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Adapting agriculture to climate change in Kenya: Household strategies and determinants

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ABSTRACT

Countries in Sub-Saharan Africa are particularly vulnerable to climate change, given dependence on agricultural production and limited adaptive capacity. Based on farm household and Participatory Rural Appraisal data collected from districts in various agroecological zones in Kenya, this paper examines farmers' perceptions of climate change, ongoing adaptation measures, and factors influencing farmers' decisions to adapt. The results show that households face considerable challenges in adapting to climate change. While many households have made small adjustments to their farming practices in response to climate change (in particular, changing planting decisions), few households are able to make more costly investments, for example in agroforestry or irrigation, although there is a desire to invest in such measures. This emphasizes the need for greater investments in rural and agricultural development to support the ability of households to make strategic, long-term decisions that affect their future well-being.

1. Introduction

Climate change is expected to adversely affect agricultural production in Africa. A range of climate models suggest median temperature increases between 3 °C and 4 °C in Africa by the end of the 21st Century, roughly 1.5 times the global mean response. This will likely result in significant yield losses of key staple crops, such as maize, sorghum, millet, groundnut, and cassava, of between 8 and 22 percent by 2050 unless key investments are made to improve agricultural productivity under climate risk (Schlenker and Lobell, 2010). In East Africa, there are very few places where rainfall means are likely to decrease; however, increases in rainfall are unlikely to increase agricultural productivity as a result of unfavorable spacing and timing of precipitation. Because of this variability, coupled with an expected increase in evapotranspiration due to higher temperatures, Kenya is expected to experience country-wide losses in the production of key staples, such as maize (Herrero et al., 2010).

Countries in Sub-Saharan Africa are particularly vulnerable to adverse impacts from climate change, because of their limited capacity to adapt. The development challenges that many African countries face are already considerable, and climate change will only add to these through losses in farm profits (Kurukulasuriya et al., 2006). These impacts are particularly important for countries such as Kenya, where the poverty rate is 52 percent and 73 percent of the labor force depends on agricultural production for their livelihood (FAOSTAT, 2010). Because agricultural production remains the main source of income for most rural communities in the region, adaptation is imperative to enhance the resilience of the agriculture sector, protect the livelihoods of the poor, and ensure food security. At the national level, this will require greater investments in drought and heat tolerant varieties, irrigation systems, disaster relief, insurance and social protection programs, and integrated strategies to reduce livelihood risks (Howden et al., 2007; Schlenker and Lobell, 2010). It also requires adjustments at the farm household and community scales.

Adaptation to climate change at the farm level includes many possible responses, such as changes in crop management practices (e.g. choice of fields, planting dates, planting densities, crop varieties), livestock management practices (e.g. livestock choice, feeding and animal health practices, transhumance timing and destinations), land use and land management (e.g. fallowing, tree planting or protection, irrigation and water harvesting, soil and water conservation measures, tillage practices, soil fertility management)

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and livelihood strategies (e.g. mix of crops or livestock produced, combination of agricultural and non-farm activities, temporary or permanent migration) (Brklacich et al., 1997; Bryant et al., 2000; Smit and Skinner, 2002; Kabubo-Mariara, 2008).

Adaptation can greatly reduce vulnerability to climate change by making rural communities better able to adjust to climate change and variability, moderate potential damages, and cope with adverse consequences (IPCC, 2001). A better understanding of farmers' perceptions of climate change, ongoing adaptation measures, and the decision-making process is important to inform policies aimed at promoting successful adaptation of the agricultural sector. Adaptation will require the involvement of multiple stakeholders, including first and foremost, farmers, but also policymakers, extension agents, NGOs, researchers, communities and the private sector.

Recent micro-econometric studies have examined the links between adaptation and agricultural productivity and net income from agricultural production under climate change (Kurukulasuriya et al., 2006; Seo and Mendelsohn, 2008; Di Falco et al., 2011; Di Falco et al., 2012). Others have focused on the factors influencing adoption of adaptation strategies and have highlighted ways in which policymakers can support adaptation through the provision of credit, information, inputs, and extension services among other measures (Maddison, 2007; Nhemachena and Hassan, 2008; Gbetibouo, 2009; Bryan et al., 2009; Deressa et al., 2009; Hisali et al., 2011; Tambo and Abdoulaye, 2012). For a review of the literature on micro-level adaptation to climate change see Below et al. (2010).

This study focuses on the factors that influence farmers' adoption of adaptation strategies at the household level in Kenya building on previous work by Bryan et al. (2009) in Ethiopia and South Africa. This study expands on previous research by integrating both qualitative and quantitative methods (similar to Thomas et al., 2007) and emphasizing differences in adaptation choices across agroecological zones (AEZs).

The article is composed of four sections. Section 2 describes the study sites and outlines data collection and analytical methods. Section 3 presents the results and is divided into two parts. The first part discusses climate change perceptions and compares these with actual climate trends. The second part examines adaptation to perceived climate change focusing on strategies undertaken by households, desired adaptation strategies, and the determinants of adaptation. Conclusions and policy implications are discussed in Section 4.

2. Methodology

2.1. Data collection

To identify and assess current and potential household-level adaptation strategies available to rural communities, data were collected from case study sites within 7 districts in Kenya (Fig. 1). Site selection took into account agro-ecological zones (AEZs), production systems (crop, mixed and pastoralist systems), agricultural management practices, policy and institutional environments, and the nature and extent of exposure and vulnerability to climate change. The study sites were selected to cover communities where World Bank–supported projects on agricultural mitigation and adaptation were operating, as well as comparable control sites. The selected sites are drawn from a range of AEZ, including arid, semi-arid, temperate, and humid areas. The study sites in Garissa, Mbeere, and Njoro are representative of semi-arid and arid areas with a predominance of pastoralists and agro-pastoralist systems. The study sites in Mukurwe-ini, Othaya, Gem, and Siaya districts are representative of humid and temperate intensive crop and livestock production areas.

