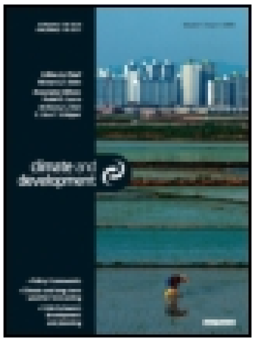

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RESEARCH ARTICLE

Adaption to climate change: a case study of two agricultural systems from Kenya

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This study contributes to a better understanding of climate change adaptation by investigating different farming systems and by including cognitive factors as explanatory variables. We compared a food crop and a horticultural farming system, regarding applied adaptation measures and factors influencing adaptation. The data were based on a field survey of 267 smallholder farmers in Laikipia County of Kenya. A binary logistic regression was conducted against individual adaptation measures to identify determinants of adaptation. Adaptation measures employed by food crop farmers were mainly risk-reducing, such as mixed- and inter-cropping, planting early-maturing crop varieties and early planting. In contrast, horticultural farmers tended to focus more on intensifying crop production and applied crop rotation, irrigation and application of agro-chemicals, artificial fertilizer and manure. Factors positively influencing adaptation included access to extension services and risk perception among horticultural farmers, and access to workforce and farmers groups among food crop farmers. Furthermore, food crop farmers with access to less risk-prone income sources than agriculture seemed to have less motivation to adapt. The study showed that as climate change progresses, social differences between horticultural and food crop farmers are likely to increase, hence leading to inequalities in adaptation at local levels. Adaptation planners need to address these differences if sustainable adaptation is to be achieved.

Keywords: sustainable adaptation; climate change; food security; horticulture; Kenya; smallholder farming systems; logistic regression

1. Introduction

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 (FAO, 2012). Kenya's agriculture accounted for 30.3% of the country's GDP in 2014 (Worldbank, 2016) and 75% of agriculture is highly dependent on rain-fed small-scale agriculture (Herrero et al., 2010). Although recent studies have shown that Kenya is experiencing an increase in rainfall variability, agriculture, especially for smallholders, is poorly developed, deficient and limited with area-specific sustainable adaptation measures (Smucker & Wisner, 2008; Speranza, Kiteme, Ambenje, Wiesmann, & Makali, 2010). A lacuna for such information calls for sustainable adaptation measures that will not only maintain rural livelihoods, but also help to increase yields and manage natural resources efficiently for enhanced food security in the wake of changing climate (Bryan et al., 2013; Wheeler & von Braun, 2013).

Adaptive behaviour at individual farm level is rarely addressed in the light of underlying political-economic and structural factors that create constraints to adaptation (Shackleton, Ziervogel, Sallu, Gill, & Tschakert, 2015). Several studies have utilized aggregated data at country or regional levels to assess impacts of climate change and applied adaptation measures (Bryan, Deressa, Gbetibouo, & Ringler, 2009; Bryan et al., 2013; Wood, Jina, Jain, Kristjanson, & DeFries, 2014). Other studies (see Rurinda et al., 2014; Thornton, Jones, Alagarswamy, & Andresen, 2009; Thornton, Jones, Alagarswamy, Andresen, & Herrero, 2010; Waha, Müller, & Rolinski, 2013) have focused on impacts of climate change on individual crops at various scales. The aforementioned studies provide useful information for crop management decisions; however, they are short of information on the socio-economic embeddedness of the farm and individual psychological barriers. As Dixon, Gulliver, and Gibbon (2001) suggested, research on adaptation at household levels requires a focus on how farming households are embedded into the larger socio-economic, biophysical context and the farms' fragmentation into its subsystems. Similar observations were picked up by Giller et al. (2011), who

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proposed a comparative farming systems approach as appropriate means to adaptation research. Indeed, information at the farming systems or micro-level (local scale) is urgently needed to enable policy-makers and extension officers to adapt national measures suitable to local circumstances and promote targeted interventions.

Secondly, existing studies have ascribed determinants of adaptation in developing countries to socio-economic and environmental variables (Deressa, Hassan, Ringler, Alemu, & Yesuf, 2009; Gbetibouo, 2009; Hassan & Nhemachena, 2008), often excluding cognitive factors (Le Dang, Li, Bruwer, & Nuberg, 2013; Shackleton et al., 2015). Those that include factors related to climate perception report a positive correlation with adaptation, especially regarding the perception of pests and diseases (Comoé & Siegrist, 2015; Shikuku et al., 2017). However, some also report that there is a need for more narrowly defined models based on psychological concepts to improve the inclusion of cognitive factors in adaptation research (Below et al., 2012). As Adger et al. (2009) argue, adaptation is more often limited by endogenous factors, such as perceptions and values within a society rather than exogenous factors. In this context, considering both socio-economic and cognitive factors helps scientists to understand the farmers' decision-making process regarding adaptation (Le Dang et al., 2013).

To undertake adaptation research that will help bridge the aforementioned gaps, this study conducts a comparative analysis of two farming systems regarding climate change adaptation and its determinants, including cognitive factors based on the protection-motivation theory (PMT) adjusted to climate change adaptation by Grothmann and Patt (2005).

The data for the analysis are based on a field survey of 267 smallholder farm households in a semi-arid region in Kenya. The chosen farming systems included a food crop and a horticultural farming system, which are both frequently encountered in the study region. Main objectives of the study are: (1) to investigate farmers' adaptation measures to climate change; (2) to determine factors, including cognitive factors, influencing the adoption of adaptation measures; (3) to compare two different farming systems in climate change adaptation and understand the drivers to different adapting strategies.

We argue that insights from a socio-economic and cognitive factors' perspective would offer an opportunity for improving adaptation options of smallholders, as well as help bridge disparities that may ensue in different farming systems at a local level. Furthermore, a comparative systems' analysis would allow for a detailed analysis and assessment of combined cognitive and resource-related determinants. This could offer ex-ante development of targeted interventions that reflect the needs of the farmers and farming systems.

2. Conceptual framework

2.1. *Adaptation measures*

Agricultural adaptation measures to climate change occur at various spatial and temporal scales. They can be described as responses that reduce vulnerability to climatic stresses, such as drought events and climate variability (Smit & Skinner, 2002). The present study focuses on *farm production practices*, since smallholder farmers' decision-making shapes adaptation at the local level. The farm operational practices are grouped into: *farm production*, *land use*, *land topography*, *irrigation* and *timing of operations* (Smit & Skinner, 2002). Table 1 lists and describes all adaptation measures considered during the survey for this study. The list was compiled based on measures frequently mentioned in the literature and adapted to the study region after the pre-test.

At this point, one might question the direct link of some of these measures to climate change, since they rather aim at intensifying crop production, for which a farmer could also have an economic motivation. We argue that every measure undertaken by the farmers brings benefit to them and helps increase their adaptive capacity to climate change, regardless of whether the farmers' action was triggered by climatic or economic incentives (see also Wood et al., 2014). Secondly, many of these measures are complementing each other and successful adaptation is most likely if measures are applied in combination. For example, from an economic perspective, Di Falco and Veronesi (2013) showed that farm adaptation based on a portfolio of measures significantly increases farm net revenues. This argument is also realistic when it comes to data collection: weather-induced changes of agricultural practice and responses to economic incentives were hard to distinguish, even for smallholder farmers themselves.

2.2. *Determinants of adaptation*

One of the aims of this study is to test the influence of socio-economic and cognitive factors on climate change adaptation of smallholder farmers. This study adopts insights from the PMT by Grothmann and Patt (2005) to integrate available resources and climate change perception into one framework (Figure 1).

