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Article

Local Perceptions and Responses to Climate Change and Variability: The Case of Laikipia District, Kenya

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Abstract: Agricultural policies in Kenya aim to improve farmers' livelihoods. With projected climate change, these policies are short of mechanisms that promote farmers' adaptation. As a result, smallholders are confronted with a variety of challenges including climate change, which hinders their agricultural production. Local knowledge can be instrumental in assisting smallholders to cope with climate change and variability. In this paper, we present empirical evidence that demonstrates local knowledge, perceptions and adaptations to climate change and variability amongst smallholders of Laikipia district of Kenya. A Palmer Drought Severity Index (PDSI) calculated for one station is compared with smallholders' perceptions. Data was collected using qualitative and quantitative methods in Umande and Muhonia sub-locations. Qualitative data included 46 transcripts from focus group discussions and key informant interviews. Quantitative data is derived from 206 interviewees. We analyzed qualitative and quantitative data using Atlas-ti and SPSS respectively. According to smallholders' perceptions, climatic variability is increasingly changing. Local perceptions include decreasing rainfalls, increasing temperatures, increasing frosts and increasing hunger. The PDSI shows a trend towards severe droughts in the last four decades, which is in accordance with farmers' perceptions. Smallholders use a combination of coping and adaptation strategies to respond to variability, including, among others, diversification of crop varieties, migration and sale of livestock. Significant relationships exist between drought perceptions and some adaptations such as migration and sale of livestock. Farmers have an in-depth knowledge of climatic variability, which they use to inform their coping and adaptation strategies. Knowledge of climatic perceptions and adaptations are vital entry points for decision makers and policy makers to learn how and where to enhance the adaptive capacity of smallholders in rainy and drought periods.

Keywords: climate change; climate variability; perceptions; smallholders; knowledge; adaptation; policy

1. Introduction

Agriculture is one of the main sources of livelihoods for vulnerable poor smallholders [1–4]. National agricultural policies aim to enhance farm livelihoods through various mechanisms [5,6]. Yet, smallholders continue to face more challenges that impede agricultural productivity. Such challenges include poor infrastructure, poverty, poor policies and poor governance [7]. Climate change is recently acknowledged as a major challenge to agriculture [7,8]. Climate change causes negative impacts on agriculture, destabilizing smallholders' livelihoods [9,10]. Although smallholders have been adapting their agriculture to the changing climate since time immemorial [11], they are still vulnerable to climate change and variability [12–15]. Climate change is a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer [16]. Climate variability means deviations in the mean state of climate and inconsistencies (e.g., in occurrence of wind and precipitation extremes), on all temporal and spatial scales beyond those of individual weather events, including short-term fluctuations that happen from year to year [17,18]. Variability in this case is an integral part of climate change, in which: a change in mean climatic conditions is experienced through changes in the nature and frequency of particular yearly conditions, including extremes [19]. In this paper, we use both terms regularly. Agriculture is a viable sector that can transform Kenya and help eradicate poverty among the majority poor [5,7,20]. However, the existing agricultural policies have produced limited benefits to smallholders because: (i) proposed responses in agriculture at national levels (macro levels) are predominantly solutions often unfavorable to the locals (micro levels) [7,21,22], (ii) government focus do not necessarily integrate climate change and variability into their strategies [23]. With a projected continued warming of the globe [13,24], glaring challenges could be in store for smallholders [25]. Agricultural improvement can be achieved if smallholders are targeted [8,26,27]. As part of targeting smallholders and solutions for climate change and variability, local knowledge of farmers becomes very important to enhancing their adaptive capacity. In the climate change literature, traditional ecological knowledge (TEK) [28,29], local knowledge (LK) and local ecological knowledge (LEK) [30] are used to refer to the cumulative body of knowledge, practice and belief, that are location specific, acquired through long-term observation of (and interaction with) the environment, and transferred through oral traditions from generation to generation. Based on the aforementioned authors [27–29], we use local knowledge to mean a cumulative body of knowledge on weather and climate, developed and applied by smallholders, which shows how this knowledge is used to shape and interact with agricultural practices to enhance smallholders' adaptive capacity towards climatic variability. This knowledge is time, place and culture specific [29,31]. Local knowledge is based on practice and assists farmers to make informed decisions about how to respond to environmental changes and how to improve the amount and quality of their yield [13,32–38]. The validity of local knowledge has been shown by scientists through comparison with quantitative climate data analysis [39–42]. The majority of studies show that farmers' resourcefulness matches quantitative data analysis: local knowledge is used to respond to the vagaries of climate such as droughts, famines, floods and other stresses that threaten crops and livestock [38,39–41,43–50]. However, there have also been cases where local knowledge failed to match quantitative climate data, making local knowledge seem unreliable, e.g., as reported from Kenya by Rao *et al*. [51].