Data collection relied on a mixed-method approach, including household surveys and participatory rural appraisals (PRAs) in each site. Within the study sites, 710 farm households were interviewed by IFPRI and KARI between July 2009 and February 2010 (Table 1). While initially 96 households were to be sampled per district, survey teams were unable to complete that number of questionnaires in some districts due to budgetary and logistic constraints (e.g. difficulty in locating pastoralist households for interviews in Garissa). Enumerators used to carry out the survey were selected from each district so that they were familiar with local customs and could speak the local language. The household survey collected information on demographic characteristics; socioeconomic status (e.g. wealth status, income sources, etc.), social capital (e.g. organizational links), land tenure, crop and livestock management, input use and expenses, productive investments, food consumption patterns and expenditures, access to information, extension, technology, markets, and credit, coping responses to climate shocks, perceptions of climate change, adaptation options undertaken today, and constraints to adaptation.

PRAs were conducted in late October–November 2009 in one community in each district. These consisted of focus groups, conducted separately for men and women and including a total of 69 men and 71 women. Older (over 50) women and men predominated, adding to almost half (46 percent) of the participants, with most of the other half (39 percent) being composed of adult participants between 30 and 50 years of age. Younger people were less numerous (15 percent) with most of those being women. In all sites—except Garissa—between 80 (Siaya) and 100 (Mukurwe-ini) percent of the participants had at least primary education, with some having attended secondary school. By contrast the large majority (92 percent) of Garissa participants had no formal education.

A PRA protocol was developed to guide the group discussions based on a thorough review of published literature, online searches, and expert consultations. The protocol was used flexibly, responding to conditions in the field and to the ways different groups of farmers responded, rather than as a rigid framework for eliciting and organizing information. The PRAs included two phases: a) freelisting, in which participants brought up issues and ideas on a variety of topics (causes, indicators, and effects of climate change, adaptations and needed resources to implement them, and additional fears and worries besides climate); b) scoring and ranking of key concerns and resources needed for adaptation. Participants also discussed indigenous climate forecast knowledge and their perceptions of relative reliability of indigenous and scientific forecasts.

2.2. Description of study sites

Kenya contains a wide range of climate and ecological conditions. The country experiences a bimodal seasonal pattern of rainfall as it lies astride the equator. The long rains fall between March and June, with a peak in April and May. Short rains typically fall from late September to November. Mean annual rainfall ranges from less than 250 mm in the arid and semi-arid areas to 2000 mm in humid areas. Mean temperatures are closely related to altitude. Only 12 percent of land area is considered ideal for farming or intensive livestock production; the reminder consists of arid and semi-arid lands (ASALs) (Kabubo-Mariara and Karanja, 2007). Based on the Farm Management Handbook of Kenya (Jaetzold and Schmidt, 1982) the country can be divided into seven AEZs. These zones are based on temperature belts (maximum temperature limits within which the main crops of Kenya can flourish) and climatic yield potential (probability of meeting the temperature and water requirements of the leading crops) in order to provide a framework for ecological land-use potential.

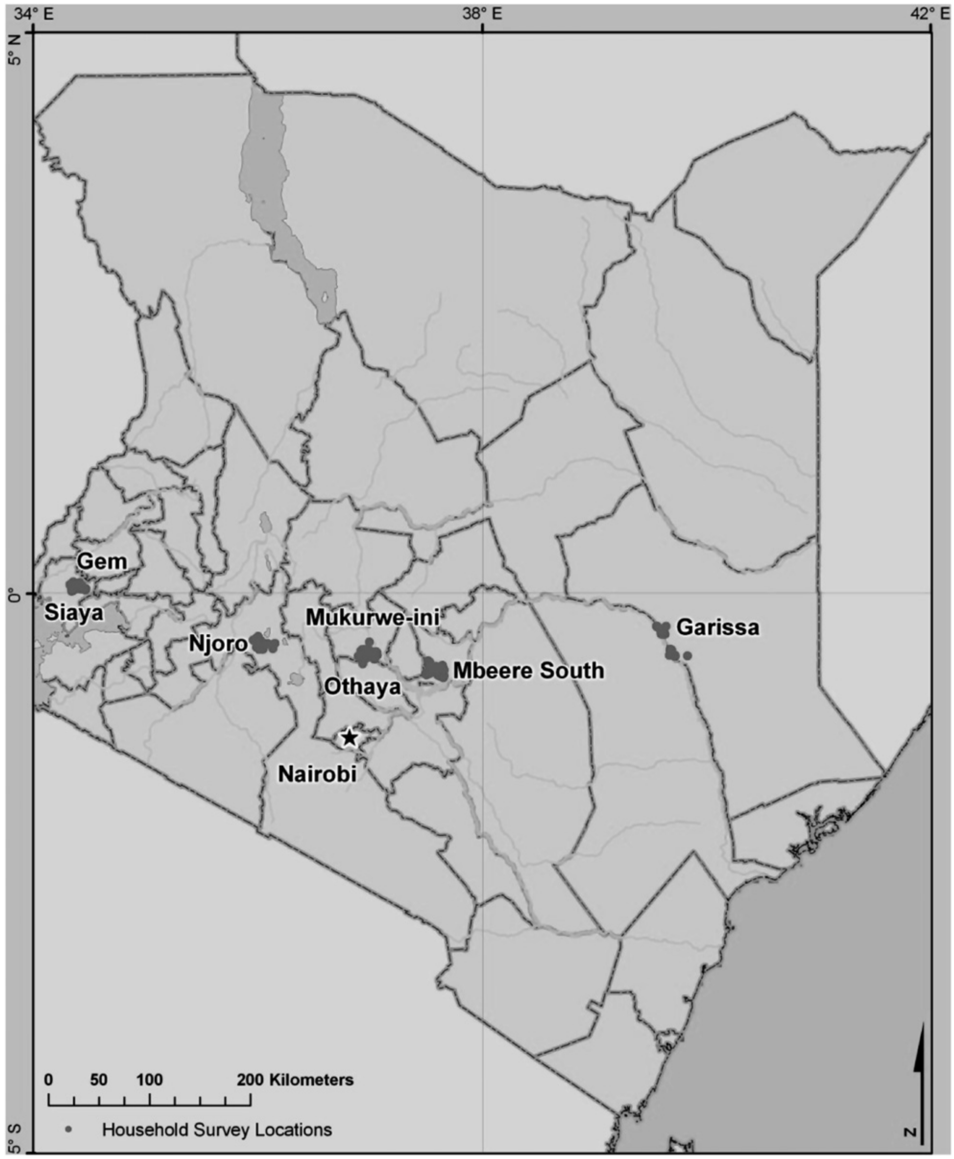

Fig. 1. Map of study sites.

