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The salience of climate change in farmer decision-making within smallholder semi-arid agroecosystems

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Abstract

Smallholder farmers in Sub-Saharan Africa are most susceptible to the impacts of climate change, including longer duration dry-spells and more frequent drought. There is a growing literature examining the psychological determinants of various climate adaptation strategies among smallholder farmers but little attention to how psychological factors vary across adaptation decisions and the underlying motivations for these decisions. We assess climate adaptation in terms of five risk management categories outlined by Agrawal (2009). Using a sample of farming households in Kenya ($N = 494$), we find that while 98% of smallholders believe that various dimensions of climate change pose a significant threat to their livelihood, these beliefs do not necessarily translate into climate actions. Results show that environmental concerns are not salient motivators for or against adaptation strategies, but food insecurity and household expenses are, suggesting a disconnect between climate beliefs and actions. Future research on decision-making related to climate adaptation within semi-arid agroecosystems should consider that while perceptions of climate change are important in shaping climate adaptive actions, they are not necessarily a salient motivator. Climate change is predicted to have significant negative impacts on food security but concerns about food security are what motivate farmers to adopt practices that will prepare them for climate change.

1 Introduction

There is substantial documentation of patterns of climate variability and change in sub-Saharan Africa (see Kotir 2011 for a review). Projected changes in both the frequency and severity of

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extreme weather events, including more frequent and longer duration drought events, are expected to have significant consequences for food security and food production in the region (IPCC 2012; Schmidhuber and Tubiello 2007; Lobell et al. 2008). The most immediate impacts of climate change are expected to be localized impacts experienced predominantly by smallholder farmers in developing countries (Morton 2007; Schneider et al. 2007).

Farmers are aware of climate change and employ coping and adaptation strategies to mitigate negative impacts (Thomas et al. 2007; Mercer et al. 2012). The climate adaptation literature has addressed demographic and economic explanations for adaptation behavior among smallholder farmers in developing countries (e.g., Below et al. 2012; Bryan et al. 2009; Deressa et al. 2009) and has started to address the importance of psychological predictors of climate adaptation behavior (e.g., Gifford 2011; Kuruppu and Liverman 2011), specifically investigating smallholder farmers' perceptions of climate change (e.g., Grothmann and Patt 2005; Mertz et al. 2008; Nyanga et al. 2011; Jain et al. 2015; Truelove et al. 2015). This growing body of literature points to the critical role of perceptions and psychological biases and barriers to climate adaptation, and importantly raises the question of whether climate change is salient to farmers or whether activities that are often interpreted as climate adaptation are simply related to other more proximate and salient factors, such as food security. In this paper, we look directly at the role of these environmental perceptions and the salience of environmental concerns in adaptation decisions.

Understanding climate adaptation decisions can be challenging given the multiple dimensions of environmental change, the temporal nature of those changes, and the complexity of the decision-making environment. Climate change itself is a complex and technical phenomenon that includes rising temperatures, erratic and more variable rainfall, more frequent extreme weather events, and shorter growing seasons (Kotir 2011). Individuals' perceptions of the climate vary because there are limits to understanding and synthesizing highly technical environmental information (Knopman 2006). There are also limits in people's attention, memory, and access to information, which make it challenging to synthesize climate events and trends (Weber 2013). Rao et al. (2011) find that it is particularly difficult for farmers to discern long-term trends given all the other factors that influence crop productivity. The result is that there are limits to climate adaptation based on how understandings of future weather and climate are constructed (Adger et al. 2009).

Individuals' assessments and tolerance of climate-related risk also play a role in shaping climate resilient behavior. Risk perception related to changing weather patterns has been demonstrated to be an important predictor of adaptation strategies (Esham and Garforth 2013; Jain et al. 2015). People are particularly responsive to risks that they perceive to be both immediate and personally relevant (Moser and Dilling 2004). Tversky and Kahneman (1973) demonstrated that people often rely on availability heuristics to estimate risk by searching their memories for vivid examples of such an event occurring. Availability heuristics can thus cause people to be more responsive to extreme weather events since they are more memorable although less probable than gradual changes in the climate (Morton 2007; Marx et al. 2007). People also underattend to low probability, high consequence risks and underappreciate the benefits of long-term investments in protection (Kunreuther et al. 2013). This cognitive bias can cause people to misjudge their personal exposure to risk from a natural hazard such as an extreme weather event (Freeman and Kunreuther 2003).

The variation in how people understand climate trends and perceive risk from climate change contributes to the difficulty of defining smallholder climate change adaptation. Definitions of adaptation often blur the underlying motivations of the decision and can range from a response to an actual environmental change to perceived threats of future change (IPCC

2012; Klein 2003). Adaptation actions can moderate the impacts of climate change (Adger et al. 2003), reduce the risk of future change (Smit and Skinner 2002) and have short- or long-term implications (Tucker et al. 2010). Adaptation decisions can take place over a range of time scales so linking short term behavior to longer term strategies can be difficult (Easterling et al. 2007). Temporal ambiguity is further reflected in the blurred distinction between the concepts of coping and adaptation, which many authors use interchangeably (Burnham and Ma 2016). We use the term climate preparedness to highlight that we are talking about actions that will facilitate preparedness for long-term changes in the environment, rather than coping and adaptation which make assumptions about motivations underlying behavior.