Various recommendations have been proposed to enhance the adaptive capacities of farmers. Mainstreaming adaptations into national development processes is one such recommendation [13]; however, it is hardly put into practice. Lack of mainstreaming often leaves the smallholders' adaptive role in agriculture overlooked [45,52]. For example, the national climate policy in Kenya, called the National Climate Change Response Strategy (NCCRS), identifies smallholders as the most vulnerable to climate change [23]. However, the NCCRS is neither thorough nor consistent in its stance on how smallholders' knowledge will be integrated into national policies concerning climate change. This apparent disregard of local knowledge of farmers in critical policy documents on climate change could be interpreted as a failure of appreciation and engagement with local knowledge and its capacities to reduce vulnerability of farmers in the wake of climate change. Such reluctance urgently calls for concerted efforts that vouch for local adaptation measures [33].

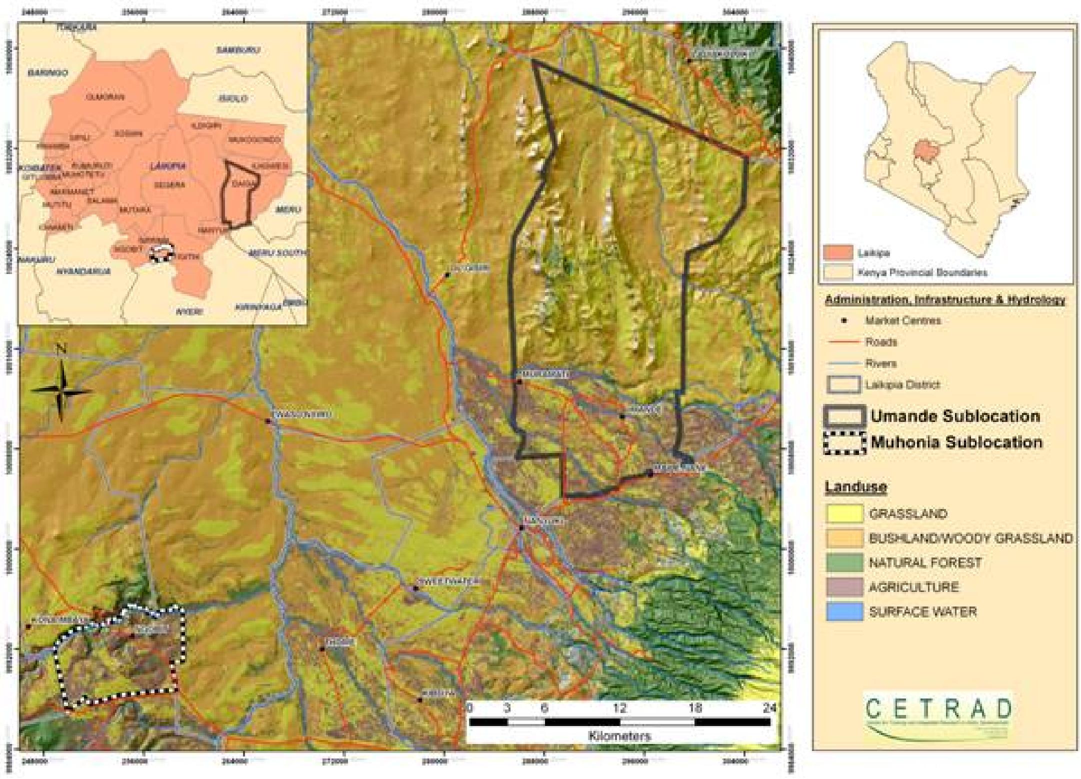
The adaptive capacity of farmers can be enhanced if national policies support climate change responses that are already being implemented by farmers [49]. We define adaptations as adjustments in ecological, social, or economic systems in response to actual or/and expected climatic stimuli and their effects or impact, as well as to the changes in processes, practices, and structures to moderate potential damages and/or to benefit from opportunities associated with climate change [53]. Adaptations are of longer-term in nature [42]. Coping strategies, on the other hand, consist of household practices used as short term measures when confronted with unexpected events such as droughts [42,54]. Building on the local knowledge would foster adaptive capacity that is acceptable to farmers by promoting and supporting locally developed adaptations. Overall, there is consensus that local knowledge is part of the solution to effective adaptation [11,38,42,45,48,49]. However, there are limited studies that have elaborated on perceptions of losses of crops and livestock that result from climate variability, yet these perceptions can shape the coping and adaptation strategies of smallholders [13]. In addition, none of these studies, which we have evaluated elaborately, studied local knowledge as a reflection of climate variability, its effects and adaptations in agriculture. This study will build on other authors who have cross-checked local knowledge with quantitative climate data to ascertain its relevance for climate variability. We adopt an approach similar to the one proposed by Roncoli *et al*. [37] to dissect perceptions in the context of climate, crops, livestock and adaptations in Laikipia district of Kenya, where serious ecological changes have already been reported previously [55]. We ask how smallholders perceive climate variability, how and why perceptions are valued. We then provide evidence of smallholder's perceptions matching with the existing quantitative historical climate data of the district for the past 35 years. We provide empirical evidence of how perceptions of droughts correspond with losses in crops and livestock due to climatic variability using both qualitative and quantitative data from Umande and Muhonia sub locations.