Our study sites come from four of these AEZs. The study site in Garissa District (Northeastern Province) is located in the very arid zone of the country where average rainfall is less than 500 mm per year. The bulk of the area is low lying (100–800 msl) and consists of plains at various levels. Floodplains and low terraces are found along Tana River, which has been recently subject to severe seasonal flooding. Most households are pastoralists and migrate in search of pasture for most of the year. Households with access to the fertile soils along the riverbank use irrigation to produce fruits and vegetables for sale in urban markets. The district borders Somalia to the west and is populated by ethnic Somalis. Garissa is one of the fastest growing towns in Kenya and one of the largest cattle markets in East Africa. The area also hosts the largest refugee camps in the world (Daadab), which is home to about half a million people and exerts enormous pressure on local natural resources and food supplies.

Table 1
Study sites.

District	Agroecological zone	No. of households
Garissa	Arid	134
Mbeere South	Semi arid	97
Njoro	Semi arid	104
Mukurwe-ini	Temperate	95
Othaya	Temperate	88
Gem	Humid	96
Siaya	Humid	96
Total		**710**

Sites in Mbeere South (formerly under Mbeere District), in the Eastern Province, and Njoro (formerly under Nakuru District), in the Rift Valley Province, are located in semi-arid areas of the country. The terrain in Mbeere South is hilly and different crops are cultivated at different altitudes: at elevations over 1000 msl, maize, banana and fruits are cultivated; at elevations of 750–1000 msl, millet, sorghum, drought resistant maize, and legumes are grown; and below 750 msl, livestock production prevails (Roncoli et al., 2010). Average rainfall varies from 550 mm to 1100 mm, but is highly unpredictable. Most parts receive less than 600 mm of rainfall. Njoro District is located near the eastern edge of the Mau forest. Njoro District spans several different AEZs from the humid highlands to the semi-arid area in which our study site is located. Rainfall averages 800–1000 mm (Walubengo, 2007), but with considerable variability: the area experienced a severe drought in 2009. The main livelihoods of the people of Njoro are saw-milling, cattle-keeping and farming. In the semi-arid areas, maize, beans, potatoes are cultivated and crop production often relies on road runoff water harvesting. At the time of the research, food resources in the area were also strained by an influx of internally displaced persons from the 2008 political strife.

Mukurwe-ini and Othaya districts (both formerly part of Nyeri District) are located in the Central Province, in the fertile highlands southwest of Mt. Kenya. Rainfall averages between 800 and 1600 mm per year. The area is inhabited by Kikuyu smallholders and has several permanent rivers that are not exploited for irrigation due to the rugged nature of the terrain and adequate rainfall. Fragmentation of land holdings and increasing soil erosion are also constraints to food security and agricultural development. Today the main cash crop is coffee (and to a lesser degree, tea), produced by smallholders organized in semi-private cooperatives that process and market the coffee. The main food crops are maize, legumes (beans and peas), tubers (potatoes), and vegetables (tomatoes, cabbage, spinach, kale). There is also some dairy milk production.

Siaya and Gem (formerly under Siaya district) are located in the Nyanza Province in the western part of Kenya, bordering the shores of Lake Victoria. The main crops are cotton, sugarcane, tobacco, green vegetables, beans, bananas, sweet potatoes, and cassava. The area hosts several rivers, streams, and wetlands but they are not widely used for irrigation. Rainfall averages 1100–2700 mm per year. The humidity is relatively high with mean evaporation being between 1800 mm and 2000 mm in a year. Despite the more favorable climate conditions, a recent survey in the Siaya, Vihiga, and Kakamega districts of Western Kenya found that between 58 and 68 percent of the population lived below the poverty line (Place et al., 2007). Local farming systems are characterized by very small landholding size (an average of 0.5–1 ha), low external input use and land productivity, declining soil fertility, and exodus of able-bodied men to secure jobs in urban areas (ibid.). High rates of HIV-AIDS, malaria, and other illnesses also affect labor resources and productivity.

2.3. Analytical methods

We analyze farmers' perceptions of climate change using binary and multinomial choice models. A binary choice model is used to estimate the factors influencing farmers' perceptions of long-term changes in rainfall variability:

$$R_i^* = X_i\alpha + \varepsilon_i$$

Where R^* is the latent variable, ε is the error term, and X denotes the set of explanatory variables or factors that influence farmers' perceptions of rainfall variability. The binary outcome is equal to one ($P_i = 1$) if farmer i perceives a change in rainfall variability over the past 20 years and 0 otherwise ($P_i = 0$).

Because perceptions regarding long-term change in average temperature and precipitation fall into several categories—perceived increase, perceived decrease, and no change—a multinomial logit (MNL) model is used to analyze the factors affecting these perceptions. This model permits the analysis of multiple responses over a chosen base category (in this case, no change was used as the base category). The probability that a household i with characteristics X, has climate perception P_j is specified as:

$$P_{ij} = X_i\alpha_j + \varepsilon_{ij},\ \ j = 0, 1 \ldots j$$

The MNL model requires that perceptions are independent of other alternative perceptions within the household. That is, the response choices are mutually exclusive so that if farmer i perceives that the temperature has increased, he or she would not also perceive that the temperature has not changed.