Although rooted in health science, the PMT model has been adapted to climate change research and tested in a number of case studies (Gebrehiwot & van der Veen, 2015; Grothmann & Reusswig, 2006; Le Dang, Li, Nuberg, & Bruwer, 2014). Adaptation is understood as a socio-cognitive-behavioural process, whereas adaptive behaviour can only happen if a person exhibits, on the one hand, the motivation to adapt (*adaptation motivation*) and on the other hand, if the necessary resources are available (*objective adaptive capacity*) (Grothmann & Patt, 2005). In this study the first dimension is represented with the

Table 1. Classification and description of adaptation measures to climate change.

Group	Adaptation measures	Description
Farm production	Change to drought-resistant variety Change to early-maturing variety	Using stress-tolerant varieties can improve yields and agricultural productivity in light of drought (Smit & Skinner, 2002). In particular in the maize seed sector farmers have the choice between different drought-resistant or early-maturing varieties (KEPHIS, 2015).
	Artificial fertilizer Animal manure	Appropriate application of mineral fertilizer and animal manure can increase yields and improve soil fertility with positive consequences for climate change resilience (Tittonell, Corbeels, van Wijk, Vanlauwe, & Giller, 2008).
	Agro-chemicals (Pesticides/Herbicides/ Fungicides)	Altered weather patterns can increase crop vulnerability to infections, pests and weeds and increase the activity of pest organisms (Rosenzweig, Iglesias, Yang, Epstein, & Chivian, 2001). Agro-chemicals 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 and represent therefore a way of dealing with climate change consequences (Nyakundi, Magoma, Ochora, & Nyende, 2010).
	Improved/drought-resistant livestock breed Change livestock feed management	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, Bryan, Ringler, Herrero, & Okoba, 2012). 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).
Land use	Mixed cropping and inter-cropping	Planting of two or more crops simultaneously in the same field can increase soil biodiversity and fertility, helps to conserve water and increases returns per hectare (Pearson, Norman, & Dixon, 1995). Spreading the risk on different crops on one plot is a typical trait of smallholder farming systems to cope with climate variability and has been practised for a long time (Pearson et al., 1995).
	Crop rotation	Crop rotation describes planting crops sequentially in the course of the year, thereby enhancing soil fertility and reducing sensitivity to pests and diseases (Thierfelder & Wall, 2015).
	Agroforestry	By planting woody species among or in proximity to the main crops, fruit, fodder and fuel wood production can be increased, while runoff or erosion is decreased and soil fertility is enhanced (Bernier et al., 2015). Trees provide shade, shelter and protection from wind (Lasco, Delfino, Catacutan, Simelton, & Wilson, 2014). Thus, agroforestry has the potential to increase farmer's resilience to climate change (Lasco et al., 2014).
	Conservation tillage (mulch-tillage (leaving crop residues on the field), reduced or zero tillage)	Conservation farming practices lead to improved on-farm water productivity, increased yields and increased farmers' ability to deal with increased climate variability (Rockström et al., 2009).
Topography	In-field water conservation (terraces, furrows, trenches, windbreaks)	Building terraces and bunds or changing the slope of the field can slow the speed of water and increases thus infiltration close to the crops' roots to improve irrigation efficiency (Ali, 2010; Bernier et al., 2015).
	Water-harvesting and storage (dams/reservoirs/ ponds)	With structures like ridges, bunds and dams, rainwater is diverted, stored and used for irrigation at a later point in time (Ali, 2010). Harvested 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, Rockström, & Barron, 2005).
Water management	Introducing/Improving irrigation system Water resource exploitation (boreholes/wells/ water pumps to access river water)	Irrigation improves farm productivity, enables diversification of production (e.g. to horticultural products) by increasing moisture retention in the soil and increasing water availability (Smit & Skinner, 2002). A precondition for irrigation is access to water, which in Laikipia County often comes from the rivers (Ngigi, 2009; Ulrich et al., 2012).

(*Continued*)

Table 1. Continued.

Group	Adaptation measures	Description
Timing	Early planting Late planting	This measure has the potential to maximize farm productivity during the growing season and reduce heat stress and moisture deficiencies (Smit & Skinner, 2002). Late planting minimizes the risk of being surprised by a late onset of the rains. Early planting is practised in order to enable replanting in case the crops do not germinate.

variables *future risk perception* – referring to a person's expectancy of being exposed to climate change in the future – and *risk experience* – describing a person's appraisal of the current impacts of climate change on crop productivity.

Variables representing *objective adaptive capacity* were deduced from the literature and included personal characteristics as well as factors related to the farms financial, physical, human and institutional capital. Table 2 provides a summary of the hypothesized influential variables used in this study together with hypothesis deduced from literature findings.

3. Data and methods

3.1. *The case study area*

The study was carried out in Laikipia County located in Central Kenya with an altitude between 1500 m and 2611 m a.s.l. and on a latitude of 0°18″–0°51″ and a longitude of 16°11″–37°24″ (GoL, 2013). It covers an area of 9462 km^2 with the major part consisting 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 (GoL, 2013). Due to its topography, climatic conditions are heterogeneously distributed ranging from arid areas in the North to the semi-humid foothills of Mt. Kenya. 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 continental rains between August and September (Ulrich et al., 2012).

Laikipia County can be described as a typical tropical highland-lowland system. Smallholder crop production mostly takes place in southern parts of Laikipia, in the semi-arid parts of Laikipia Plateau and the semi-humid slopes of Mt. Kenya. Livelihoods are primarily based on crop production and livestock keeping with land-holdings of about 1.2–2.4 ha (Ulrich et al., 2012). Typically grown crops include maize, beans and potatoes, which all belong to Kenya's most important staple crops. During the last two decades, a number of farmers have started to expand their farms and to add horticultural products, thereby improving their income (Ogalleh, Vogl, Eitzinger, & Hauser, 2012; Ulrich et al., 2012). Towards the arid north, pastoralism becomes the predominant livelihood strategy.

The region has experienced an extreme population growth since Kenya's independence in 1963, which has increased pressure on the limited natural resources in the area, such as rivers and land (Kiteme, Liniger, Notter, Wiesmann, & Kohler, 2008). 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).

Analysis of climatic trends of the past decades has shown that total rain failures during rainy seasons have increased and that major rivers indicate a declining runoff (Ulrich et al., 2012). Indeed, climate change is perceived as a threat to agricultural productivity by smallholders in most parts of Kenya (Bryan et al., 2013; Tongruksawattana, 2014). Lack of resources, limited water access and insufficient 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 measures to cope with consequences from drought, floods and impacts from pests and diseases (Tongruksawattana, 2014). Adaptation measures often include simple measures, such as changing planting dates, mixed cropping, migration and sale of livestock (Ogalleh et al., 2012).

3.2. *Data collection*

Data were collected during a household survey in May 2015 with a total of 267 smallholder farmers. Nine enumerators familiar to the area and fluent in local languages (English, Swahili and Kikuyu) were recruited to collect data using the pre-designed household questionnaires. Enumerators were first trained on the questionnaire and on basic skills for the data collection. During the survey, purposive sampling ensured that respondents making agriculturally based decisions in the households were targeted, in this case mostly the female or male household heads. Each questionnaire interview took approximately 1 hour.

Table 2. Hypothesized determinants of adaptation.