Wise et al. (2014) reviewed the literature on climate change adaptation and found little evidence of actions being taken, except in sectors that are more sensitive to climate impacts. They also found that in many cases, climate change was rarely the sole motivator for adaptation actions since farmers' actions were often catalyzed by extreme events rather than long-term trends. Our research focuses on individuals' underlying motivations for engaging in activities often construed by researchers of as climate adaptation, an area that has received little attention in the literature. Ambiguity related to the multiple dimensions of climate change, how adaptation is defined, and what farmers cognitively respond to demonstrate how little is known about what motivates farmers' decisions regarding climate preparedness.

We attempt to resolve some of the ambiguity through the following research questions: (1) Do farmers appear to be implementing common adaptation strategies and is there consensus about which activities are the most effective? (2) What are the most salient motivations for engaging in specific climate adaptation practices? (3) How are environmental perceptions and changes in the climate as measured by observational climate data related to the decision to employ or not employ these adaptation activities? We investigate these questions by analyzing a subset of activities that are often characterized as climate adaptation. We look at these activities, not in terms of the murky terms coping and adaptation but rather in terms of the different conceptions of risk that they embody (Agrawal 2009). By answering these questions, we shed light on the salience of climate changes to farmers when engaging in various activities. This research is conducted with farmers in a semi-arid area of Kenya in the midst of consecutive low rainfall growing seasons.

Given the ambiguity around climate change and adaptation, we focus on the salience of climate change for adaptation actions. Much of the literature on the salience of climate change revolves around perceptions, politics, identity, and the extent to which political mobilization shapes the concern about climate change (Brulle et al. 2012; Unsworth and Fielding 2014; Weber and Stern 2011). Climate adaptation strategies have been developed for the most affected areas in the USA (for example Miami and New York City), but little attention has been devoted to understanding behavioral barriers and adaptation strategies in a developing world context. Researchers have found that climate messaging and imagery can enhance salience (O'Neill et al. 2013) and noted the salience of climate-related events on adaptive actions (Spence et al. 2011) in the developed world but we do not know what effective climate communication might look like with farmers in developing countries. In our work, we marry the information we gather about climate change salience with adaptation behaviors for Kenyan farmers who are among the people projected to be the most impacted globally by climate change.

There is complex causality between climate change and food insecurity, which are cognitively associated for farmers in different ways. While climate change can lead to food insecurity or income loss, numerous other factors can contribute including crop loss from pests, poorly designed agricultural policies, or disease and family health issues. This study does not address the multidirectional causality involved in climate preparedness but rather focuses on identifying the most salient or plausible explanation to the farmer for their given actions. We purposefully select activities that we believe best represent different dimensions of risk faced by farmers (Agrawal 2009) and that have been determined to be climate adaptation in previous studies (Burnham and Ma 2016). We assess five adaptation activities (in parentheses) that align with these risk categories; managing risk across space (migration for work), time (planting early maturing maize), asset classes (doing casual labor or piecework on another farm), households (borrowing food), and through market exchange (selling livestock). We treat these activities as unique responses to risk with unique outcomes.

2 Rainfall variability and climate adaptation in Kenya

2.1 The upper Ewaso Ng'iro river basin

This study takes place in a semi-arid region in the central plateau of Kenya near the base of Mount Kenya across Laikipia, Meru, and Nyeri counties. The central plateau is dominated by the largest ethnic group, the Kikuyu (69% in our sample). Smaller numbers of Kimeru (29% in our sample) and members of other ethnic groups also live in the region, including Kimaasai pastoralist communities who farm periodically in the more arid lowlands. The study area falls within the Upper Ewaso Ng'iro River basin, which encompasses parts of Mount Kenya and the neighboring Aberdare Range (Fig. 1a).

Precipitation patterns in the study area roughly follow the contour lines of Mt. Kenya, with higher elevation areas receiving approximately 1000 mm of precipitation annually, and the semi-arid lowlands receiving less than 500 mm annually (Gichangi et al. 2015). Franz et al. (2010) found that total precipitation in the region is not changing over time but that storm

