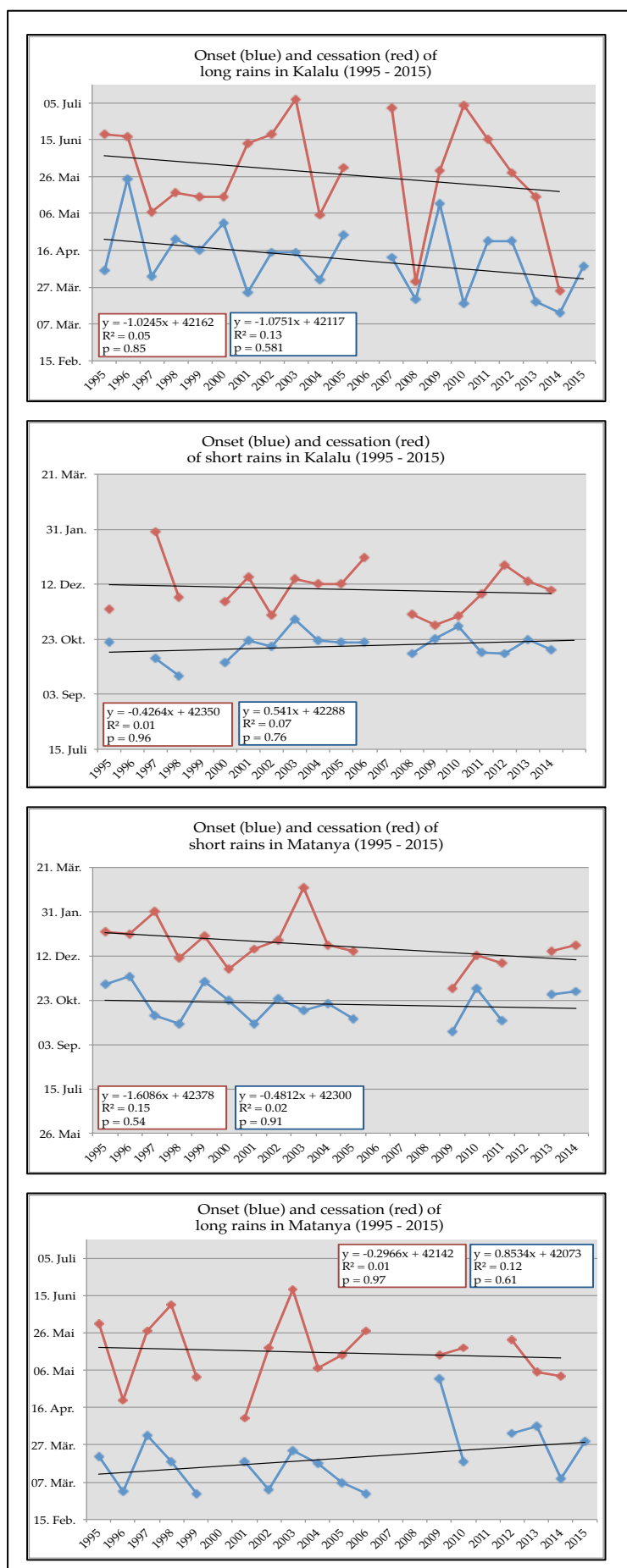


Fig. C-6: Onset and cessation of the rainy seasons in Kalalu and Matanya 1995-2015.

Appendix D – Correlation explanatory variables

Table D-1: Pearson correlation (two-sided) between explanatory variables. Significant correlations are indicated with * if $p < 0.05$ and ** if $p < 0.01$.

Food crops												
No.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
I	1											
II	0.178*	1										
III	0.066	-0.087	1									
IV	-0.06	-0.266**	-0.003	1								
V	0.204*	-0.126	0.319**	0.132	1							
VI	0.199*	-0.023	0.197*	0.124	.249**	1						
VII	-0.016	0.035	0.028	0.144	0.002	0.074	1					
VIII	0.161*	-0.009	0.163*	0.159*	0.011	-0.038	0.297**	1				
IX	0.173*	-0.053	0.259**	-0.064	0.364**	-0.053	-0.102	0.026	1			
X	0.04	-0.059	0.103	0.086	-0.129	-0.109	0.055	0.114	-0.048	1		
XI	0.037	-0.146	-0.056	0.127	-0.11	0.01	-0.188*	0.027	-0.018	0.032	1	
XII	-0.009	-0.220**	0.025	0.104	-0.195*	0.255**	-0.088	-0.258**	-0.155	0.129	0.183*	1