No	Variable	Description	Level of measurement	Hypotheses
I	Gender	Gender of respondent	Dummy (0 = Female, 1 = Male)	H1: Gender has an influence on the adoption of adaptation measures, for the benefit of either male or female farmers depending on the measure (Bernier et al., 2015; Petermann, Behrmann, & Quisumbing, 2010).
II	Age	Age of respondent	Continuous	H2: Older farmers are more likely to adapt, since they have a higher farming experience and are therefore more aware of practices (Deressa et al., 2009).
III	Education	Years in education	Continuous	H3: Educated farmers are more likely to adapt (Deressa et al., 2009).
IV	Available workforce	Number of casual employees during the last 12 months	Continuous	H4: Households with more available workforce are more likely to adapt (Deressa et al., 2009).
V	Total income	Total household income in KES from farm and off-farm activities during the year 2014. Classification adapted from Ulrich et al. (2012) by considering inflation rates.	Categorical (1 = low income (<90k KES), 2 = middle income (90–200k KES), 3 = high income (>200k KES))	H5: Households with a higher income are more likely to adapt (Bryan et al., 2013, 2009; Deressa et al., 2009).
VI	Farm size	Total arable land in Laikipia (number of acres used for crop cultivation in Laikipia, including rented-in acres)	Continuous	H6: Households with access to more land are more likely to adapt (Tongruksawattana, 2014).
VII	Access to extension services	Access to extension service during the last 12 months.	Dummy (0 = no, 1 = yes)	H7: Households with access to extension services are more likely to adapt (Below et al., 2012; Bryan et al., 2013, 2009; Hassan & Nhemachena, 2008).
VIII	Access to farmers' group' and cooperatives	Access to farmers' groups or cooperatives during the last 12 months.	Dummy (0 = no, 1 = yes)	H8: Households with access to farmers' groups and cooperatives are more likely to adapt (Washington-Ottombre & Pijanowski, 2013).
IX	Access to non-agricultural income	Access to income from non-agricultural activities in 2014	Dummy (0 = no, 1 = yes)	H9: Non-agricultural income has either a positive or a negative influence on the adoption of adaptation measures (Deressa et al., 2009).
X	Future risk perception	Perception of the climate becoming better, ambivalent or worse in the future.	Dummy (0 = perceives that climate will be ambivalent or improve in the future, 1 = perceives that climate will worsen in the future)	H10: Farmers perceiving a high risk of climate change in the future are more likely to adapt (Grothmann & Patt, 2005).
XI	Risk experience	Self-assessed impacts of drought on crop productivity	Dummy (0 = perceived medium or low impact (Likert scale rated 1–6), 1 = perceived high impact (Likert scale rated 7–10)	H11: Farmers perceiving stronger impacts from climate change are more likely to adapt (Comoé & Siegrist, 2015).

The questionnaire comprised a section entailing closed-ended questions on personal (age, gender, education), household (income, access to extension services, farmers' groups and cooperatives) and farm variables (crop types planted, acreage, livestock activities, fertilizer and irrigation practices, number of employees, household consumption, drought impacts). The second section covered questions on future risk perception and risk experience. Future risk perception was measured using a 3-point Likert scale. Farmers were asked to state whether climate would improve, be ambivalent or worsen in the next 10 years from now. To obtain risk experience, farmers were asked to rate the extent of drought impacts on their crop production on a scale from 1 to 10. We considered farmers checking between 7 and 10 as experiencing a high impact. The final section of the questionnaire covered questions on the adoption of adaptation strategies to reoccurring drought events. We employed a strategy that has been tested and utilized by similar studies in Iran (Keshavarz, Karami, & Zibaei, 2014), where enumerators jotted down measures mentioned by the farmer and utilized the list to check afterwards on any possibly forgotten measures. This way, on-farm activities were captured exhaustively; even when farmers did not consider nor link such measures directly to climate but would use such measures to increase their farms productivity. The final questionnaire was validated with knowledge from experts from various institutions that work within the region and tested on comprehensibility to farmers during a pre-test.

The survey was conducted with respondents from eight different sub-locations that represent areas suitable for agricultural production within Laikipia County (see Figure 2). Each of the sampling sites can be assigned to one of the Laikipia's three constituencies, Laikipia East (Locations 1–5), Laikipia North (Location 6) and Laikipia West (Locations 7 and 8). A non-probability sampling strategy was used to select households' respondents, namely quota sampling, as characteristics of the study population were known (Bird, 2009). Respondents were purposively chosen according to crop types cultivated and location. The target was to reach equal sample size of horticultural and food crops smallholder farmers, as well as a sample distribution that is proportionate to the number of farming households in the targeted areas. Two focus group discussions were conducted to gain in-depth qualitative information on climate change issues and food crops and horticultural farmers' perceptions. Data generated from the group discussions were not statistically analysed but allowed for a broader exploration of the research topic and used to support triangulation and interpretation of the results.

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. Farmers using on average at least 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 more than 70% of their arable land for growing maize, common beans, potatoes or wheat were classified as 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 (Kulecho & Weatherhead, 2006; Weinberger & Lumpkin, 2007). Furthermore, the majority of horticultural farmers still uses a substantial amount of their plots for food crop[1] cultivation. The classification was verified by comparing it to the farmers personal perception about their major crops and to examples from the literature. In 85% of the cases, farmers' self-perception corresponded to the assigned farming system. In a classification developed by van de Steeg, Verburg, Baltenweck, and Staal (2010) for farming systems in the Kenyan highlands, cash crop farmers used on average 30% of their area for planting cash crops.

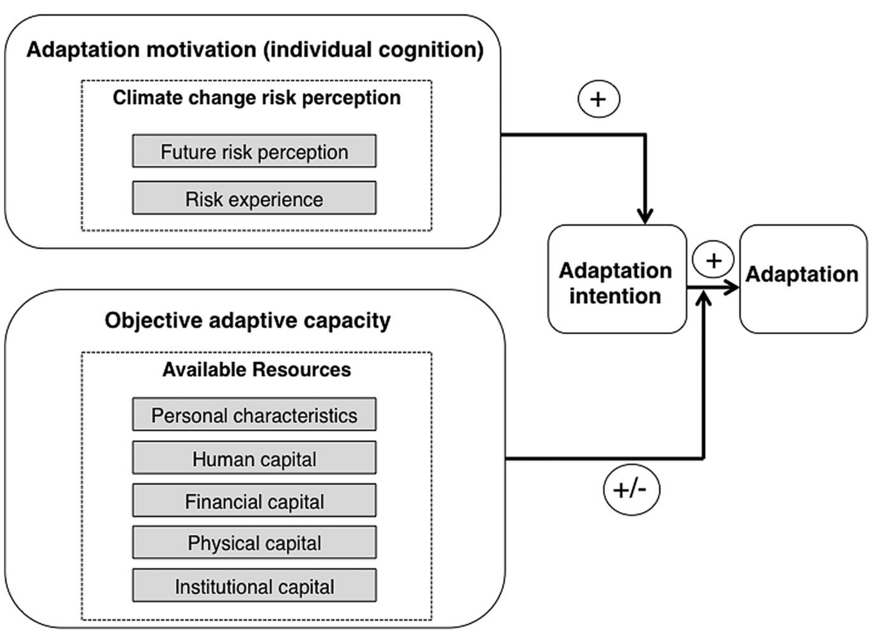

Figure 1. Theoretical framework to integrate cognitive and resource-related factors in adaptation research. + and − indicate a positive or negative influence of the respective factors on the decision to adapt. Source: Authors illustration adapted from Grothmann and Patt (2005).