To examine the factors influencing adaptation strategies, a binary response model was used. In order to choose to adapt to climate change, households must first acknowledge that the climate is changing and perceive that this change poses a risk to their well-being that warrants a response, whether it be proactive or reactive. Following previous studies, we consider that a farm household will chose to implement climate change adaptation strategies if adoption increases perceived net benefits (Mendelsohn, 2000; Di Falco et al., 2011). These benefits may include increased net income from agricultural production or reduced production risk under climate variability (Kato et al., 2011). That is, expected benefits from adaptation are equal to A^*, where:

$$A_i^* = X_i\alpha + \varepsilon_i$$

In this equation, A^* is the unobserved, or latent variable; which indicates that household i will chose to adapt to climate change ($A_i = 1$) if expected benefits are greater than zero ($A^* > 0$), and zero otherwise. ε is the error term and X denotes the set of explanatory variables or factors that influence the expected benefits of adaptation. These factors include the physical characteristics of the farm (e.g. soil type, soil fertility), characteristics of the farm household (e.g. gender of the household head, farming experience, social capital, family size, assets, and non-farm income), and access to services and safety nets (e.g. various types of extension services, credit and food or other aid received). Because climate conditions (rainfall and temperature) did not vary much across households within each of the district sites, we use district fixed effects to control for any differences in climate conditions as well as any other unobservable differences across districts.

While other studies have used a multinomial logit (MNL) model to assess farmers' decisions to adapt as a choice between multiple adaptation decisions (e.g. Nhemachena and Hassan, 2008; Gbetibouo, 2009; Deressa et al., 2009; Hisali et al., 2011), we feel that this modeling approach is not warranted in this case, given that most households reported adopting several adaptation options simultaneously and the number of response categories was too great to perform a MNL, even after grouping similar responses. Moreover, grouping adaptation responses into artificial categories such as "livelihood diversification" or "change planting decisions," would confound the analysis of the factors influencing farmers' decision to adopt key strategies and would necessitate creating combinations of responses such as "change planting decisions + agroforestry" or "soil and water conservation + change planting decisions," which we felt would not enable meaningful analysis of adoption decisions. In addition, the set of explanatory variables differs for each adaptation option. For example, we would not expect livestock-related extension services to influence whether or not farmers chose to plant a new crop variety. Therefore, we use a logit model to determine the factors that influence farmers' decisions to adopt each particular adaptation option.

Information collected through PRAs was written on flipchart sheets, which were then compiled, transcribed, coded thematically, and analyzed quantitatively in an Excel spreadsheet. The data were analyzed in terms of differences based on gender and agro-ecological zone (humid/temperate and arid/semi-arid). The results from the analysis of PRA data were used to interpret the quantitative analyses described above.

3. Results and discussion

3.1. Climate change perceptions

A number of studies have underscored the importance of farmers' perceptions of climate change in choosing to adapt (O'Brien et al., 2006; Maddison, 2007; Adger et al., 2009; Jones and Boyd, 2011). Farmers' behavior is shaped more by their perceptions of climate change and climate risk, rather than by the actual climate patterns as measured by scientific methods (Adger et al., 2009; Mertz et al., 2009). More recent studies have emphasized that risk perceptions and socio-cognitive processes of decision-makers are also important for motivating adaptation decisions (Grothmann and Patt, 2005; Frank et al., 2011). While farmers' perceptions are based in part on past observation, several studies have suggested that farmers place greater emphasis on recent climate events in forming their perceptions of climate risk and in making decisions about adaptive behavior (Maddison, 2007; Gbetibouo, 2009).

In this study, we define climate change as perceived changes in average temperature, average rainfall or rainfall variability over the last 20 years. Respondents were asked about their perception of long-term changes in climate. Separate questions asked whether farmers had noticed any long-term changes in the average temperature, average rainfall and rainfall variability over the last 20 years. We define rainfall variability as pertaining to the temporal and the spatial distribution of rainfall as well as the frequency of extreme events, such as drought or flood. To distinguish between responses to long-term climate change and climate shocks, the survey also asked respondents about experience with recent climate shocks and coping strategies (results not shown).

The results show that an overwhelming majority of farmers perceived an increase in average temperatures (94 percent) and a decrease in average precipitation (88 percent) over the last 20 years while only 2 and 6 percent of households observed a decrease in temperature and an increase in rainfall, respectively, over the recall period. When asked whether they had perceived a long-term change in rainfall variability, 91 percent of farmers responded positively. These perceptions were consistent across the surveyed districts despite differences in agroecological conditions.

With regard to rainfall variability, farmers specified which changes they had noticed. These perceptions tended to vary more by district. Overall, 75 percent of farmers who reported a change in rainfall variability noted that rainfall had become more erratic. Eighty-six percent of farmers observed a change in the timing of rainfall with 71 percent reporting that rains are coming later than expected and 15 percent reporting that rainfall was occurring earlier than expected. Farmers also noted increasingly prolonged periods of drought or dry spells between rainy seasons over the past 20 years (51 percent). Changes reported less frequently included an increase in the number of floods (10 percent) and heavier rains (7 percent).

The main change reported by households in Garissa, was a later onset of the rains, especially the long rains which leads to a shortening of the rainfall season. In the other districts, farmers reported more erratic rains, later onset of rains, and longer periods of drought or dry periods between rainfall seasons as the main changes in rainfall variability. In only one district, Mukurwe-ini, was a greater incidence of flooding reported by many households as an important change in rainfall variability.

While farmers perceived long-term changes in temperature and precipitation, actual climate data[1] for the period from 1957 to 1996 from weather stations closest to the surveyed sites show no significant trends in terms of average yearly temperature or precipitation, with the exception of Mukurwe-ini/Othaya where temperature showed a declining trend. However, Ogutu et al. (2007) show that minimum temperatures rose during 1960–2003 in the Mara-Serengeti ecosystem of Kenya and Tanzania, particularly during the wet season. Temperature increases have a significant impact on water availability, thus exacerbating the effects of drought. Therefore, farmers' perceptions may be based on a decrease in water availability (which is also affected by other environmental and social drivers such as changes in soil conditions or population density). Perceptions may also be influenced by the prolonged and severe droughts and higher temperatures experienced in recent years (Ogutu et al., 2007).