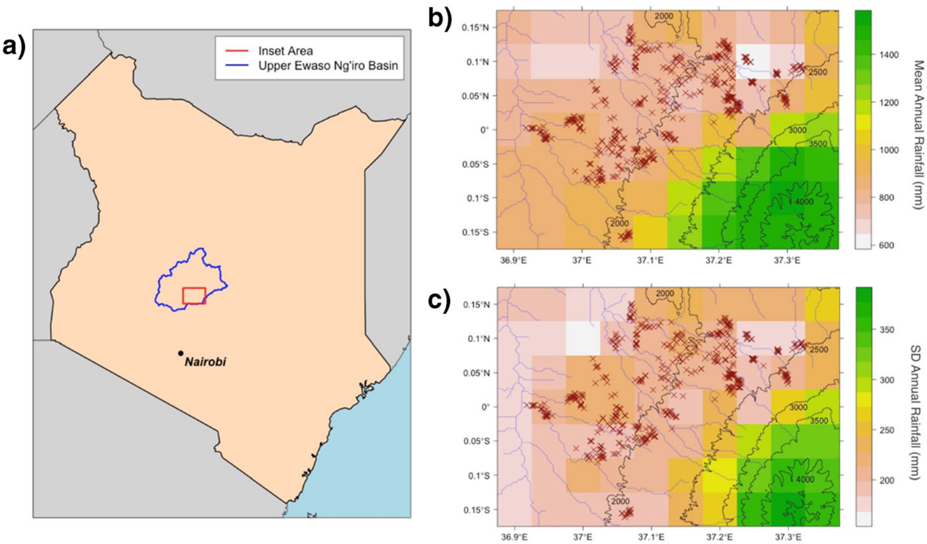

Fig. 1 **a** Study area and Upper Ewaso Ng'iro basin in Kenya, **b** Mean annual rainfall with household locations, **c** Standard deviation of annual rainfall with household locations. Note: Household survey locations noted by red crosses in panels **b** and **c**

depth is increasing and the arrival rate of storm events is decreasing. While higher elevation areas in the Mt. Kenya region receive more rainfall than lowland areas, the areas with highest rainfall (in Fig. 1b) are not suitable for agricultural production due to topographic and accessibility constraints. The variation in rainfall is roughly consistent with the total annual rainfall, with higher rainfall areas having higher standard deviations in rainfall.

Agricultural production in this area is largely rainfed but most farmers receive varying amounts of water for both domestic use and irrigation through Community Water Projects (CWPs). CWPs consist of a network of pipes that distribute water from the source, typically a river, to a main reservoir, and then to individual households of project members. Membership in a CWP requires a joining fee, which precludes some households from joining (mean membership fee = \$77.23; standard deviation = 44.19). There is a monthly maintenance fee (mean maintenance fee = \$1.49; standard deviation = \$0.89) and, in some cases, work requirements to support maintenance of the pipe network. CWPs can range from 10 households to hundreds of households depending on the capacity of water the CWP carries, the demand of the surrounding population, and the decision of the CWP management committee to expand or not. Members in higher elevation areas have better access to the pipe networks and generally higher water pressure and flow rates depending on their distance from the main irrigation lines.

Maize production dominates in the region, and access to irrigation allows households to grow maize in an area where it is otherwise very risky through earlier planting or irrigating during dry periods between rain events. Subsistence farming is common but there is some market exchange in the nearby market town of Nanyuki. A number of commercial flower farms and other cash crop farms, run mostly by expatriates, also fall within the study area and compete with smallholders for water access by capturing surface water and groundwater from rivers and boreholes, respectively. These commercial producers, along with population growth in the region, have contributed to tension among water users related to decreased water flow since the 1960s (Ngigi et al. 2007).

In response to growing tensions of water use at the national level, the government reorganized administration of water distribution across the country. The 2002 Water Act established the Water Resources Management Authority (WRMA) to manage water withdrawals through rotation policies and permits at the regional and catchment level. The Water Act also established Water Resource Users Associations (WRUA) to coordinate water delivery and resolve conflicts among community water projects and commercial users. These two governing bodies coordinate water use through water sharing during times of scarcity (McCord et al. 2017), thereby helping to mitigate conflicts between upstream and downstream users (Baldwin et al. 2016).

2.2 Household survey and sample population

In March and April 2017, a household survey was conducted for a period of 4 weeks where farmers were visited at their homesteads. The first stage of the sampling strategy involved 25 CWPs, which fall under 5 different WRUAs: Likii, Nanyuki, Ngusishi, Timau, and Ngare Nything. We sampled a representative number of households from each CWP as follows: For smaller CWPs with fewer than 15-member households, we attempted to survey all member households, while in CWPs larger than 15, we randomly selected 30% of households from a list provided by the chairperson of the CWP and interviewed as many of these as possible. If no one was available at a household for two subsequent visits, we skipped that household.

Approximately one third of the overall sample included households that were not part of a CWP but were in the proximity of a CWP. They were typically households that lacked the financial resources to pay the CWP member initiation fee and/or the infrastructure to connect to the CWP water network. In a second stage, we randomly selected households through agriculture extension lists in the same vicinity. This strategy allowed us to reach more non-CWP households as well as new households spread across an additional 32 CWPs. The total number of households sampled was 494 from 57 CWPs.