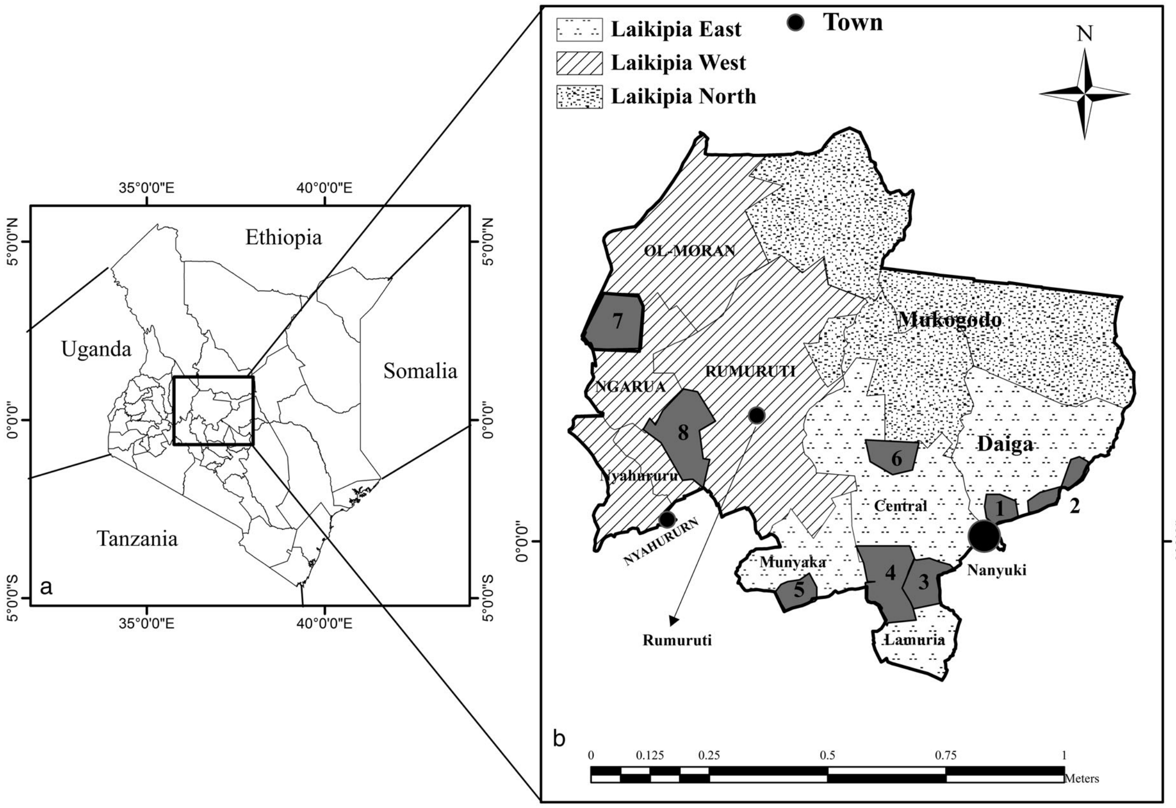

Figure 2. (a) The Republic of Kenya. (b) Study sites in Laikipia County (1: Nyariginu; 2: Ngenia; 3: Matanya; 4: Lamuria; 5: Ngobit; 6: Segera; 7: Kinamba; 8: Melwa). Source: Authors illustration.

3.3. *Analytical methods*

A binary logistic regression was performed separately for each farming system to ascertain the effects of the hypothesized independent variables on single adaptation measures. It is a suitable method used to predict the probability of a person adopting a certain adaptation measure and has been applied in previous analyses regarding similar research questions (see Comoé & Siegrist, 2015). We considered other options of analysis such as weighting and summarizing adaptation measures to an adaptation index for each farming system (similar to Below et al., 2012) or applying multinomial logistic regression by including adaptation measures as a categorical dependent variable (see for example Poppenborg & Koellner, 2013). The latter would have also allowed for exploring the complementarity and interactions between simultaneously applied adaptation measures. However, the creation of a categorical dependent variable for multinomial logistic regression would have required a grouping of adaptation measures (e.g. 'water management', 'soil management' and 'planting decisions'), otherwise the high number of adaptation measures would have rendered the dependent variable highly complex. This grouping but also the development of an adaptation index would have meant losing measure-specific information and could have impeded comparability with other studies (Bryan et al., 2013). In this paper, we chose to focus on providing measure-specific information to adaptation planners, as we expected each adaptation measure to be influenced by another set of explanatory variables (Bryan et al., 2013). Thus, we considered binary logistic regression as most advantageous for the purpose of our study as it sheds light on obstacles and opportunities for each adaptation measure separately. The statistical software SPSS (IBM SPSS Statistics for Windows, Version 21.0) was used for all statistical analyses. The logistic regression expresses the probability of an event occurring given known logarithmic values of one or several predictor variables (Field, 2009). The model is represented by the following function:

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

with $P(Y)$ being the probability of adaptation occurring, with Y being the dichotomous dependent variable = 1 if a person has adopted a particular adaptation measure and 0 if a person did not adopt the adaptation measure; $X_1 \ldots X_n$ being predictor variables, either continuous or categorical; b being regression coefficient, calculated with a maximum-likelihood estimation.

Since the relationship between predictors and the dependent variable is of logistic nature, the regression coefficient cannot be directly interpreted. The results for *b* are 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).

For each adaptation measure, a single regression was performed. Only those regressions with sufficiently high model quality are presented and discussed in this paper. To enable farming system comparison, two of the measures were analysed for both systems in common, namely the application of animal manure and the planting of trees (agroforestry). The third and fourth of the analysed measures included late planting and irrigation for food crop farmers, and in-field water conservation and application of artificial fertilizer for horticultural farmers, respectively. The set of predictors was kept the same for all adaptation measures, since the regression models are based on a theoretical framework and previous scientific research, to which the results should be comparable. Collinearity was checked by considering variance inflation factors (VIF) and tolerance values for each predictor. Collinearity effects were expected to occur to some extent (see the Pearson correlation of explanatory variables in the supplemental material to this article). However, in all regression models, VIF were below 5 and tolerance values were above 0.25, as recommended by Urban and Mayerl (2008). Furthermore, standardized residuals and Cook's distance were checked to detect outliers. Cases with standardized residuals exceeding the range between −3.29 and +3.29 or a Cook's distance higher than 1 were excluded from analysis as recommended by Field (2009). Standard errors were carefully observed to check for incomplete information from the predictor. Values below 2 were considered satisfactory (Field, 2009). The categorical variable total income was incorporated into the regression by using high income as a reference category. The hypotheses were accepted if the significance level was $p < .05$.

4. Results and discussion

4.1. *Characteristics of the sample population*

In total, the survey covered 113 horticultural and 154 food crop farmers. Table 3 provides a summary of the characteristics of the two farming systems regarding demographic, agronomic, financial and institutional attributes.

Gender distribution showed that horticulture was clearly a male-dominated business, while in the food crop farming system gender distribution was more balanced with only 46.8% of surveyed farmers being male. Average age of respondents was high for both farming systems, with 52.5 years for food crop farmers and 46.0 years for horticultural farmers. The younger average age of horticultural farmers may be partly related to the fact that vegetable farming has evolved recently in Laikipia County, while maize is traditionally a major crop grown among smallholder farmers (Ulrich et al., 2012). Almost all the farmers have received primary education, about half have completed secondary school, and only a few have completed college, the majority of them being horticultural farmers.

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 in semi-arid farming regions and is practised to reduce risks from high rainfall variability (McCord, Cox, Schmitt-Harsh, & Evans, 2015). Maize, potatoes and common beans belonged to the most dominant food crops in Laikipia County. Common vegetables included cabbage, French beans, tomatoes and onions. In both farming systems, a high percentage of farmers owned livestock and a small share of on-farm grazing land. Keeping of dairy cattle was more spread among food crop farmers compared to horticultural farmers. Farmers owning dairy cattle have an additional income from selling milk and other dairy products, making it an important strategy to bridge food deficit periods (Ulrich et al., 2012). Application of 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. In addition, the proportion of horticultural farmers irrigating their crops was much higher compared to farmers growing food crops. Vegetables have high irrigation requirements and irrigation access is a precondition for their cultivation (Weinberger & Lumpkin, 2007). 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 consequences became evident in the percentage of farmers experiencing total crop failure in the drought year 2014, which was much lower among horticultural farmers compared to food crop farmers.

Farmers growing food crops were more subsistence-oriented and had a much lower income from agricultural activities, while horticultural farmers appeared to be market-oriented and obtained higher revenues from their 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 (Weinberger & Lumpkin, 2007). Food crops are mainly cultivated for household consumption and are only sold if produced in excess (Kang'ethe, 2011). In both farming systems, about one-third of farmers had access to non-agricultural income, indicating that livelihood diversification was at

Table 3. Characteristics of the survey population.