The analysis of the factors influencing farmers' perceptions of climate change confirmed the findings of previous studies (Maddison, 2007; Gbetibouo, 2009)—that observation over time shapes farmers' climate change perceptions. The results in Table 2 show that farmers with more farming experience were more likely to perceive long-term changes in rainfall variability, an increase in average temperature, and a decrease in average rainfall. Those households that did not receive visits from extension agents were more likely to perceive a decrease in temperature. This suggests that households without access to extension services are less familiar with the general discourse in the country that temperatures are increasing. Female-headed households were more inclined to perceive an increase in rainfall than male-headed households. Households in the humid AEZ (districts Gem and Siaya) were more likely to perceive a decrease and less likely to perceive an increase in rainfall compared to households in arid Garissa. Households in semi-arid Mbeere South were also more likely to perceive a decrease in rainfall compared to households in Garissa.

The main concern expressed by PRA participants centered on changes in rainfall variability. Farmers often expressed concern about greater variability and seasonal changes, which hindered their ability to predict rainfall patterns and plan their farming activities accordingly. In addition, many farmers reported that the shortening of the rainy seasons has led to longer dry periods in between seasons, which result in greater pressure on their ability to produce enough food. In Siaya and Garissa, farmers reported that an increase in rainfall intensity has exacerbated the problems of flooding and soil erosion. While farmers largely focused on changes in rainfall variability (partly a function of the timing of the PRAs, which coincided with a delayed onset of the short rains), many also acknowledged increases in temperature over the long term (Roncoli et al., 2010). Some participants, particularly in Garissa, reported increased wind intensity, while a few mentioned other parameters (snow cover on Mt. Kenya and occurrence of fog, frost and hail).

While these PRA results do support the findings of the household survey, they also help explain the discrepancy between farmers' perceptions and scientific data pertaining to climate change. These findings suggest that farmers' perceptions of long term decreases in rainfall—recorded by the household survey—may be based on their experiences with rainfall variability,

[1] Precipitation data is from the "Global Historical Climatology Network" (GHCN) database available at http://www.ncdc.noaa.gov/ghcnm/. Daily temperature data is from the "Global Surface Summary of Day" database built based on data exchanged under the World Meteorological Organization, (WMO) World Weather Watch Program, which is made available online through the National Climate Data Center of the United States (NCDC), available at http://lwf.ncdc.noaa.gov/cgi-bin/res40.pl?page=gsod.html.

Table 2
Factors influencing farmers' perceptions of climate change, marginal effects.

Variable	Perceive change in rain variability	Perceive change in average temperature (base: no change perceived)		Perceive change in average rainfall (base: no change perceived)	
		Perceive temperature increase	Perceive temperature decrease	Perceive rainfall increase	Perceive rainfall decrease
Gender of hh head	0.025	0.012	−0.021	−0.047*	0.022
Education of hh head	0.004	0.000	0.001	0.002	−0.001
Years involved in farming	0.004**	0.002*	0.000	0.001	0.002*
Irrigation	0.011	0.022	−0.013	−0.004	0.015
Extension field visits	0.004	0.000	−0.029*	0.008	−0.004
Extension (ffs and ffe)	0.041	0.060	−0.035	−0.058	0.094
Extension (frg and cig)	−0.025	0.020	−0.011	−0.012	0.006
Weather forecasts	0.045	0.003	−0.001	0.016	0.025
Seasonal forecast	−0.006	0.400	−0.369	0.029	−0.007
Early warning	−0.024	−0.038	0.001	0.016	−0.041
Drought in the last 5 years	0.031	0.026	0.008	0.040	0.025
Flood in the last 5 years	0.036	−0.020	0.014	0.109	0.545
Gem (base Garissa)	0.126*	0.076	0.004	−0.133***	0.177***
Mbeere South (base Garissa)	0.075	0.044	−0.002	−0.079	0.165**
Mukurwe-ini (base Garissa)	0.087	0.554	0.051	−0.082	0.765
Njoro (base Garissa)		0.602	−0.014	−0.024	0.710
Othaya (base Garissa)		0.596	−0.003	−0.036	0.718
Siaya (base Garissa)	0.074	0.042	−0.020	−0.152***	0.184***
N	503	691	691	691	691

*$p < .1$; **$p < .05$; ***$p < .01$.
Abbreviations: household (hh), farmer field schools (ffs), farmer-to-farmer exchange (ffe), farmer research group (frg), and common interest group (cig).

and particularly shifts in timing and distribution of rainfall, rather than average quantities of annual rainfall. This may explain why farmers perceive a decrease in rainfall associated with climate change despite the fact that actual climate data have not shown a significant trend.

3.2. Adaptation to climate change

The study aimed to uncover household responses to perceived long-term climate change, as opposed to short-term climate shocks. Often these responses are ex-ante strategies aimed at preventing or mitigating future climate risks. However, in many cases these responses are built on tried-and-proven adaptations to short-term variability and the relationship between the latter and climate change is generally understood by local farmers more as a continuum rather than a dichotomy.

3.2.1. Household adaptation strategies and priorities

The household survey results showed that farmers adopted a range of practices in response to perceived climate change. The most common responses included changing crop variety (33 percent), changing planting dates (20 percent), and changing crop type (18 percent). Other responses included planting trees (9 percent), decreasing the number of livestock (7 percent), diversifying, changing, or supplementing livestock feeds (7 percent), changing fertilizer application (7 percent), and soil and water conservation practices (5 percent). While the number of farmers who did not adjust their farming practices in response to perceived climate change (19 percent) may seem high, this figure is relatively low compared to similar data collected from Ethiopia and South Africa, where 37 percent and 62 percent of farm households, respectively, did not adapt (Bryan et al., 2009).

A key finding is that households in the arid district of Garissa are much less likely to report any adaptation to climate change compared to the other AEZs. The low rate of reported adaptation in Garissa may be due to several factors. First, many households in the arid zone are already practicing livelihood strategies that may be considered climate resilient (for example, migrating over longer distances, irrigating crops, and diversifying into non-climate dependent income sources like petty trade) and may have exhausted the range of adaptation possibilities. In fact, the total number of measures reported by households in Garissa was far less than in the other sites (10 different strategies compared to over 20 different measures in the other sites). Second, households in Garissa were also much less willing to engage with the enumerators during the household survey. The lack of reported adaptation, therefore, may also reflect cultural sensitivities about sharing personal information. In the other sites, where adaptation is more common and the range of possibilities greater, it is likely that those households that did not adapt either do not view climate change as a livelihood risk or are constrained due to lack of resources or information.