Many of the farmers we surveyed are part of water user organizations designed to mitigate the impact of changing climate conditions on water supplies so they have been potentially exposed to more information about climate change than the average Kenyan farmer. We intentionally avoided priming farmers about climate change and tried to categorize their stated and thus most salient motivations for various activities in the way that characterized their responses most accurately.

2.3 Methodological approach

We presented farmers with a list of activities that are commonly considered climate adaptation activities, drawn from a meta-analysis of farmer climate change adaptation decisions (Burnham and Ma 2016). We tailored the list to the Kenyan context through a combination of field testing and discussion with local experts to create a list of 20 activities. We asked farmers whether they employed these activities in the previous growing season, which was considered a below average rainfall season by a majority of the sample, and whether they employed the activities in the three previous years (including the growing season that was just completed). For each of the activities they reported, we then asked them how effective the selected activities were in coping with drought during the previous season and how effective the activities were in the prior 3 years for adapting to climate variability. We assess the relationship between the prevalence of the activities and the perceived effectiveness (research question 1).

From the list of 20 activities, we then selected five specific adaptation activities that best represent the five analytical categories of climate-related risk mitigation outlined by Agrawal (2009). The five activities were purposively selected to reflect the five risk management categories as follows: migrating for work (risk across space), planting early maturing maize (risk across time), doing off-farm casual labor (risk across asset classes), borrowing food or money to buy food (risk across households), and selling livestock (market exchange). Note that some activities could fall in multiple risk categories; for example, planting an early maturing maize variety could be viewed in terms of diversifying across both time and asset classes. The potential overlap in the risk categories is indicative of the overlapping causality in the motivations for actions, which can also include food insecurity, and income needs. For many farmers, these factors are often interrelated. We are focused on identifying the most salient or plausible motivations to farmers as opposed to understanding how factors might be interrelated.

To understand the drivers of these activities (research question 2), we asked farmers why they did or did not employ each of the five activities. Eliciting reasons for an action is an approach similar to that used by Attari et al. (2014) to identify reasons why people cooperate or defect in social dilemmas, allowing for analysis of both close-ended choices and open-ended explanations of the participants' actions. The close-ended questions in the survey included a list of pre-tested motivations for each activity (one activity had as few as five options and others had as many as eight) and enumerators were instructed to select as many responses as were mentioned by the respondent. We also provided an open-ended text entry response option to allow for responses that did not fit into the predefined categories. A single coder coded the open-ended motivations and incorporated these responses into predefined categories if they fit or created new categories, generating between 5 and 10 total categories for each response. The coder then aggregated the responses into motivational categories for doing or not doing each activity. We interpret the responses as constructed motivations or the plausible or most salient response, as opposed to the most accurate (as per Nisbett and Wilson 1977).

To understand the role of climate-specific risk perceptions in adaptation (research question 3), we estimated five separate logistic regressions, where the dependent variable is whether a household employed each of the five activities in the last season: migrating elsewhere for work, planting an early maturing maize variety, doing casual labor or piecework on another farm, borrowing food, or, and selling livestock. We hypothesize that adaptation is a function of an assessment of socioeconomic determinants (and constraints), psychological factors, and weather conditions over a 30-year period. Predictors include basic socioeconomic variables (assets and income), farm-specific assets (farm size, and labor/household size), management-related variables (education, whether they belonged to a community water project), psycho-social variables (described below), and mean annual rainfall quantity and standard deviation in annual rainfall from 1983 to present (described below).

We quantified psychological determinants of climate adaptation by asking respondents about their climate change beliefs and perceptions about the weather and climate. To characterize climate change beliefs, we asked farmers if they perceived the following to be a threat to their agricultural productivity in the next 5 years: increased drought or extreme weather events, shortening of the length of the growing season, and higher variability in rainfall (not at all, somewhat, very much). The variable “Rain characterization” is the respondent’s assessment of the amount of rain during the previous growing season (drought, below average, average, above average, and excess rainfall). “Rain optimism” captures the relative optimism of individuals about future rainfall events by comparing their assessment of the amount of rain in coming 2017 long rains season with the previous 2016 long rains season (the same, more rain, less rain). We attempt to capture the risk associated with drought in three ways. “Drought probability” is a how frequently the respondent perceives they experience a year with drought. “Drought changing” represents an individual’s perceptions of whether droughts occur more often, less often, or with the same frequency as when they were a child. “Rain onset delay” is the difference between an individual’s perception of when the long rains begin in 2016 and approximately 10 years ago.

Rainfall data used in the regressions comes from the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) dataset (Funk et al. 2015). This is a pan-tropical (50° N to 50° S) dataset with 5-km-daily resolution satellite-derived precipitation from 1981 to present fused with local meteorological station data. The dataset combines satellite imagery with station data to create a gridded rainfall time series for trend analysis. The technique was developed to support hydrological forecasts and trend analysis in areas where there is a dearth of surface data, and is particularly well suited for quantifying hydrological impacts of decreasing precipitation in Africa.

3 Results

The results are divided into three sections. First, we document the prevalence of various adaptation activities among smallholders and the perceived effectiveness of these activities.