	Food crops (n = 154)	Horticulture (n = 113)
Gender of respondent		
Female (%)	53.2	24.8
Male (%)	46.8	75.2
Average age (years)	52.50	46.00
Educational level		
No school (%)	1.90	0.00
Primary school (%)	98.10	100.00
Secondary school (%)	43.50	54.00
College (%)	7.80	12.40
University (%)	0.60	0.00
Acreage		
Mean area under crop production (acres)	3.3	2.8
Mean grazing land (acres)	1.3	1.1
Major crop types (% of farmers growing this crop)		
Maize (%)	98.1	66.4
Beans (%)	76.0	38.9
Potatoes (%)	61.0	31.0
French Beans (%)	9.7	45.1
Cabbage (%)	5.8	55.8
Tomatoes (%)	11.0	42.5
Onions (%)	9.1	38.9
Livestock activities		
Livestock owner (%)	98.7	87.6
Dairy cattle owner (%)	82.9	74.7
Fertilizer		
Farmers using manure (%)	86.4	85.1
Farmers using chemical fertilizer (%)	76.6	94.7
Farmers practising irrigation (%)	35.7	94.7
Farmers experiencing total crop failure during 2014 (%)	46.8	15.8
Average share of total harvest consumed at the household during past 5 seasons (average household consumption) (%)	72.6	23.7
Average income from livestock and crop activities in 2014 (median in USD)	304.34	1404.67
Farmers with access to non-agricultural income during the past 12 months (%)	34.4	29.2
Farmers with access to extension services during the past 12 months (%)	48.1	64.0
Farmers with access to farmers' groups or cooperatives during the past 12 months (%)	41.6	60.2
Farmers with access to credit from banks/micro-financing during the past 12 months (%)	22.7	37.7

an advanced state. Lastly, horticultural farmers had a higher rate of participation in extension programmes, as well as farmers' groups and cooperatives, which most probably also increased the likelihood of credit access from banks or micro-finance institutions as some of these groups work as localized saving or micro-credit groups (Washington-Ottombre & Pijanowski, 2013).

4.2. *Applied on-farm adaptation measures*

Figure 3 shows the percentage of applicants for each adaptation measure. Major adaptation measures among 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 is one of the most important risk-reducing measures among smallholder farmers and has been a typical trait of farming systems in Laikipia County for a very long time (Mwalusepo et al., 2015; Ogalleh et al., 2012). Farmers mix long- and short-cycle crops to maximize the probability of harvest during different times of the year. Similar to this is early planting, which allows for replanting in case of germination failure and is thus also a risk-reducing way of coping with increased rainfall variability. Seeds for early-maturing varieties are in particular available for maize (e.g. Variety type 614 and 513), which explains the predominance of this measure among food crop farmers (see also Ogalleh et al., 2012). The same applies for conservation tillage, which requires crop residues to be left on the field to build up adequate soil cover. Conservation tillage in Sub-Saharan Africa is so far mainly practised in maize farming systems in crop rotation with a grain legume (Corbeels, Sakyi, Kühne, & Whitbread, 2014). The high frequency of agro-chemicals should be alarming regarding the fact that commonly, farmers apply chemicals to their fields without prior

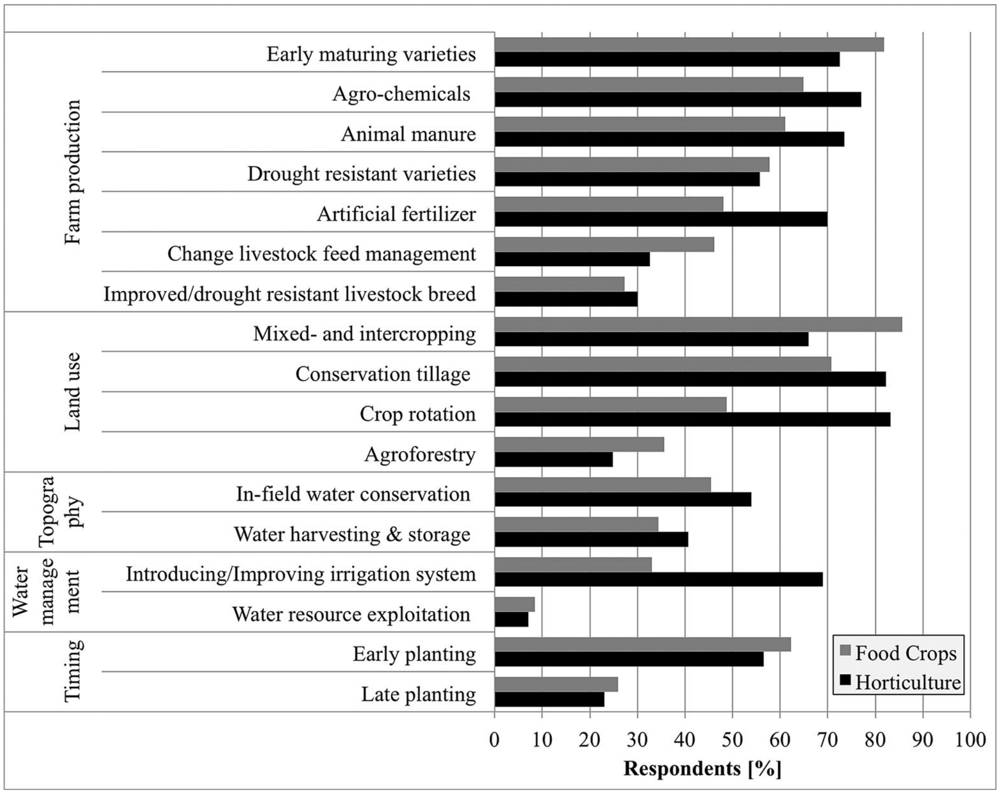

Figure 3. Frequency of assessed adaptation measures in the food crop and the horticultural farming system.

instruction. Negative consequences for humans and natural systems have already been recorded in other parts of Kenya (Nyakundi et al. 2010).

Major adaptation measures among horticultural farmers included crop rotation, conservation tillage, planting of early-maturing varieties, application of agro-chemicals, animal manure and artificial fertilizer and introducing irrigation systems. Horticultural farmers typically cultivate a diversity of crops on small plots and throughout the year (Kulecho & Weatherhead, 2006; Weinberger & Lumpkin, 2007). This enables the rotation of different crops in the course of the year, increasing thereby soil fertility and maximizing production on small land size. Conservation tillage is not a typical practice for horticultural farmers, since it requires high labour input and effort if applied on small vegetable plots. The high abundance of this measure 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. The same applies for the use of early-maturing varieties, which referred most likely to maize varieties used on horticultural farms, since such seeds are not available for vegetables. The high frequency of agro-chemicals, animal manure and artificial fertilizer implied that horticultural farmers invested much more in intensifying production and improving soil fertility compared to food crop farmers. There could be two explanations for this result: Firstly, as benefits from selling cash crops (horticultural crops) were greater, willingness and ability to invest in inputs could have been higher in the horticultural farming system. Secondly, as reported by Ogalleh et al. (2012; Ogalleh, Vogl, & Hauser, 2013), smallholders reported a high incidence of crop pests on horticultural crops, necessitating for the use of agro-chemicals to abate them, or otherwise, risk losing the crops to pests. The majority of farmers might have opted to invest in the use of agro-chemicals.

Introduction or improving irrigation systems was expected to be frequently mentioned by horticultural farmers, as vegetables are commonly irrigated crops by smallholder farmers in Kenya (Kulecho & Weatherhead, 2006).

Practices related to production intensification seemed to have also benefited staple crops on horticultural farms. Mean productivity for maize was around 1025 kg/ha in the food crop and around 1885 kg/ha in the horticultural farming system. Thus, some of the measures worked synergistically, and therefore are likely to have increased adaptive capacity of a farm as a whole and not only benefited the major crops.