The main adaptation measures adopted by farmers varied across AEZs. Changing planting decisions—choosing a new crop or crop variety and changing planting dates—was the key adaptation measure in all but the arid zone. In this zone, moving animals, presumably to regions with lower temperature and more rainfall to support grazing, was the key adaptation strategy, followed by changing the crop or the variety (but not planting date) and changing livestock feed. In the semi-arid zone, farmers have also increasingly switched from cropping systems to mixed crop/livestock systems and have planted trees to adapt to climate change. Changing fertilizer application was a primary strategy in the temperate and humid zones, while changing livestock feeding regimes and increasing cultivated land, respectively, were also reported as key strategies.

It is notable that most of the surveyed farmers did report adaptations to perceived climate change that, apart from planting trees, require little investment to implement—such as purchasing new varieties or crop types, or seeking training or information on soil and water conservation. When farmers' actual adaptations are compared with those changes that farmers would like to implement, we find that the latter require greater investments. In other words, farmers would like to make more significant changes to their farming practices but are unable to do so due to constraints, including lack of money needed for the investment, lack of resources (water or land), lack of inputs, and lack of information.

Among desired adaptations, almost half of the farmers mentioned that they would like to invest in irrigation (49 percent) and agroforestry (39 percent). These changes require greater initial investment by farmers; and, in the case of irrigation, access to water is also crucial. Despite the relatively lower cost of implementation, about one third of farmers (32 percent) also responded that they would like to change crop variety, suggesting that access to improved varieties may be problematic for many farmers.

During the PRAs, participants discussed potential adaptation strategies to climate change. These included both actual as well as desired adaptations, given that it was difficult to distinguish between the two in a group setting, where actual adaptations for some farmers may be desired but unfeasible adaptations for others. Feasibility was, however, assessed by eliciting information on constraints to adoption. During group discussions, livelihood diversification (including integrating crop and livestock production and seeking off-farm income sources, such as jobs, trade, food-for-work, and even illegal activities, such as smuggling, commercial sex, theft, etc.) emerged as the most common adaptation strategy (Roncoli et al., 2010). This was true for both men and women, and all agro-ecological zones, though in the humid zone tree planting and agro-forestry were also very important. Livelihood diversification received less attention during the household survey due to an emphasis on changes in farming practices as a result of climate change, rather than the whole range of possible adaptations.

Consistent with the household survey results, changing planting decisions was frequently mentioned by PRA participants, particularly women. This includes planting more drought resistant crops (for example, cassava, sweet potatoes, pigeon peas, dolichos) as well as planting early-maturing varieties to cope with a shortened rainy season and hybrid seed to improve crop productivity. Farmers also reported planting more napier grass rather than maize, shifting toward more livestock production, and adopting more drought resistant livestock breeds (Roncoli et al., 2010). Among constraints to implementation, farmers in most of the PRA sites complained about the poor quality of seed and inputs and unreliability of packaging information, which they attributed to a lack of quality controls by the government and fraudulent business practices by traders.

Irrigation and water harvesting schemes were ranked at the top among priority adaptations during the PRAs regardless of gender or agro-ecological area, although typically as desired rather than actual adaptations. In fact, the household survey indicated that while many farmers are interested in irrigation and water harvesting, few actually invested in these practices. Among priorities for adaptation, PRA participants also pointed to the need for viable, accessible, and affordable seed for drought resistant and high yielding varieties, and seedlings for agro-forestry. This is true especially among women, for whom it ranked second, and for farmers (of both genders) from humid and temperate areas, for whom it ranked third. Women in particular prioritized supports for improving the quality and obtaining good prices for their crops, over having access to credit (which ranked second for men and for farmers from humid and temperate zones). This was explained in terms of lack of collateral and, in some cases, previous negative experiences with unscrupulous lenders.

In addition to technical responses, PRA participants in each of the sites emphasized the need for investments in human and organizational capacity building, which was ranked first (tied with water infrastructure) by men and third by women. This included access to literacy and numeracy programs and to technical training on entrepreneurship, processing for value added, and marketing as well as support for group formation and management. These capacities were seen as instrumental for farmers' ability to diversify their livelihoods by undertaking profitable non-climate dependent enterprises. Furthermore, participants highlighted the crucial role of good governance (ranked third by men) in improving marketing of agricultural commodities, enforcing quality controls on seed and input distribution, and upholding the rule of law in rural areas. The latter is essential to ensuring that goods, animals, and humans can circulate safely and people are confident enough to access services and invest in economic ventures.

Echoing survey respondents, PRA participants identified lack of resources as the most significant constraint to adaptation. Poverty or lack of resources was ranked highest by both men and women regardless of AEZ. However, men also stressed political factors (governance and leadership) particularly in arid and semi-arid areas, where conflict and insecurity were more prevalent. Health problems—which resulted in poor labor productivity and additional strain on household financial resources—were also mentioned among constraints (ranking second in humid and temperate areas and third in arid and semi-arid areas).

3.2.2. Determinants of adaptation

The results from the logit regressions (marginal effects) on the determinants of adaptation are presented in Table 3. We find that only a limited number of factors influence the decision to adopt any adaptation strategies or not. Only access to food aid or other assistance and weather forecasts increase the likelihood of adaptation while all other factors are not statistically significant. It is difficult to draw any conclusions from this result given that the individual adaptation choices underlying this aggregate variable for adaptation are vastly different. Therefore, it is unlikely that the factors that influence one adaptation strategy, say changing crop variety, will be the same or similar for an entirely different strategy, such as tree planting. In fact, when we look at adoption of individual adaptation strategies, it appears that the analysis of farmers' decision to adapt or not masks important differences in the factors influencing adoption of particular strategies.

Only a few factors influence whether farmers change crop type or planting dates. However, there are some noteworthy findings with respect to planting decisions. Access to irrigation is a significant determinant of changing crop type. This suggests that farmers that have access to irrigation are switching to high value crops, which other studies have suggested is essential for moving out of poverty (Krishna et al., 2004; Kristjanson et al., 2005, 2009). With regard to changing planting dates, having access to social safety nets (i.e. food emergency relief, food subsidies, or other farm support[2]), access to extension services (in particular, farmer research groups or common interest groups), and access to seasonal climate forecasts were important determinants.