Horticulture												
No.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
I	1											
II	-0.044	1										
III	0.216*	0.104	1									
IV	-0.108	-0.056	0.065	1								
V	0.164	-0.189*	0.091	0.206*	1							
VI	-0.026	0.12	0.197*	0.228*	0.313**	1						
VII	-0.007	0.08	0.038	0.054	-0.073	-0.089	1					
VIII	0.036	0.094	-0.02	-0.177	-0.014	-0.05	0.251**	1				
IX	0.025	-0.159	0.053	0.022	0.220*	0.001	-0.258**	-0.06	1			
X	0.007	0.066	0.11	0.063	0.013	0.203*	-0.114	-0.076	0.086	1		
XI	-0.133	0.051	-0.188*	-0.071	-0.137	-0.178	-0.005	-0.13	-0.1	-0.006	1	
XII	0.058	-0.069	0.077	0.186*	0.083	0.136	0.047	-0.367**	0.073	0.047	-0.044	1

Appendix E – Additional open questions

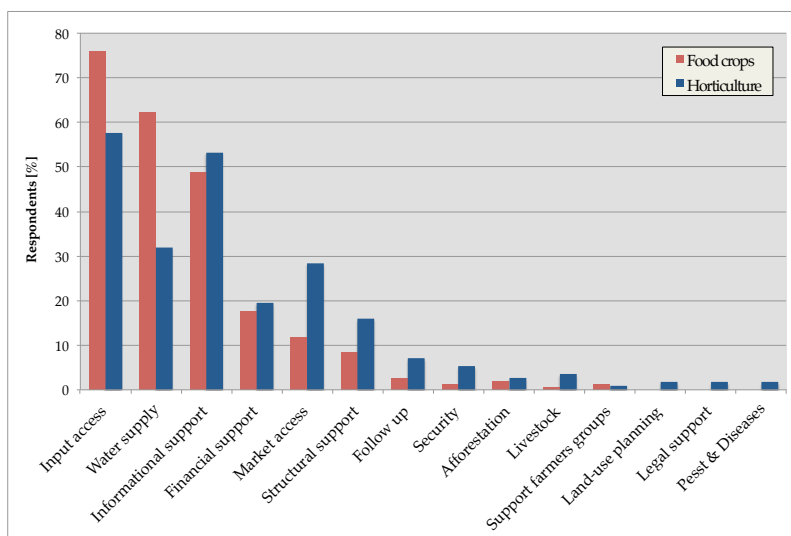


Fig. E-1: Issues where farmers require support (n=267). *Water supply* includes: the construction water harvesting facilities (dams, tanks) and water supply from rivers or tapped water. *Informational support* includes: extension services from private or governmental organizations, access to weather information, market information and information on technological innovations.

Appendix F – Focus Group Discussion Guideline

Focus Group Discussion climate change perception & adaptation

Time: 10-12.00 Location: Ibis Hotel

Questions:

1. Introduction: Greetings, explain aim and duration of focus group discussion
Make a profile from each respondent: Name, origin, major crop enterprises

2. Climate change perception:

Aim:	Questions:	Comment:
Find out if there are regional differences in changes of climate	<i>Have you noticed any changes in climate during the past few years?</i>	Make a list on the white board, if too many items -> group them; let everyone speak
Find out relative importance of each change	<i>Which of these changes are the most significant for agricultural production?</i>	Make a ranking with the items on the list

3. Climate change impacts

Aim:	Questions:	Comment:
Find out what impacts experience farmers (on crops) from climate change / drought in particular	<i>What impacts do you experience from each of these items from the list?</i>	Go through the list (or grouped list) and make a ranking of biggest impacts

4. Adaptation strategies

Aim:	Questions:	Comment:
Find out what farmers do to adapt to drought in particular	<i>Is there anything you can do to make your farm more resistant to future climate change impacts?</i>	Make a list of adaptation measures against three most important impacts from climate change (see Q3), if possible: gather some information on crop specific possibilities (maize, beans, cabbages)
Find out which of these measures are the most helpful	<i>Which of the measures on the list would you say will help you the most?</i>	Make a ranking of the three most helpful measures
Find out the particular benefit of each measure	<i>What is the particular benefit of each of these measures?</i>	Add the particular benefit for each measure to the list
Find out easiness to implement and drivers of implementation	<i>Which of the measures on the list would you say are the easiest to implement and why?</i>	Make a second ranking of the list and add drivers and barriers of implementation

5. Institutional context

Aim:	Questions:	Comment:
Find out what kind of external help farmers get in this region	<i>Where and what kind of help can you get to help you with improving something on your farm?</i>	Collect comments (include informal help)
Find out about benefits / critique points regarding this help	<i>Is it beneficiary for you to receive this help? If yes why, if no why not?</i>	Collect comments

Final question:

What are your next plans for your farm?