We argue that adaptation differences between the farming systems can be explained by considering the socio-economic context. Farmers from the market-oriented horticultural farming system invested predominantly in innovative measures that aimed at intensifying crop production. Some of these measures such as irrigation require an initial financial investment and information access for a successful implementation (Bryan et al., 2013). In contrast, farmers belonging to the food crop farming system focused mainly on risk-reducing measures, which require less capital investments but are not benefit-maximizing and do not decrease as much the systems' vulnerability to climate change (Kristjanson et al., 2012; Shikuku et al., 2017). A possible explanation for this pattern could be that higher benefits from selling cash crops and better access to extension services might have increased the horticultural farmers' ability to react to climate change and to intensify crop production. Food crop farmers, on the other hand, might be caught-up in a vicious cycle that could be described the following way: the low crop income and high vulnerability to climate change force farmers to divert into non-agricultural activities, which are regarded less risk-prone income sources compared to agricultural production. In such a situation, farmers would become more risk averse and less motivated to invest in sustainable agricultural strategies. This in turn further decreases the farms resilience to climate change and crop income.

Such a situation is reminiscent to what has been described and elaborated by Holler (2014), where wealthy households benefit from adaptive actions, while more vulnerable households cannot afford costly and sustainable investments. Holler (2014) argued further that unsustainable coping measures keep such households stuck in a poverty trap. Following this argument, Holler (2014) interpreted that adaptation to climate change may be reproducing social injustice rather than social equity. We adopt this argument and align it to our findings, which have shown insights that social differences between horticultural and food crop farmers are likely to be exacerbated as climatic related variability increased. There is a need for adaptation planners to stop such a development, as it produces further injustice and conflicts.

4.3. *Determinants of adaptation for single adaptive measures in the two farming systems*

The results of the regression models are presented in Tables 4 and 5. Testing of the full models against models entailing the constant only showed that all regression models were significant, indicating that the set of explanatory variables reliably distinguishes between adaptors and non-adaptors. Prediction success ranged between 73.7% and 82.8%. Nagelkerke R-square values ranged between 0.27 and 0.55. Interpreting these values in the context of this study means that the models can explain 27–55% of the total variance in adaptation. This is comparable to the results from other adaptation studies that used similar approaches of analysis. Comoé and Siegrist (2015) reached Nagelkerke R-square values of between 0.27 and 0.38 when identifying influential factors regarding specific adaptation actions in Côte d'Ivoire. Although these results indicate that there is still a large amount of unexplained variability in the models, they are considered sufficient when studying multifactorial social systems (Below et al., 2012). In this study, some of the predictors were probably not measurable and/or captured during data collection due to the methodology used to acquire data as well as operationalization of concepts.

The comparison between farming systems revealed considerable differences regarding factors influencing adaptation. In the following, the results for each of the explanatory variables are presented and discussed.

Gender: The results indicated no significant influence of gender on the adoption of most adaptation measures. In the horticultural farming system, women seemed to be more likely to apply artificial fertilizer compared to men. Whether a measure is more likely to be adopted by men or by women depends on whether the corresponding sphere of life is of gendered nature, e.g. in some cultures measures related to crop productivity are traditionally the women's responsibility (Twyman et al., 2014). A study by Caretta and Börjeson (2015) found that the introduction of cash crops on smallholder farms in rural Kenya has brought change to gender division of labour. Although average livelihood was improved, women faced a higher workload, as women remained responsible for field labour while men's tasks shifted to crop selling and crop management decision-making (Caretta & Börjeson, 2015).

Age: A significant influence of age on adaptation could be found for application of animal manure and late planting in the food crop farming system and agroforestry among horticultural farmers. Although not significant, it is still noteworthy that more innovative and recently introduced practices like in-field water conservation, irrigation and the application of artificial fertilizer all exhibited negative relationships with age. The result leads to the conclusion that older farmers with a longer farming experience seemed to be aware of the more traditional practices and their benefits, of which they can make use now as climate variability increases.

Education: Education was not found to have a significant positive influence on investigated adaptation measures.

Available workforce: This factor had a significant influence on adaptation particularly in the food crop farming system, namely on the application of animal manure, agroforestry and late planting. In the horticultural farming system, the factor was significantly influencing the application of animal manure and artificial fertilizer. The results undermine the importance of manpower for climate change adaptation since many of these measures are labour-intensive (Croppenstedt, Demeke, & Meschi, 2003).

Table 4. Factors influencing adaptation measures of farmers growing food crops.

Animal manure		Predictor	β	SE	p	e^{β}
	I	Gender	0.488	0.467	.296	1.628
	II	**Age****	**0.048**	**0.021**	**.025**	**1.049**
	III	Education	0.037	0.076	.626	1.038
	IV	**Available workforce****	**0.172**	**0.068**	**.012**	**1.188**
	V	Total income			.915	
		Low vs. high income	−0.218	0.710	.759	0.804
		Middle vs. high income	−0.348	0.828	.674	0.706
	VI	Total arable land	−0.052	0.091	.565	0.949
	VII	**Extension services*****	**1.402**	**0.447**	**.002**	**4.064**
	VIII	**Farmers group or cooperative*****	**1.455**	**0.492**	**.003**	**4.285**
	IX	**Access to non-agricultural income****	**−0.924**	**0.443**	**.037**	**0.397**
	X	Future risk perception	0.341	0.435	.433	1.407
	XI	Risk experience	0.052	0.504	.918	1.053
	Constant		−3.792	1.909	.047	0.023
Model:	$N = 151$, $\chi^2 = 57.063$ $p = .000$, Nagelkerke $R^2 = 0.429$, Percentage of correctly classified = 77.5					
Agroforestry		Predictor	β	SE	p	e^{β}
	I	Gender	−0.394	0.421	.350	0.674
	II	Age	0.029	0.019	.119	1.030
	III	Education	0.087	0.075	.248	1.091
	IV	**Available workforce*****	**0.110**	**0.041**	**.007**	**1.116**
	V	Total income			.367	
		Low vs. high income	0.210	0.617	.734	1.233
		Middle vs. high income	−0.705	0.810	.384	0.494
	VI	Total arable land	−0.076	0.087	.383	0.927
	VII	**Extension services****	**1.003**	**0.417**	**.016**	**2.726**
	VIII	Farmers group or cooperative	−0.199	0.419	.634	0.819
	IX	Access to of non-agricultural income	−0.405	0.414	.328	0.667
	X	**Future risk perception****	**1.047**	**0.425**	**.014**	**2.850**
	XI	Risk experience	0.516	0.474	.277	1.675
	Constant		−4.383	1.763	.013	0.012
Model:	$N = 152$, $\chi^2 = 33.307$, $p = .001$, Nagelkerke $R^2 = 0.270$, Percentage of correctly classified = 73.7					
Late planting		Predictor	β	SE	p	e^{β}
	I	Gender	−0.018	0.534	.973	0.982
	II	**Age****	**0.054**	**0.024**	**.027**	**1.055**
	III	Education	0.074	0.092	.422	1.077
	IV	**Available workforce*****	**0.187**	**0.049**	**.000**	**1.206**
	V	Total income			.788	
		Low vs. high income	0.326	0.883	.712	1.385
		Middle vs. high income	0.685	1.020	.502	1.983
	VI	**Total arable land****	**−0.313**	**0.129**	**.015**	**0.731**
	VII	Extension services	0.646	0.505	.201	1.908
	VIII	Farmers group or cooperative	0.841	0.520	.106	2.318
	IX	**Access to non-agricultural income*****	**−1.582**	**0.576**	**.006**	**0.206**
	X	**Future risk perception****	**−1.300**	**0.515**	**.012**	**0.272**
	XI	**Risk experience****	**1.834**	**0.740**	**.013**	**6.258**
	Constant		−6.009	2.323	.010	0.002
Model:	$N = 151$, $\chi^2 = 5.140$, $p = .000$, Nagelkerke $R^2 = 0.452$, Percentage of correctly classified = 82.8					
Irrigation		Predictor	β	SE	p	e^{β}
	I	Gender	0.000	0.453	.999	1.000
	II	Age	−0.002	0.020	.912	0.998
	III	Education	−0.002	0.082	.980	0.998
	IV	Available workforce	0.054	0.039	.166	1.056
	V	Total income			.754	
		Low vs. high income	−0.137	0.660	.836	0.872
		Middle vs. high income	0.331	0.797	.678	1.392
	VI	Total arable land	−0.007	0.092	.937	0.993
	VII	**Extension services****	**1.031**	**0.442**	**.020**	**2.803**
	VIII	**Farmers group or cooperative*****	**1.432**	**0.452**	**.002**	**4.186**
	IX	**Access to non-agricultural income*****	**−1.302**	**0.470**	**.006**	**0.272**
	X	Future risk perception	0.648	0.448	.148	1.912

(*Continued*)

Table 4. Continued.