Then, we isolate the motivations for a selection of these activities through open and close-ended questions. Finally, we describe environmental perceptions and estimate logistic regressions exploring the socioeconomic, psychological, and environmental determinants for these selected adaptation activities.

3.1 Prevalence and perceived effectiveness of adaptation activities

Table 1 displays the list of adaptation activities we asked farmers about. There is little difference in the proportion of farmers employing activities in the previous season versus in the last 3 years. On average, 37% of farmers practiced any of the selected activities in the past 3 years, while 32% practiced any of the activities in the last season. Overall, this suggests that farmers do not or are not able to alter their adaptation strategies from year to year. Activities with larger differences in the proportion of farmers employing them between the two time periods include mixing different maize varieties and planting late maturing varieties. We would expect the decrease in the percent of farmers mixing maize seed varieties to be connected to the decrease in planting late maturing varieties (i.e., farmers were mixing maize varieties of different maturity), but the correlation between the two variables is relatively low ($p = 0.206$). Regardless, it appears that seed choice is one of the few activities that varied between the time periods.

The activity perceived to be the most effective in dealing with the drought last season (and one of the most effective in the prior 3 years) is construction of a water harvesting reservoir, which allows farmers to supplement rainfed production with small-scale irrigation. Doing off-farm piecework or casual labor was also a relatively common and effective way for people to

Table 1 Proportion of farmers reporting having engaged in each activity and their perception of effectiveness of each activity in dealing with drought during the last season and with weather variability in the last 3 years

Activity	Last season			3 years prior		
	Obs[1] (%)	Mean eff.[2]	Std. dev.	Obs (%)	Mean eff.	Std. dev.
Practice crop diversification	83	2.17	0.71	82	2.48	0.68
Practice crop rotation	73	1.95	0.75	77	2.29	0.79
Participate in a self-help/borrowing group	61	2.17	0.73	60	2.33	0.74
Plant an early maturing maize variety	52	1.93	0.75	59	2.53	0.65
Sell livestock	45	2.18	0.75	51	2.26	0.68
Mix different varieties of maize	42	1.94	0.74	65	2.48	0.69
Off-farm piecework or casual labor	41	2.34	0.58	39	2.35	0.64
Leave field fallow	36	1.91	0.79	36	2.35	0.76
On-farm piecework or casual labor	35	2.25	0.59	36	2.28	0.69
Water harvesting reservoir	33	2.46	0.68	36	2.68	0.60
Plant a drought resistant crop	26	2.06	0.77	35	2.48	0.65
Practice conservation farming	26	2.23	0.76	24	2.61	0.65
Plant a late maturing maize variety	21	1.99	0.72	58	2.53	0.61
Harvest maize for silage	20	2.28	0.61	27	2.77	0.46
Borrow food or money to buy food	18	1.94	0.53	11	1.81	0.62
Migrate or work and send remittances	12	2.18	0.68	13	2.20	0.67
Bee keeping	7	1.70	0.68	9	2.02	0.75
Maintain fish pond	5	1.74	0.81	7	2.45	0.71
Rent out land	3	2.25	0.77	2	2.17	0.83
Sell assets (including land/water)	2	1.88	0.83	4	2.47	0.70

[1] Obs, percentage of sample (total = 494) who reported practicing a given activity. [2] Mean effectiveness: respondents were asked to rate the effectiveness of the activity on a simple Likert scale: 1 = not effective, 2 = somewhat effective, 3 = very effective; Std. dev is the standard deviation of the effectiveness rating

deal with the drought and weather variability. On-farm piecework or casual labor was also widely practiced and considered to be relatively effective in the last season and 3 years prior. Some of the least effective activities included leaving a field fallow, selling assets, or activities such as fish farming and beekeeping. On average, farmers perceived each activity to be more effective in dealing with general weather variability in the past 3 years than dealing with the drought conditions experienced during the last growing season. This suggests that many of activities are likely long-term strategies for farmers and are not explicitly employed to deal with short-term or extreme weather events.

Table 1 illustrates that the prevalence of an activity is not strongly correlated with the perceived effectiveness of the activity, since many of the most prevalent activities are not perceived to be effective during the last season or 3 years prior. For example, water harvesting is perceived to be the most effective in dealing with drought (2.46) but only 33% of the sample reported doing it, while crop rotation is practiced by 80% of the sample but has a relatively low perceived effectiveness rating (1.95). There is low correlation between how prevalent an activity was and its average effectiveness rating (6 months, rho = 0.21; 3 years, rho = 0.30). This demonstrates that beliefs about the relative effectiveness of an activity are not an important determinant of someone having employed that activity.

3.2 Motivations for climate adaptation activities

Table 2 summarizes the top three aggregated responses for doing or not doing each of the five selected activities. Overall, we found that few respondents cited any environmental motivations and that for many farmers the activities were not available or accessible (such as borrowing food, migrating elsewhere, or doing off-farm casual labor).