2. Research Methods

2.1. Overview of the Study Area

Data was collected in the sub locations of Umande and Muhonia that differ in distance from the administrative Nanyuki town, in the Laikipia district of the Rift Valley Province of Kenya between October 2010 and September 2011. Both sub locations have a semi arid climate [55] and are ecologically fragile and susceptible to frequent droughts [5]. The district is characterized by a limited and diminishing natural resources base, coupled with dynamic socio-economic and land use changes [55]. The Laikipia district (Figure 1) has a total area of 9229 km^2 [56] and lies between 1,600 and 2,300 meters above sea level north-west of Mt. Kenya [55].

Figure 1. Map of Kenya (upper left corner) showing the Laikipia District (upper right corner) with Umande (in bold black line) and Muhonia (in white and black line) Sub Locations. Source: [57]



The population of the Laikipia district stands at 322,187 with a density of 35 persons per Km^2 [56]. Smallholders in both sub locations have migrated from the central and densely populated highlands in search of land for agriculture and grazing land for livestock [55]. With small land holdings, such farmers have limited scope for diversifying crops in the face of climate variability, and are exposed to uncertainty in their agricultural production [18].

2.2. Data Collection

The study integrated both qualitative and quantitative methods to build on their complementarities for cross-checking information received from the respondents [58,59]. Available historical climate data on precipitation and temperature of Laikipia, covering the period from 1975 to 2010 were sourced from the Kenya Meteorological Department (KMD) for analysis and generation of PDSI index. The index is based on a supply-and-demand model of soil water content for a medium soil, and considers precipitation and air temperatures as inputs and self-calibrated on evapotranspiration [60,61].

Ten explorative interviews, 34 key informant interviews and 20 focus group discussions (FGD) with a total of 190 farmers were undertaken to understand in detail the perceptions of variability and responses. These interviews provided data for developing and designing appropriate questionnaire for the structured and semi structured interviews [62]. Discussants of FGD, key informant interviews and questionnaires were purposively selected based on four criteria: (a) settled in the area for ≥19 years, (b) practice agricultural farming for livelihoods for ≥19 years (c) knowledge on climatic conditions of the area; (d) Sub location. These criteria accounted for the varying years of settlement within the locations and recall ability of the farmers.

The number of participants in FGD meetings ranged between six and twelve. A discussion guide was used to moderate the FGD [63]. FGD highlighted the differences between participants [64]. Focus group discussants helped to identify appropriate key informants from both sub locations based on the four criteria mentioned. A checklist of questions guided the key informant interviews with a purposeful sample of 34 smallholders (17 from each sub location).

Ten households participated in a pre-test survey conducted in order to identify potential problems associated with the interpretation of the questionnaires. This allowed for restructuring of questions and solving all questionnaire-related problems before the intensive data collection [62]. 206 purposively sampled households were administered on the questionnaire, with 106 from Umande and 100 from Muhonia sub locations. Questionnaires combined quantitative measurable variables (structured) and qualitative variables (unstructured) [58,59] relevant to the study objective.

The language used for interviews and discussions was Kiswahili, but where respondents preferred to converse in Kikuyu (the predominant local language in Central Kenya), a member of the local community acted as an interpreter after prior training. The recruited interpreter was a fluent speaker of the local language and had firsthand knowledge of the area under study. We recorded all interviews and discussions with the respondents after seeking prior informed consent [65]. Interviews were translated from Kikuyu into English during interviews and thereafter during transcription. Duration of interviews ranged between 30 and 90 minutes.