Animal manure		Predictor	β	SE	p	e^β
	XI	Risk experience	0.766	0.535	.152	2.152
	Constant		−2.539	1.834	.166	0.079
Model:	$N = 152$, $\chi^2 = 45.640$, $p = .000$, Nagelkerke $R^2 = 0.362$, Percentage of correctly classified = 73.7					

Note: ***,**,* significant at 1%, 5% and 10% probability level, respectively. β, regression coefficient; SE, standard error; p, significance; e^β, odds ratio.

Total income/farm size: Surprisingly, total income and total arable land, both indicators of liquidity and wealth, were not found to have any positive influence on the adoption of adaptive measures. Only in the case of the horticultural farming system, middle-income farmers seemed to be less likely to adopt agroforestry measures compared to high-income 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 & Nhemachena, 2008). There are two possible reasons for the present outcome. Firstly, fertilizers, as well as seedlings for agroforestry, are available already at low prices at local tree nursery farmer groups and agro-vet[2] stores, respectively, and therefore affordable to most Kenyan smallholder farmers (Ariga & Jayne, 2011). Other measures, such as in-field water conservation, are easy to realize even with simple farm tools, such as hoes. Thus, farmers might have tried out many adaptation measures requiring only a small initial investment. Some of these easily implemented measures might have been realized at the expense of quality and it must be assumed that not all of them can be called successful adaptation to climate change. However, this assumption could not be further explored, as the question of maladaptation was not subject of this study. Secondly, financial capital could be reflected indirectly through other factors in the regression, in particular available workforce. In order to pay for casual labour, a household needs a minimum of financial liquidity.

Access to extension services: The results indicate that access to extension services is one of the most important factors for the adoption of analysed adaptation measures. Horticultural farmers with access to extension services were 11 times more likely to practice in-field water conservation, 15 times more likely to apply artificial fertilizer and 5 times more likely to apply animal manure, compared to farmers without access to extension services. Food crop farmers with access to extension services were 4 times more likely to apply animal manure to their fields, 3 times more likely to adopt agroforestry and 3 times more likely to adopt irrigation. Access to agricultural extension services has already been previously shown to improve adaptation in low-, middle- and high-income farming systems (Bryan, Deressa, Gbetibouo, & Ringler, 2009). The result of this study indicates that especially horticultural farmers seemed to rely on additional support from extension officers in order to adopt new agricultural practices.

Access to farmers' groups and cooperatives: A positive influence of access to farmers' groups and cooperatives on adaptation was found for the application of animal manure and irrigation in the food crop farming system. In groups and cooperatives, farmers have the possibility to step into contact with each other, to exchange information and resources (Washington-Ottombre & Pijanowski, 2013). In this study, access to farmers' groups and cooperatives was positively correlating with credit access (Pearson correlation of 0.47, Sig. < .001). Thus, we argue that this factor represents indirectly the importance of financial and physical capital for resource-poor food crop farmers.

Access to non-agricultural income: Having additional income from off-farm activities was not found to have a significant positive influence on any of the investigated adaptation measures. On the contrary, access to non-agricultural income was negatively associated with most adaptation measures in the food crop farming system. Food crop farmers with access to non-agricultural income were significantly less likely to apply animal manure, apply late planting or adopt irrigation. 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). In this context, the fact that in Laikipia County diversification into off-farm employment has evolved already over decades might have played a crucial role in creating a distinctive socio-economic environment in which income from off-farm activities is not necessarily reinvested in improved farming practices (Ulrich et al., 2012).

Thus, these results bring in a new view on livelihood diversification, for which non-agricultural income is taken as a proxy: as food crop farming is a risk-prone enterprise, farmers tend to rely on non-agricultural income sources, which make them less dependent on their agricultural productivity. Farmers might experience that relying on non-agricultural business is more lucrative and less risk-prone, thus spurring them to abandon full-time agricultural activities and avoid the risk of financial loss through investments in new agricultural practices. A livelihood strategy of this

Table 5. Factors influencing adaptation measures of horticultural farmers.

Animal manure		Predictor	β	SE	p	e^{β}
	I	Gender	0.414	0.721	.565	1.513
	II	Age	−0.023	0.029	.417	0.977
	III	Education	−0.154	0.128	.227	0.857
	IV	**Available workforce*** **	**0.321**	**0.129**	**.013**	**1.379**
	V	Total income			.211	
		Low vs. high income*	**1.494**	**0.883**	**.091**	**4.456**
		Middle vs. high income	0.771	0.744	.300	2.161
	VI	Total arable land	−0.158	0.163	.333	0.854
	VII	**Extension services*** **	**1.722**	**0.623**	**.006**	**5.594**
	VIII	Farmers group or cooperative	0.321	0.593	.589	1.378
	IX	Access to non-agricultural income	0.521	0.662	.431	1.684
	X	Future risk perception	0.760	0.624	.224	2.137
	XI	Risk experience	−0.969	0.624	.120	0.380
	Constant		0.989	2.003	.621	2.689
Model:	$N = 111$, $\chi^2 = 37.595$, $p = .000$, Nagelkerke $R^2 = 0.424$, Percentage of correctly classified = 78.4					
Agroforestry		Predictor	β	SE	p	e^{β}
	I	Gender	0.437	0.679	.520	1.548
	II	**Age*** **	**0.072**	**0.027**	**.008**	**1.075**
	III	Education	−0.091	0.126	.469	0.913
	IV	Available workforce	0.027	0.049	.588	1.027
	V	Total income			.065	
		Low vs. high income	−0.681	0.775	.380	0.506
		Middle v. high income* *	**−1.982**	**0.848**	**.019**	**0.138**
	VI	Total arable land	−0.113	0.153	.461	0.893
	VII	Extension services	0.921	0.647	.154	2.512
	VIII	**Farmers group or cooperative***	**1.214**	**0.658**	**.065**	**3.367**
	IX	Access to non-agricultural income	0.913	0.662	.168	2.492
	X	**Future risk perception*** **	**2.697**	**0.792**	**.001**	**14.838**
	XI	Risk experience	0.446	0.630	.479	1.562
	Constant		−7.094	2.456	.004	0.001
Model:	$N = 112$, $\chi^2 = 33.770$, $p = .001$, Nagelkerke $R^2 = 0.389$, Percentage of correctly classified = 77.7					
In-field water conservation		Predictor	β	SE	p	e^{β}
	I	Gender	0.086	0.525	.869	1.090
	II	Age	−0.023	0.022	.300	0.977
	III	Education	0.147	0.102	.149	1.159
	IV	Available workforce	−0.023	0.042	.583	0.977
	V	Total income			.721	
		Low vs. high income	−0.108	0.602	.858	0.898
		Middle vs. high income	0.383	0.595	.520	1.467
	VI	Total arable land	0.149	0.127	.243	1.160
	VII	**Extension services*** **	**2.458**	**0.573**	**.000**	**11.677**
	VIII	**Farmers group or cooperative*** *	**−1.182**	**0.551**	**.032**	**0.307**
	IX	Access to non-agricultural income	−0.900	0.552	.103	0.406
	X	Future risk perception	0.743	0.477	.119	2.103
	XI	Risk experience	−0.466	0.497	.349	0.628
	Constant		−1.343	1.659	.418	0.261
Model:	$N = 112$, $\chi^2 = 32.954$, $p = .001$, Nagelkerke $R^2 = 0.340$, Percentage of correctly classified = 74.1					
Artificial fertilizer	Predictor		β	SE	p	e^{β}
	I	**Gender*** *	**2.192**	**0.924**	**.018**	**8.956**
	II	Age	−0.012	0.031	.710	0.989
	III	**Education***	**−0.242**	**0.131**	**.065**	**0.785**
	IV	**Available workforce*** **	**0.477**	**0.158**	**.003**	**1.611**
	V	Total income			.546	
		Low vs. high income	0.919	0.835	.271	2.506
		Middle vs. high income	0.357	0.786	.650	1.428
	VI	**Total arable land***	**−0.440**	**0.208**	**.034**	**0.644**
	VII	**Extension services*** **	**2.719**	**0.788**	**.001**	**15.163**
	VIII	**Farmers group or cooperative*** **	**−2.051**	**0.787**	**.009**	**0.129**
	IX	Access to non-agricultural income	0.487	0.714	.495	1.628
	X	**Future risk perception*** *	**1.698**	**0.710**	**.017**	**5.461**