"Migration for work" was the least common activity ($n = 60$) since many households did not need or desire to work away from home (53%), had no household labor available to migrate (37%), or could not find work opportunities (17%). Those who did migrate were motivated by better opportunities, suggesting that migration is not an accessible strategy for most households. The motivations offered for "planting an early maturing maize" variety are inconsistent rains (76%) and shorter growing season (48%), almost entirely climate-related. Reasons for not planting early maturing maize involved performance, motivations, or preferences for specific attributes (including yield) in addition to environmental concerns. Motivations cited for "casual labor on another farm" involved needing income (48%), food insufficiency (46%), and always doing casual labor (46%), suggesting that casual labor is a persistent strategy for many households, not necessarily related to climate change. Three quarters of farmers reported that they do not do casual labor because they have no additional household labor available. The overwhelming motivation for "borrowing food" was related to inadequate maize production due to poor harvest (89%) and to a much less extent, small farm size. Only 6% of farmers reported regularly borrowing food due to chronic food shortage. The reasons for not borrowing food were related to food sufficiency (45%), purchasing food through local markets (40%), and a firm habit of not borrowing food. The most prominent motivations for "selling livestock" were largely related to a need to generate cash to purchase food (31%) or other expenses (30%). Livestock sales were also motivated by an inability to keep livestock sufficiently fed. The reasons for not selling livestock however were focused on needing the livestock for a source of food and or milk (58%) or not needing to sell livestock (40%). There is some association with environmental drivers in terms of having sufficient feed for animals or losing them due to drought.

Table 2 Motivations for doing or not doing various adaptation activities ($n = 494$)

Activity	Obs	Reason for doing activity	%	Obs	Reason for not doing activity	%
Migrate for work	60	No work opportunities at home	62	434	No need or desire to work elsewhere	53
		Better job opportunities elsewhere	42		No labor to spare	37
		Always migrate for work	5		No work opportunities to be found	17
Plant early maize	260	Rainfall has become inconsistent/unreliable	76	243	Early varieties are inferior	46
		Growing season is shorter	48		Rain is inconsistent/season is shorter	42
		Have preference for their attributes	13		Do not plant at this time	11
Casual labor (on farm)	171	Needed additional sources of income	48	323	No labor to spare	72
		I always do casual labor	46		No opportunities to do casual labor	16
		Concern about food insufficiency	23		No need for additional income now	11
Borrow food	90	Poor maize harvest and food insufficiency	89	404	Had enough food this season	45
		Insufficient farm size	11		Purchased food	40
		Always borrow food (insufficient production)	6		Never borrow food	16
Sell Livestock	220	Needed cash to buy food	31	274	Needed livestock for food or milk	58
		Needed cash to pay for other expenses	30		No need or desire to sell livestock	40
		Livestock survival or feed sufficiency	28		Do not own any livestock	16

Percentages for each activity do not add up to 100% since respondents were permitted to provide multiple reasons for why they do or do not do the activity

3.3 Environmental perceptions and psycho-social determinants of various adaptation activities

Farmers overwhelmingly reported that increased drought or extreme weather events, shortening of the length of the growing season, and higher variability in rainfall would negatively impact their agricultural productivity in the next 5 years (96%, 99%, and 96% respectively). Only 25% of farmers considered the previous season to be a "drought," while more than 70% characterized it as below average (rain characterization). Forty-six percent of respondents think there will be less rain in the coming long rains season than the previous long rains season, 49% believe there will be more rain, and only 5% believe the rain will be the same (rain optimism). The majority of farmers estimate an occurrence of drought every 3 to 5 years with some respondents indicating that drought occurred as frequently as every year or as infrequently as 6 or more years (drought probability). Eight percent of farmers think droughts occur more frequently then when they were children, 3% believe they occur with the same frequency, while 17% believe that droughts occur less frequently (drought changing). Farmers estimated the average rain onset to be 1.81 weeks over the last 10 years with a standard deviation of 2.87 years (rain onset delay).

Table 3 presents the results of logistic regressions for each of the five activities in the previous season. We clustered the standard errors at the level of the community water project to capture the effect of living in that community as well as to generally capture the spatial clustering of households. The significance and magnitude of various predictors varies, demonstrating that it is hard to determine who will employ a given adaption activity. Considering these differences, it is unsurprising that the overall variance explained by the regressions ranges from 11 to 34%.

"Migration to another household for work" is mainly motivated by income generation and available to those who have successful farms and can spare the labor thus spreading risk across space. Respondents that were optimistic about future rains and experienced a wetter season were more likely to have individuals migrate but less likely if they believed that drought was becoming more frequent. Migration for work was also more likely to occur in areas with higher rainfall variability, supporting the notion that migration is a way to pool risk across space.

"Planting an early maturing maize variety" was a strategy for farmers who want to spread risk across time because they are motivated by environmental concerns and perceive the rainy season to be getting shorter. Respondents are also more likely to plant early maturing maize if they perceive the rains to be getting later, which is consistent with the qualitative motivations. Households in areas with lower mean annual rainfall are also more likely to plant early maturing maize.