2.3. Data Analysis

The available historical climate data of 35 years were used to calculate the course of the drought conditions of the weather station site on a monthly basis using the Palmer Drought Severity Index (PDSI). Based on this index, one can characterize the monthly conditions as ranging from extreme wetness (index value +5) to extreme drought (index value −5). We utilize the PDSI to examine the variations in meteorological droughts and wet spells over the Laikipia region from 1975 to 2010, as well as compare the index to the farmers' perceptions of droughts and lack of rains.

From all conducted exploratory interviews, FGD and key informant interviews, 46 primary documents were subjected to Atlas-ti based content analysis [66]. *Ex-situ* coding was conducted where codes were categorized based on (a) perceptions of climate change and variability (b) local responses to climate change and variability.

Quantitative data was analyzed by SPSS software to generate cross tabulations and frequency tables. Chi-square analysis as used by Eriksen *et al.* [67] to determine coping strategies in Kenya and Tanzania was followed to determine relationships between drought perceptions, coping strategies and adaptations.

3. Results and Discussion

3.1. Farmers' Knowledge and Perceptions of Climate Change and Variability

Through FGD and questionnaire interviews, farmers from both study sites generally concurred that in the 1960's, 1970's and 1980's when they settled in the study area, rainfalls were more regular and predictable in seasons. Rainfall seasons were distinct, but currently, rains have become more unpredictable. In questionnaire interviews, about 88% of farmers value 'good' climate at the time of settlement and about 89% of the farmers in both sub-locations value current climate as 'bad' (Table 1). Farmers' constantly stressed declining agricultural production due to unpredictable, sometimes incessant rains on the one hand, as well as low rainfall, coupled with high temperatures on the other hand, and the occurrence of extreme climatic events including hailstorms, frost and persistent droughts. The farmers consent from both sub locations that the previous climates at time of settlement were 'good' compared to the current climate reported to be 'bad', is consistent with climate data showing increasing trend to droughts from the Laikipia Air Base station (Figure 2). Rainfalls are valued as decreased, while temperature and wind are valued as increased. Discussants recognize long and short season rains based on the rainfall amounts and duration. According to the interviewees, the long rains occur between March and June, while the short rains occur between September and December. Farmers explained that rainfalls have reduced in both quantity (amounts per rainfall) and quality (ability of the rains to sustain the crops for a reasonable period to crops maturity) in comparison to the time they settled in the area. Changes in rainfall amount and patterns, affects soil erosion rates and soil moisture, both of which are significant for crop yields [68]. In addition, increasing temperatures make it difficult for the crops to grow with little rains, while increased wind puts crops at risk of being blown away or destroyed. These findings show the ability of farmers to value their climate as either 'good', 'constant', 'bad' or 'very bad', which farmers are able to define subjectively is an indicator of their in-depth local knowledge and perceptions (see explanations below Table 1).

Table 1. Farmers' perception of climates of Umande and Muhonia Sub Locations (n = 106 for Umande sub location and n = 100 for Muhonia sub location; total n = 206).