(*Continued*)

Table 5. Continued.

Animal manure		Predictor	β	SE	p	e^{β}
	XI	**Risk experience****	**−1.680**	**0.693**	**.015**	**0.186**
	Constant		1.983	2.033	.329	7.261
Model:	$N = 111$, $\chi^2 = 54.366$, $p = .000$, Nagelkerke $R^2 = 0.554$, Percentage of correctly classified = 81.1					

Note: ***,**,* significant at 1%, 5% and 10% probability level, respectively; β, regression coefficient; SE, standard error; p, significance; e^{β}, odds ratio.

type could become even more attractive to farmers with increasing variability and climatic changes. This result is also in-line with our previous hypothesis that food crop farmers mainly invest in risk-reducing measures and miss out on investing in innovative and intensifying measures.

Future risk perception: A significantly positive influence of future risk perception on adaptation was found for agroforestry in both farming systems and artificial fertilizer in the horticultural farming system. These measures exhibit long-term benefits, such as the reduction of erosion and carbon sequestration in the case of agroforestry and building up soil fertility in the case of fertilizer application. Thus, the linkage between future risk perception and the analysed measures could be justified with the farmers' ability of long-term planning. Shikuku et al. (2017) made a similar point by showing that soil, land and water management practices were not favoured by resource-poor farm households as these measures are often weighted towards the future and require investment costs in the current period, which is contradictive to the short-run perspective of the farm household decision-making. Bryan et al. (2009) 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. Such a pattern can be recognized in the present results, as risk perception seemed to be a more influential factor in the horticultural farming system.

Risk experience: A significantly positive influence of risk experience on adaptation was only found in case of late planting among food crop farmers, indicating that this low cost and rather reactive measure is associated with farmers perceiving higher impacts from drought. Thus, by implication this factor indicated that households with more complex adaptation measures experienced fewer impacts from drought, as could be interpreted from the fact that horticultural farmers applying artificial fertilizer are less likely to experience drought impacts on crop production. Our results, therefore, support the argument by García de Jalón, Silvestri, Granados, and Iglesias (2015) that awareness of climate change impacts is not a major barrier to adaptive behaviour. Rather, knowledge and information on future climate seems to reduce behavioural barriers to adaptation (García de Jalón et al., 2015).

4.4. *Limitations of the study*

In general, farmers have stated to apply surprisingly many adaptation measures compared to other studies. In this study, 99.3% of farmers have adopted at least one adaptation measure and 78.8% applied more than five adaptation measures. Results from Deressa et al. (2009) in Ethiopia and Bryan et al. (2013) in Kenya indicated that 42% and 19%, respectively, of farmers did not adapt to climate change. In contrast to the present study, the aforementioned authors have used a mix of closed and open-ended questions when asking for climate change adaptation in order to complement the methods. Our use of closed-ended questions may have restricted the farmers potential to respond what was actually available to them and might have tempted them to state what they knew. Secondly, the concept of maladaptation as presented in climate change debates was beyond the objective of our study and therefore not considered. Thirdly, other analytical methods might have offered further options of exploring the complementarity of different adaptation measures, an aspect that could not be addressed thoroughly with our method.

Nevertheless, the findings presented in this study are valid and statistically robust, presenting the reality from farmers' perspectives as well as variables that are relevant to the adaptation debate in developing countries. These results also represent a window where planning for adaptation, policy interventions and decision-making need to integrate such knowledge to enhance the adaptive capacity.

5. Conclusions

This study investigated two different smallholder farming systems regarding applied adaptation measures to climate change and factors influencing adaptation. Technological and agronomic adaptation measures were compared between a horticultural and a food crop farming system and a binary logistic regression was conducted for adaptation measures to identify determinants of adaptation.

Results showed that adopted adaptation measures reflected livelihood measures and properties of both farming systems. Adaptation measures among the subsistence-oriented food crop farmers were mainly risk-reducing or reactive in nature, while measures among the more market-oriented horticultural farmers aimed primarily at intensifying crop production and were more innovative.

While horticultural farmers received strong adaptation impulses from extension services and a higher risk perception, adaptation among food crop farmers was fostered by access to human capital and access to farmers' groups and cooperatives, which guaranteed higher access to physical, financial and informational resources. Apparently, as farm income increases, limiting factors shift from access to resources and financial capital to the farmers' personal attitude (risk perception) and knowledge of adaptation possibilities.

Factors influencing adaptation depended also on the context of different adaptation measures. Access to workforce was a decisive factor regarding labour-intensive adaptation measures and future risk perception was positively associated with measures entailing long-term benefits.

Furthermore, access to non-agricultural income, that is livelihood diversification, was found to negatively influence most adaptation measures in the food crop farming system. Food crop farmers with access to less risk-prone income sources than agriculture seemed to have little motivation to invest in crop production.

These results are critical to designing agricultural extension programmes that aim to increase adaptive capacities of farmers in Laikipia and other areas that experience similar conditions. Measures that increase incentives and innovation of farmers should be explored to guarantee increased adaptation at local levels.

Otherwise, as climate change progresses, social differences between horticultural and food crop farmers are likely to further increase. This is a good pointer to food security debates in Kenya, which is considered food insecure. Adaptation planners should pay particular attention to the food crop farming system, which is operating far below its potential productivity, and seek measures that abate this low level of production. Growing staple food needs to become an attractive and livelihood-maintaining business. The promotion of farmers' organizations and groups would be a promising way of triggering adaptation among food crop farmers, as it increases knowledge exchange and sharing as well as access to financial capital, aspects that will increase the adaptive capacity of farmers. For the case of horticultural farmers, providing more information from external sources, such as extension services, is a promising starting point for Kenyan adaptation planners.

Also, to avoid biased answers regarding applied adaptation measures as described above, future adaptation research should consider on-farm participatory research methods, including field visits together with the farmers and drawing maps of the farm in order to capture available agricultural practices.

Furthermore, there is a need for more research on a farming systems approach to adaptation. This study could show that the farming systems approach is useful, as 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, apply to other regions in Kenya or SSA. Such evidence could support the development of widely applicable, but still system-targeted, adaptation measures.

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Notes

1. In this study, the term 'food crop' is used synonymously to 'staple crop'.
2. Stores that sell agro-chemicals, livestock feed and medication.

Supplemental data

Supplemental data for this article can be accessed at 10.1080/17565529.2017.1411241.

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