"Piecework or casual labor on another farm" was employed to diversify risk across asset classes by poorer households living in higher rainfall areas motivated by economic concerns. It is less likely among households that have higher off-farm income, a higher education level, and better water access (CWP membership) but more likely in households that have more labor available (i.e., larger household size). Individuals who perceived higher rainfall last season are also more likely to have done casual labor suggesting that one must live in a relatively high rainfall area to find available opportunities.

"Borrowing food or money to buy food" is a strategy that spreads risk across poorer households who are motivated by food security and economic concerns. The more optimism people have about future rains the less likely they are to borrow food, and people who perceive

Table 3 Logistic regressions of whether selected activities were employed in previous season

	Migrate for work		Plant early maturing maize		Casual labor on another farm		Borrow food from another HH		Sell livestock	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Socioeconomic variables										
Asset index (PCS quintiles 1–5) [a]	0.106	0.121	0.234***	0.100	− 0.126	0.091	− 0.171**	0.100	0.130	0.087
Livestock owned (TLU) [b]	− 0.107	0.099	0.009	0.074	− 0.057	0.053	− 0.190**	0.083	0.200***	0.037
Total non-farm income (‘000 Ksh)	0.002**	0.001	0.000	0.001	− 0.003**	0.001	− 0.002**	0.001	0.001	0.001
Farm size (acres)	0.093	0.145	0.005	0.125	− 0.170	0.079	0.188	0.106	− 0.108	0.088
Household size (total people)	− 0.099	0.090	− 0.078	0.055	0.285***	0.049	0.096	0.083	0.051	0.045
Household head education (years)	0.119	0.153	0.086	0.063	− 0.210***	0.056	− 0.095	0.079	− 0.244***	0.081
CWP membership (projects)	− 0.305	0.194	− 0.907***	0.203	− 0.574***	0.174	− 0.198	0.177	− 0.431***	0.166
Planted in short rains (1 = yes; 0 = no)	0.007	0.376	3.287***	0.377	− 0.132	0.260	0.691**	0.290	− 0.349	0.191
Total maize harvested (kg)	− 0.002	0.002	0.000	0.001	0.001	0.001	0.000	0.001	0.002**	0.001
Environmental perceptions variables										
Future rain optimism (− 1, 0, 1) [c]	0.496***	0.149	− 0.083	0.125	− 0.043	0.102	− 0.420***	0.145	− 0.076	0.077
Rain characterization (1–5) [d]	0.554**	0.237	0.061	0.201	0.316**	0.153	− 0.140	0.227	0.152	0.170
Drought probability [e]	0.047	1.065	− 0.367	0.463	− 0.104	0.654	0.822**	0.415	− 1.179***	0.461
Drought changing (1–3) [f]	− 0.689***	0.163	− 0.108	0.230	0.231	0.141	0.189	0.315	0.453***	0.125
Rain onset delay (weeks) [g]	− 0.057	0.077	0.086***	0.034	0.032	0.028	0.091***	0.028	0.099***	0.041
Environmental variables										
Average annual rainfall (‘00 mm)	− 0.344	0.195	− 0.705***	0.345	0.218***	0.181	− 0.003	0.303	− 0.014	0.319
Annual rainfall std. dev. (‘00 mm)	3.816***	0.984	0.724	1.106	− 0.028***	1.195	− 0.270	1.039	− 0.165	1.306
Constant	− 6.717***	2.433	2.233	3.537	− 2.390	1.512	− 1.088***	2.102	− 0.737	1.222
Model fit statistics										
Observations (n)	482		482		482		482		482	
Affirmative observations (Y = yes)	60		260		171		90		220	
Pseudo R^2	0.12		0.34		0.14		0.11		0.11	
Pseudo likelihood	− 155		− 221		− 267		− 203		− 295	

[a] Asset index is the first principle component from a principle component analysis of common farm and non-farm assets owned by between 5 and 95% of households (Filmer and Pritchett 2001). [b] Livestock owned is a single weighted measure of livestock using tropical livestock units (TLU) based on the following conversion factors: cattle = 0.7, sheep = 0.1, goats = 0.1, pigs = 0.2, chicken = 0.01. [c] Effects coded: less rain (− 1), the same (0), and more rain (+ 1). [d] Drought (1), below average (2), average (3), above average (4), excess rainfall (5). [e] Drought probability, $P = (1/x)$ where x is every how many years they expect drought to occur. [f] (1) Less often, (2) with the same frequency, (3) more often. [g] Number of weeks between perceived start of current rainy season and season start 10 years ago

the rains to be getting later are more likely to borrow food. Borrowing food is clearly motivated by food security for households, which is interrelated with environmental conditions such as how good the rains are and when they arrive.