Appendix G – Questionnaire

Q-No (to be filled out by researcher): _____ 1

QUESTIONNAIRE: Farmers' perception and adaptation to climate change

Coding: 1:Yes, 0:No, -99:Don't know, -88:N/A Checked (by researcher after data collection)

QUESTIONNAIRE IDENTIFICATION

1. Date of interview: / /

2. Start time: _____

3. End time: _____

4. Name of enumerator: _____

5. District: _____ (1:Laikipia East, 2:Laikipia West, 3:Laikipia Central, 4:Laikipia North)

6. Location: _____ (1:Matanya, 2: Nyariginu, 3:Ngenia, 4:Tigithi, 5:Ngasenda, 6:Ngobit 7:Other: _____)

INTRODUCTORY STATEMENT

Hello, my name is ____ . This is a research project from University of Basel in Switzerland. The purpose of this survey is to get information about the weather in your region and your farming practice. Please feel free to answer the questions. Data will be aggregated from other farmers in your region and confidentiality will be maintained. Your answers will be noted down by me.

7. What is your full Name? _____

8. Telephone Number: _____

9. What has been your major crop during the last 12 months (in terms of area planted)? _____ (1:Maize, 2:Vegetables)

SECTION A: HOUSEHOLD VARIABLES

In the first section you will be asked questions about yourself, your household and your farming activities.

PERSONAL INFORMATION

10. In which year were you born? _____

11. Gender: _____ (1: Female, 2: Male)

12. Have you attended school? _____ (1:Yes, 0:No)

IF YES:

12.1 Please specify:

	(1: Yes, 0: No)	How many years?
a) Primary school?		
b) Secondary school?		
c) College or technical school?		
d) University?		
e) Informal education?		

13. In which year did you start farming? _____

14. Who is the person in your household taking most of the decisions on farming activities? _____ (1:Wife, 2: Husband, 3:Son, 4:Daughter, 5: Him- or herself (single household), 6: Other, specify: _____)

HOUSEHOLD INFORMATION

15. What is the number of people that were dependent on your farm production in the last 12 months? _____

Q-No (to be filled out by researcher): _____ 2

16. How many people work on a regular or casual basis on your farm during the last 12 months?

a) Family member (not paid)	b) Casual labour (in kind)	c) Casual labour (paid)	d) Fully employed (paid)

LAND USE

	17. How many acres do you own yourself?			17.1 How many acres are rented in?			17.2 How many acres are rented out / given out in kind?
	Homestead	Arable land	Grazing land	Homestead	Arable land	Grazing land	
a) Laikipia:							
b) Other Regions:							

18. Has your arable land increased, decreased or stayed the same since you started farming? _____ (1:Increased, 2:Decreased, 3:Stayed the same)

19. What was your major crop (in terms of area planted) during long rains this year (March, April, May 2015)?

	19.1 How many acres did you plant (from self-owned and rented in land)?	19.2 Did you irrigate this crop? (1:Yes, 0:No)
a)		
b)		
c)		

(1:Maize, 2:Common beans, 3:French beans, 4:Potatoes, 5:Kale, 6:Onions, 7:Spinach, 8:Cabbage, 9:Garden peas, 10:Snow peas, 11:Tomatoes, 12:Capsicums, 13:Other, specify: _____)

20. What was your major crop (in terms of area planted) during short rains last year (Sept, Oct, Nov 2014)?

	20.1 How many acres did you plant (from self-owned and rented in land)?	20.2 Did you irrigate this crop? (1:Yes, 0:No)	20.3 What was the total harvest? (kg)	20.4 How much did you put aside for self-consumption? (kg)	20.5 How much did you sell? (kg)	20.6 What is the market price for this crop? (ksh/kg)
a)						
b)						
c)						

21. What was your major crop (in terms of area planted) during long rains last year (March, April, May 2014)?

	21.1 How many acres did you plant (from self-owned and rented in land)?	21.2 Did you irrigate this crop? (1:Yes, 0:No)	21.3 What was the total harvest? (kg)	21.4 How much did you put aside for self-consumption? (kg)	21.5 How much did you sell? (kg)	21.6 What is the market price for this crop (ksh/kg)
a)						
b)						
c)						