Similarly, food or other aid and extension services (including involvement in on-farm research or common interest groups) influenced farmers' decision to change crop variety. While food aid is likely targeted to poorer farmers who are unable to make large productive investments in their farms, it appears to enable these households to take more moderate risks, such as changing planting dates or adopting a new crop variety. In addition, farmers with access to fertile soils, larger land holdings, and those engaged in both crop and livestock production, were more likely to change crop variety. It is interesting that membership in associations (i.e. the number of associations to which members of the household belong) negatively influences the likelihood of changing crop variety. This is likely due to the fact that most of the associations reported by surveyed households were women's associations. These networks are often responsible for storage and sharing of seeds and therefore may be less likely to purchase seed from external sources, including improved varieties.

Given that planting trees is a larger financial investment than changing planting decisions, it is not surprising that those who are more likely to adopt this practice are wealthier households—that is

[2] Only a few households reported receiving aid from food for work or cash for work programs.

Table 3
Determinants of adaptation, marginal effects.

Variable	Adaptation	Change variety	Change type	Change planting dates	Plant trees	Destocking	Change feeds	Change fertilizer	Soil and water conservation
Gender of hh head	−0.022	−0.033	−0.027	−0.049	0.014	0.007	0.070*	0.016	−0.024
Education of hh head	−0.001	0.000	0.007	−0.004	−0.002	0.002	−0.002	0.002	−0.003
Years involved in farming	0.000	−0.002	0.000	0.000	0.002	0.000	0.002**	0.000	0.001*
Household size	−0.001	0.006	−0.002	−0.004	0.004	−0.003	−0.005	0.000	0.007*
Access to electricity	0.062	−0.023	0.005	0.035	0.060*	0.013	−0.043**	0.045	0.005
Food or other aid received	0.088***	0.055**	0.036	0.069***	−0.038*	−0.030*	0.039**	0.003	0.001
Associations membership	−0.042	−0.077**	−0.033	0.002	0.050*	−0.016	−0.041	−0.028	0.008
Soil fertility high (base poor)	0.055	0.112**	−0.021	0.021	0.003	−0.019	0.006	0.019	−0.043
Soil fertility moderate (base poor)	0.064	0.025	0.005	0.023	0.035	−0.008	−0.032	0.008	0.007
Land title	−0.010	0.046	0.025	−0.016	0.003	0.016	−0.077***	0.055*	0.017
Land area	0.005	0.008*	0.000	0.004	0.004**	−0.001	0.001	0.002	0.003*
Mix crop and livestock production	−0.022	0.095**	0.062	−0.042	−0.007	−0.011	0.030	0.110**	0.030
Irrigation	0.054	0.134	0.244***	−0.196		−0.052	−0.042		−0.007
Extension field visits	0.049								
Extension (ffs and ffe)	−0.018								
Extension (frg and cig)	0.042								
Crop extension field visits		0.008	0.028	0.012	0.067***			0.007	0.055***
Crop extension (ffs and ffe)		−0.050	−0.056	−0.066	0.074***			0.040*	0.018
Crop extension (frg and cig)		0.142***	0.022	0.080**	0.050*			0.032	0.029
Livestock extension field visits						−0.020	0.038*		
Livestock extension (ffs and ffe)						0.006	−0.004		
Livestock extension (frg and cig)						0.003	−0.002		
Weather forecasts	0.079**	0.051	0.026	0.016	0.032	0.014	0.008	−0.036	0.011
Seasonal forecast	−0.001	−0.090**	0.024	0.077*	0.008	−0.010	0.041	−0.026	0.022
Early warning	0.003	0.021	−0.020	0.051	−0.009	0.011	−0.003	0.026	−0.003
Formal credit	0.017	−0.017	0.029	0.012	−0.011	0.002	−0.007	0.001	0.014
Informal credit	0.014	−0.047	0.036	0.050	−0.016	0.039*	0.050**	−0.012	−0.021
Nonfarm income	0.000	0.000	0.000	0.000	0.000*	0.000	0.000	0.000**	0.000*
Gem (base Garissa)	0.151	0.256	0.224*	2.042	0.131	−0.017	−0.033	0.819	0.716
Mbeere South (base Garissa)	0.357***	0.631***	0.246**	2.198	0.200**	0.146	−0.079	0.738	0.817
Mukurwe-ini (base Garissa)	0.689***	0.919***	0.175	2.061	0.006	0.065	0.003	0.898	0.790
Njoro (base Garissa)	0.287***	0.680***	0.234*	2.189	0.096	0.084	0.011	0.780	
Othaya (base Garissa)	0.359***	0.747***	0.097	1.873	0.200**	0.123	0.005	0.791	0.702
Siaya (base Garissa)	0.378***	0.479***	0.295**	2.179	0.003	−0.007	−0.043	0.853	0.705
N	657	657	657	657	595	657	657	595	559

*$p < .1$; **$p < .05$; ***$p < .01$.
Abbreviations: household (hh), farmer field schools (ffs), farmer-to-farmer exchange (ffe), farmer research group (frg), and common interest group (cig).

households with access to electricity (an indicator of wealth), nonfarm sources of income, and larger land holdings. By contrast, access to food emergency relief and other sources of aid (which are usually targeted to the poorest) is shown to negatively influence the decision to plant trees. Access to crop extension services of all types is also a significant determinant of whether a farmer plants trees in response to perceived climate change. Unlike the case of changing crop variety, membership in associations increases the likelihood of planting trees. This is likely because engaging in agroforestry requires new knowledge and significant investment, which may be facilitated by group membership. In addition, agroforestry is often implemented by groups within the community, for example, through the establishment of communal tree nurseries, or through NGO-supported projects, which also tend to work with farmers by organizing them into groups.