The most prominent motivations for "livestock sales" were related to food security and income, which is consistent with the narrative of using livestock to diversify risk through market exchange. The odds of selling livestock are lower the more water access the household has, suggesting that livestock husbandry may be a necessity for some less water secure households. If individuals believe that drought is getting worse in the long run and the rains are getting later they are more likely to have sold livestock, suggesting that these individuals may have moved more towards livestock husbandry as a strategy that is relatively less sensitive to rainfall vicissitudes than crop production.

4 Discussion

We find that farmers minimally change agricultural strategies from year to year, bolstering Agrawal's assertion that the distinction between coping and adaptation may not be important. This finding is also consistent with the notion that people who experience persistent livelihood stress do not distinguish between short- and long-term strategies, because they face repeated exposure to climate hazards (Osbahr et al. 2011; Agrawal 2009). The second important finding is that not all activities that are conceptualized as climate adaptation are perceived as such by farmers, nor are they perceived to be the most effective climate adaptation strategies. Together, these findings suggest that farmers do not employ some of these activities either because they are unable to or because there may be a lack of consensus about which activities are the most effective for adaptation. This lack of consensus in perceived effectiveness of activities also suggests that it may be more important to view specific adaptation decisions as individual decisions with unique constraints and benefits. Predicting adaptation using indices of activities (such as Below et al. 2012), assumes homogeneity across activities that are motivated by different goals and risk management strategies (Agrawal 2009).

Environmental factors are not salient motivators for many, if not most, strategies that are associated with climate change adaptation. The only activity where environmental motivators were frequently cited was the planting of earlier maturing varieties. Either farmers do not employ these activities in response to climate change or they do, but they think about more immediate, proximate causes for these behaviors such as those related to food security and markets. Tucker et al. (2010) posit that farmers are more concerned about market volatility than weather volatility because market risk affects everyone simultaneously, whereas weather variability is diffuse and ubiquitous. While psychological biases have been associated with overemphasizing the significance of recent or memorable extreme climate events (Kunreuther et al. 2013), in the absence of extreme events, everyday observations about markets and food stocks may be more salient drivers of behavior. Environmental change and climate change remain distal concerns for farmers (van der Linden et al. 2015), while food security and market-related risks remain proximal and require more immediate action.

It is important to create a tighter link between a farmer's perception of climate change and knowledge of which adaptation strategies might help cope with specific types of risk management or manifestations of climate change. Adaptation is a complex concept and environmental perceptions are equally multi-faceted. Conceptually, one could imagine that an individual adaptation behavior is associated with a specific environmental perception, rather than adaptation as a whole being motivated by one's general belief in climate change or perception that climate change is occurring. For example, delayed rainy season onset and mid-season dry periods are both linked to climate change but are mitigated by very different adaptation options. Our results are consistent with studies that look at specific adaptation behaviors and related environmental perceptions such as Waldman et al. (2017), who found that farmer's perceptions of change in rainy season onset date is associated with an increased likelihood of planting an early maturing maize variety. Another example, within this study, is that selling livestock is more common among individuals who perceive that drought is becoming more frequent. Environmental perceptions appear to be linked very closely with individual adaptation strategies, again supporting the notion that climate adaptation may be best thought of in terms of a specific activity rather than a broader concept. Observing changes in the climate may not be enough to compel farmers to adopt more climate resilient behaviors, until the point where food security is severely threatened by climate change.

5 Conclusions

There is nearly unanimous belief among households we surveyed that the climate is changing and poses immediate threats to their livelihoods but these beliefs do not necessarily translate into specific climate perceptions or motivations for behavioral change. Individual farm level actions are undertaken for far more complex reasons than simply weather or climate concerns. Farmers do not necessarily implement activities they perceive to be the most effective for dealing with drought or weather variability, suggesting that there are barriers to adopting these activities, and that the efficacy of the activities is context dependent. These behaviors should be investigated as individual- or household-level decisions with unique socioeconomic, environmental and psychological exigencies. Assuming or misinterpreting an activity as climate adaptation that is not directly motivated by climate concerns obscures our general understanding of how and why people make decisions that will prepare them for climate changes. Further, the misunderstanding may send erroneous signals to policy makers and development practitioners about how to communicate with farmers about climate effects and effective behavioral responses. Creating a tighter link between a farmer's perception of climate change and knowledge of which strategies might facilitate decreasing specific types of risk is crucial.

Even in the midst of an extended drought in this study area, we find that few activities undertaken by farmers are motivated by environmental concerns. Many of these activities are simply motivated by financial or food security reasons, even though more distant climate factors may also come into play. The only activities that shifted inter-annually or where environmental concerns were salient are those directly related to the temporal dimensions of precipitation, specifically maize seed choice. Researchers should be aware that promoting behavior that will help farmers prepare for climate change is contingent on a nuanced understanding of how perceptions of specific dimensions of climate change are related to individual behaviors. Communication with farmers about climate preparedness can be improved through messaging and policies that are focused on food security rather than climate more broadly, as food security is the more salient driver of behavioral change.

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