22. What was your major crop (in terms of area planted) during short rains 2013 (Sept, Oct, Nov 2013)?

	22.1 How many acres did you plant (from self-owned and rented in land)?	22.2 Did you irrigate this crop? (1:Yes, 0:No)
a)		

Q-No (to be filled out by researcher): _____ 3

b)		
c)		

23. What was your major crop (in terms of area planted) during long rains 2013 (March, April, May 2013)?

	23.1 How many acres did you plant (from self-owned and rented in land)?	23.2 Did you irrigate this crop? (1:Yes, 0:No)
a)		
b)		
c)		

If Irrigation was mentioned in question 20 or 21 continue here! Otherwise go directly to question 27.

24. What methods of irrigation did you use in 2014? _____ (1:Flood irrigation 2:Water pipe, 3:Sprinkler, 4:Drip, 5:Other, specify: _____)

25. What was the major source of your irrigation water in 2014? _____ (1:Harvested water (ponds, tanks, dams), 2:Shallow well/Borehole, 3:River, 4:Tapped water, 5:Other, specify: _____)

26. How would you describe the reliability of this water source during the cropping season?

Very unreliable ← $\begin{matrix} \text{Sometimes reliable} \\ \text{Sometimes unreliable} \end{matrix}$ → Very reliable
-5 -4 -3 -2 -1 0 1 2 3 4 5

27. Do you use fertilizer? _____ (1:Yes, 0:No)

IF YES:

28. What type of fertilizer did you use in 2014? _____ (1:Yes, 0:No) 28.1 How much did you apply (kg/acre)?

a) Animal manure		
b) Chemical fertilizer		
c) Other, specify:		

29. How difficult do you find it to maintain soil fertility?

Very difficult ← $\begin{matrix} \text{Sometimes easy} \\ \text{Sometimes difficult} \end{matrix}$ → Very easy
-5 -4 -3 -2 -1 0 1 2 3 4 5

LIVESTOCK

30. Does your household have livestock? _____ (1:Yes, 2:No)

IF YES:

31.1 How many heads of livestock do you currently have?

	Number	31.1 How much do you think it is worth? (total in Ksh)	Number	31.1 How much do you think it is worth? (total in Ksh)
a) Oxen			g) Pigs	
b) Dairy Cattle			h) Poultry	
c) Beef			i) Camels	
d) Donkeys			j) Other:	
e) Goats			k) Other:	
f) Sheep			l) Other:	

Q-No (to be filled out by researcher): _____ 4

31.2 How big was your income from selling animal products or animals during the last 12 months? _____ ksh

ACCESS TO INPUTS AND OUTPUT MARKET

32. Which inputs do you buy regularly for your farming practice?

	(1:Yes, 0:No)	32.1 How difficult or easy is it for you to obtain these inputs? Very difficult ← $\begin{matrix} \text{Sometimes easy} \\ \text{Sometimes difficult} \end{matrix}$ → Very easy -5 -4 -3 -2 -1 0 1 2 3 4 5
a) Good quality seeds		
b) Seedlings		
c) Fertilizer		
d) Pesticides		
e) Herbicides		
f) Machinery/Equipment		
g) Other:		

33. Where do you sell your major crop? _____ (1:Yes, 0:No)

a) Local market	
b) Nairobi market	
c) International market (Exporting)	
d) To Neighbours	
e) To Middleman/Brooker	
f) To the state marketing board	
g) Other:	

34. What difficulties do you experience to transport your major crops to the market place? _____ (1:Yes, 0:No)

a) Bad road conditions	
b) Access to vehicles	
c) Lack of transportation boxes	
d) Other:	

35. During which months of the year are prices usually high or low for your major crop? (1:Average, 2:Low, 3:High)

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
a) Maize												
b) Vegetables												

INCOME

36. Do you have any other sources of income besides agriculture (crops and livestock on farm)? _____ (1:Yes, 0:No)

IF YES:

37. What was the income from the source besides agriculture during last 12 months? _____ ksh

Q-No (to be filled out by researcher): _____ 5

CAPITAL ASSETS

38. How many of these agricultural assets do you own?

	Number	38.1 How much do you think it is worth? (Total in Ksh)		Number	38.1 How much do you think it is worth? (Total in Ksh)
a) Carts			p) Solar power		
b) Wheel barrows			q) Windmills		
c) Hoes/Jembes			r) Other:		
d) Tractors			s) Other:		
e) Pangas/Slashers			t) Other:		
f) Plough					
g) Water pumps					
h) Pipes for irrigation system					
i) Generator					
j) Planters					
k) Ridgers					
l) Drippers for irrigation					
m) Green house					
n) Vehicles/Motorbikes/Bicycles					
o) Knapsack					

SECTION B: PERCEPTION OF CLIMATE CHANGE
In the next section you will be asked questions about changes in crop yield and weather.