Several factors influence farmers' decision to adjust their livestock practices in response to perceived climate change. As with planting trees, farmers that appear to be better off financially (i.e. they do not receive food or other sources of aid) are more likely to reduce the number of livestock as an adaptation strategy. This may be an indication that households that engage in destocking have other livelihood sources or investment alternatives they can rely on, while poorer households may hold on to their livestock as their only investment option (Silvestri et al., 2012). In addition, when livestock is transformed into cash, poor households may find that cash is quickly dissipated by their many needs, while wealthy households may be better able to hold on to the capital and reinvest it productively. Cultural and social factors, such as the strong value placed on large herds by pastoralists, may also prevent some households from reducing the number of livestock (Watson and van Binsbergen, 2006). Pastoral households may also be more reluctant to sell livestock because those with large herd sizes and greater mobility have been shown to have increased resilience to drought (Little et al., 2008).

Households that are more likely to change livestock feeds tend to be male-headed and more experienced in farming. This may be partly explained by the fact that women may have more limited ability to purchase supplemental feed than men (because they have less money) or need (because they have smaller herds and smaller livestock). In addition, both male-headed households and more experienced farmers may have greater awareness of and access to alternate sources of feed. Livestock extension, specifically field visits, encourages farmers to change or supplement livestock feeds. As opposed to the case with destocking, it appears that poorer households (characterized by lack of electricity and dependence on food aid) and households without formal land titles are more likely to change livestock feeds. Lack of electricity and lack of a formal land title may indicate that many of the households changing livestock feeds are pastoralists. Having access to informal sources of credit is an important determinant of both destocking and changing livestock feeds.[3]

[3] Access to credit is captured by a dummy variable for whether the household has borrowed from formal or informal sources over the previous year. This is an imperfect proxy for access to credit—not all households that did not borrow are necessarily credit-constrained. Rather some farmers may chose not to borrow because they feel it is too risky or for other reasons.

Farmers with mixed crop and livestock systems, access to non-farm sources of income, and access to extension (specifically farmer-to-farmer exchange programs or farmer field schools) were more likely to adjust fertilizer applications. Wealthier households (using access to electricity as proxy) are also more able to change fertilizer applications in response to climate change.

Finally, households with more household members, more farming experience, large land holdings, and greater access to non-farm income and to extension services (specifically field visits) are more likely to implement soil and water conservation practices.

Overall, we found access to extension services, credit, and diversified sources of income to be supportive of adaptation. The results also indicate that the deteriorating land base of many farming households due to population growth, appropriation of lands, and the practice of subdividing farms among heirs (Klopp, 2000) is a serious constraint to adaptation—particularly with regard to changing crop varieties, planting trees and soil and water conservation. Furthermore, the results suggest that efforts to reduce poverty throughout the country would also enable many farmers to adapt to climate change. This is particularly important as poverty has been increasing in recent years (Krishna et al., 2004; Kristjanson et al., 2009). In particular, many farmers expressed interest in agroforestry and changing crop variety, yet were unable to adopt these measures.

4. Conclusions and policy implications

Climate change is expected to have a significant impact on Kenya, including increases in average temperature and rainfall. However, there is considerable uncertainty surrounding rainfall projections and indications that there will be a great deal of regional variation in precipitation across the country. Moreover, little can be said about future changes in the frequency of extreme events such as drought and flood (Herrero et al., 2010). Smallholder producers, therefore, must make decisions in an environment of great uncertainty. This research shows that despite limited evidence of climate change, farmers and pastoralists do indeed perceive the climate to be changing and are particularly concerned with perceived changes in rainfall variability. Perceptions of climate change appear to be mainly based on farmers' experience—those who had been involved in farming longer were more likely to perceive long-term changes in temperature, precipitation, and rainfall variability.

Farmers are taking measures to protect their livelihoods against perceived changes in climate. However, many households face considerable challenges in adapting to climate change. While farmers have made adjustments to their farming practices in response to climate change (in particular, changing planting decisions), few of them are able to make large investments to reduce their vulnerability, for example in agroforestry or irrigation, although there is a desire to invest in such measures. In the case of agroforestry, those farmers who are able to make the investment appear to have greater access to resources (such as non-farm income), social networks, and information through extension services. Even changing crop varieties—the most common, less costly, adaptation—faces obstacles, including lack of suitable land and poor access to extension services. In addition, there is some indication that access to improved seeds may be problematic. This may be due to the fact that some households rely on traditional seed sharing and storage systems through local networks, but also to the fact that seed sold on rural markets is often of poor quality and improperly labeled.

The government, the private sector, non-governmental organizations, and donor agencies all have important roles in addressing these barriers, ranging from development of desirable crop traits adapted to the various agroecological zones of Kenya to capacity building and knowledge dissemination through public and private extension services, to ensuring that viable and suitable seeds are available in remote rural regions. Public and private sector support for the design and construction of irrigation infrastructure is also important for adaptation and livelihood resilience. In particular, access to irrigation is shown to be an important determinant of whether farmers change crop types, suggesting that investments in irrigation infrastructure would help farmers switch to higher value crops, thereby increasing farm revenues.

In general, the results emphasize the need for greater investments in rural and agricultural development to support the ability of households to make strategic long-term decisions that affect their future well-being. Autonomous adaptation is insufficient to address the threats posed by climate change. The rural poor need more support from the government, NGOs, and the private sector to enable them to move beyond short-term coping measures in response to climate shocks and to invest in long-term, anticipatory strategies that enhance resilience to climate change through the accumulation of assets, livelihood diversification, and the adoption of agricultural technologies that allow for increased productivity and profitability.

This is particularly true in arid areas, where households face greater constraints in adapting to climate change and have limited options to increase resilience to future climate change. Numerous NGOs and government agencies are already operating in these areas. Much assistance is provided in the way of emergency relief, such as food aid. However, in addition to providing a safety net following major climate shocks, more should be done to build the resilience of these communities to withstand future climate crises. In particular, drought management and drought preparedness plans should be integrated into rural development efforts. In addition, plans to address flood risks and soil erosion will also become increasingly important, as rainfall intensity and volume is set to increase across the country.

While the household survey data provide compelling evidence to support these results, they are further substantiated by the qualitative methods employed. Additionally, participatory methods were instrumental in broadening the original focus on the agricultural sector and in illuminating the need for investments and adaptations in livelihood diversification, human and organizational capacity, and improved governance.

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