PERCEIVED CHANGES IN CROP YIELD

39. Has your crop yields increased, decreased or stayed the same since you started farming? _____ (1:Increased, 2:Decreased, 3:Stayed the same)

IF INCREASED:

40.1 How relevant were the following factors for increasing your crop yield?

	Not relevant at all	1	2	3	4	5	6	7	8	9	10	Very relevant
a) Change in agricultural practice (conservation agriculture, introduction of fertilizer, pesticides)												
b) More favorable weather conditions (more rainfall)												
c) Drought resistant varieties												
d) Pest & disease resistant varieties												
e) Other:												

Q-No (to be filled out by researcher): _____ 6

IF DECREASED:

40.2 How relevant were the following factors for decreasing your crop yield?

	Not relevant at all	1	2	3	4	5	6	7	8	9	10	Very relevant
a) Less access to agricultural inputs (seed, fertilizer)												
b) Less favorable weather conditions (changes in rainfall, droughts, floods, frost, hail)												
c) More crop diseases and pests												
d) Other:												

PERCEIVED PROBABILITY & SEVERITY

41. Do you think climate will become better or worse for agriculture in the future (5-10 years from now)?

Very much worse ← $\begin{matrix} \text{Sometimes better} \\ \text{Sometimes worse} \end{matrix}$ → Very much better

42. Do you think your agricultural production will be harmed or will profit by this change in the future (5-10 years from now)?

Harmed very much ← $\begin{matrix} \text{Neither harmed} \\ \text{Nor profit} \end{matrix}$ → Profit very much

PERCEIVED CLIMATE CHANGE

43. Have you noticed any changes in climate during the past few years? _____ (1:Yes, 0:No)

IF YES:

44. Please indicate what changes you have noticed.

Changes noticed:

a)	e)
b)	f)
c)	g)
d)	h)

45. Do you feel that rainfall has increased or decreased during certain months in the past few years? _____ (1:Yes, 0:No)

IF YES:

46. Please specify during which months: (1:rainfall has increased, -1:rainfall has decreased, 0:no change)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec

47. Have you noticed any changes in rainfall intensity in the past few (5) years? _____ (1:Yes, 0:No)

IF YES:

48. Please specify what has changed and how much.

Q-No (to be filled out by researcher): _____ 7

	(1:Yes, 0:No)	Substantially decreased ← -5 -4 -3 -2 -1 0 1 2 3 4 5 → Substantially increased Sometimes increase, sometimes decrease
a) Intensity of rainfall during long rains		
b) Intensity of rainfall during short rains		

49. Have you noticed any changes in the duration of rain events? (days or hours) _____ (1:Yes, 0:No)

IF YES:

50. Please specify what has changed and how much.

	(1:Yes, 0:No)	Substantially decreased ← -5 -4 -3 -2 -1 0 1 2 3 4 5 → Substantially increased Sometimes increase, sometimes decrease
a) Duration of rain during long rains		
b) Duration of rain during short rains		

51. Have you noticed any changes of the onset date or end date of the short or long rains in the past few (5) years? _____ (1:Yes, 0:No)

IF YES:

52. Please specify what has changed and how much.

	(1:Yes, 0:No)	Substantially earlier ← -5 -4 -3 -2 -1 0 1 2 3 4 5 → Substantially later Sometimes later, sometimes earlier
a) Long rains onset		
b) Long rains end date		
c) Short rains onset		
d) Short rains end date		

53. Do you feel certain months of the year have become colder or warmer in the past few (5) years? _____ (1:Yes, 0:No)

IF YES:

54. Please specify during which months: (1:temperature has increased, -1:temperature has decreased, 0:no change)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec

55. Have you noticed any changes concerning dry periods? _____ (1:Yes, 0:No)

IF YES:

56. Please specify what has changed and how much.

	(1:Yes, 0:No)	Substantially shorter ← -5 -4 -3 -2 -1 0 1 2 3 4 5 → Substantially longer Sometimes longer, sometimes shorter
a) Duration of dry periods		
b) Frequency of dry periods		Substantially less frequent ← -5 -4 -3 -2 -1 0 1 2 3 4 5 → Substantially more frequent Sometimes more, sometimes less frequent

Q-No (to be filled out by researcher): _____ 8

DROUGHT PERCEPTION

57. During which years since 1980 have you experienced serious drought events?

80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
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Don't remember before year _____

58. In which months of the year do you feel that dry periods usually occur? (1:Yes, 0:No)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec

SECTION C: PERCEIVED DROUGHT IMPACTS

In the next section you will be asked question about how weather and especially drought events in your region impact on your life and your farming activities and what do you do about it.

CROP VULNERABILITY

59. Do you experience any of the following problems during a drought event?

	(1:Yes, 0:No)	59.1 How much does this problem affect you during a drought event? Not affected ← 1 2 3 4 5 6 7 8 9 10 → Highly affected	59.2 What do you usually do against this problem?
a) Yield reduction of major crop			
b) Reduction of yield quality			
c) Soil fertility reduction			
d) Soil erosion			
e) Pests & diseases			
f) Other:			

LIVELIHOOD VULNERABILITY

60. Do you experience any of the following problems during a drought event?

	(1:Yes, 0:No)	60.1 How much does this problem affect you during a drought event? Not affected ← 1 2 3 4 5 6 7 8 9 10 → Highly affected	60.2 What do you usually do against this problem?
a) Food shortage			
b) Human diseases			

Q-No (to be filled out by researcher): _____ 9

c) Income decrease			
e) Loss of savings/household assets			
f) Impaired access to inputs (Seed, animal feed, tools)			
g) Other:			

SECTION D: DROUGHT ADAPTATION STRATEGIES
In this section you will be asked if and how you have changed your farming practice to cope better with drought related problems.

ADAPTATION MEASURES TO AGRICULTURAL PRODUCTIVITY

61. Have you changed anything about the crop varieties you plant, planting dates or crop treatment in the past few years? _____ (1:Yes, 0:No)

IF YES:
62. Please specify:

	(1:Yes, 0:No)	62.1 How much does this measure improve your ability to deal with drought related problems? Not at all ← 1 2 3 4 5 6 7 8 9 10 → Very much	62. 2 Did you receive external help for the implementation? (1:Yes, 0:No)
a) Drought resistant varieties			
b) Early maturing varieties			
c) Early planting			
d) Late planting			
e) Mixed cropping			
f) Crop rotation			
g) Inter-cropping			
h) Change area between crops & livestock			
i) Pesticides/ Herbicides			

63. Have you changed anything about your tillage or soil treatment during the past few years? _____ (1:Yes, 0:No)

IF YES:
64. Please specify:

	(1:Yes, 0:No)	64.1 How much does this measure improve your ability to deal with drought related problems? Not at all ← 1 2 3 4 5 6 7 8 9 10 → Very much	64. 2 Did you receive external help for the implementation? (1:Yes, 0:No)
a) Conservation tillage			
b) Mulching			

Q-No (to be filled out by researcher): _____ 10

c) In-field water conservation (terraces, trenches, furrows, windbreaks)			
d) Leave crop residue			
e) Introduce artificial fertilizer			
f) Use organic manure			
g) Soil testing			
h) Soil correction (pH)			
i) Tree planting/ Afforestation			

65. Have you changed anything about your on-farm water management during the past few years? _____ (1:Yes, 0:No)

IF YES:
66. Please specify:

	(1:Yes, 0:No)	66.1 How much does this measure improve your ability to deal with drought related problems? Not at all ← 1 2 3 4 5 6 7 8 9 10 → Very much	66. 2 Did you receive external help for the implementation? (1:Yes, 0:No)
a) Using irrigation system			
b) Introduce water harvesting system			
c) Building a water reservoir/pond/tank			
d) Digging well/ borehole			

67. Have you changed anything about your livestock management during the past few years? _____ (1:Yes, 0:No)

IF YES:
68. Please specify:

	(1:Yes, 0:No)	68.1 How much does this measure improve your ability to deal with drought related problems? Not at all ← 1 2 3 4 5 6 7 8 9 10 → Very much	68. 2 Did you receive external help for the implementation? (1:Yes, 0:No)
a) Introduce drought resistant livestock			
b) Introduce new animal feed			
c) Other:			
d) Other:			
e) Other:			