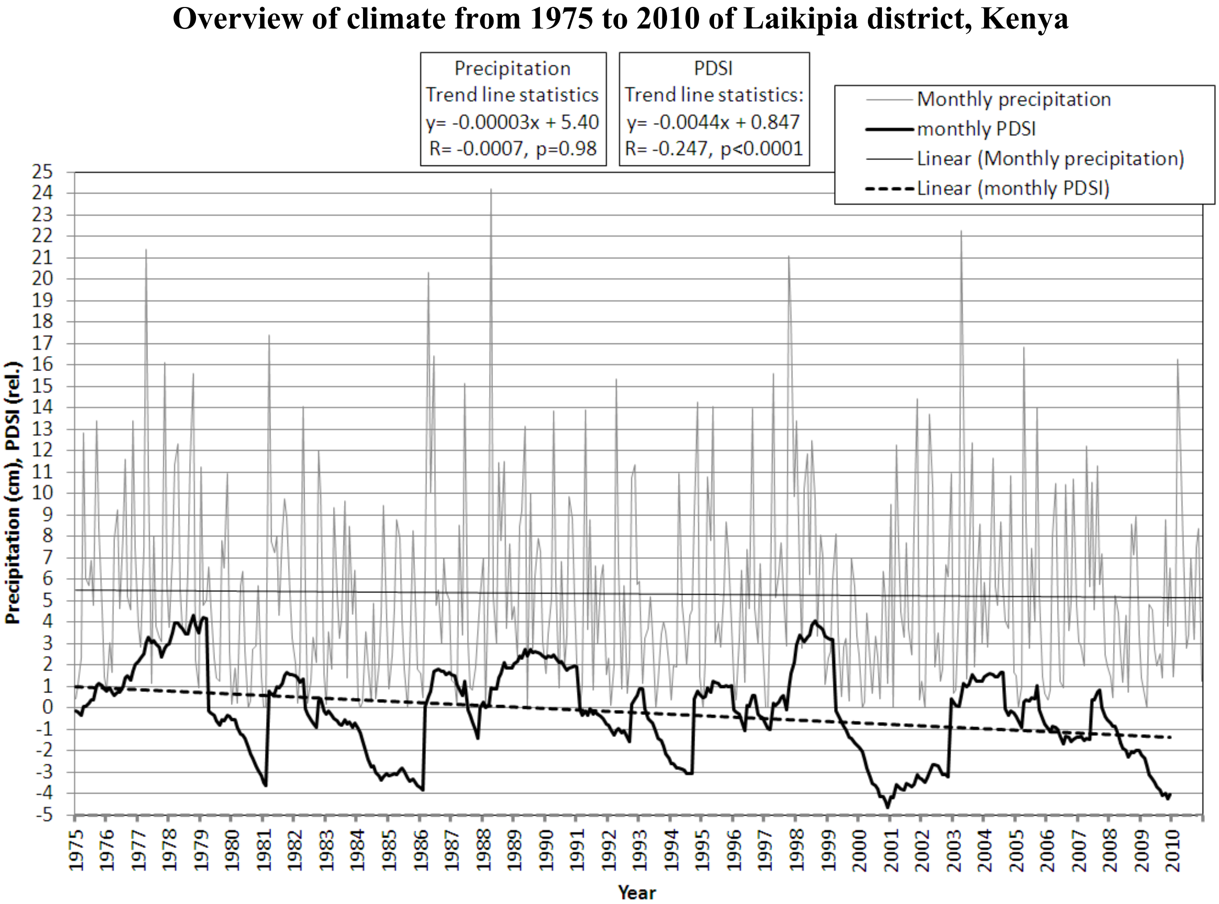
Variable		Umande sub location (% of n)	Muhonia sub location (% of n)	Both sub locations (% of total n)
Current perception of climate	good	7.5	4	5.8
	bad	84.0	95	89.3
	very bad	6.6	0	3.4
	constant	1.9	1	1.5
Perception at settlement time	good	86.8	89	87.9
	bad	11.3	10	10.7
	very bad	0.9	0	0.5
	constant	0.9	1	1.0
Rainfall	increased	3.8	2	2.9
	decreased	92.5	97	94.7
	constant	3.8	1	2.4
Temperature	increased	97.2	95	96.1
	decreased	0.0	3	1.5
	constant	2.8	5	3.9
Wind	increased	95.3	84	89.8
	decreased	2.8	12	7.3
	constant	0.9	4	2.4
	unsure	0.9	0	0.5
Sun's heat	increased	98.1	92	95.1
	decreased	1.9	7	4.4
	constant	0.0	0	0.0
Frequency of droughts	increased	96.2	95	95.6
	decreased	1.9	4	2.9
	constant	1.9	0	1.0
	unsure	0	1	0.5
Frequency of drying rivers	increased	98.1	95	96.6
	decreased	1.9	1	1.5
	constant	0.0	3	1.5
	unsure	0	3	1.5
Incidence of crop diseases	increased	89.6	95	94.3
	decreased	6.6	3.8	10.4
	constant	0.9	0	0.9
	unsure	2.8	0.9	3.8
incidence of animal disease	increased	54.7	76	65.0
	decreased	20.8	19	19.9
	constant	17.0	4	10.7
	unsure	7.5	1	4.4
frequency of hunger	increased	97.2	98	97.6
	decreased	1.9	2	1.9
	constant	0.9	0	0.5

Table 1. *Cont.*

Variable		Umande sub location (% of n)	Muhonia sub location (% of n)	Both sub locations (% of total n)
incidence of human diseases	increased	75.5	75	75.2
	decreased	10.4	10	10.2
	constant	11.3	13	12.1
	unsure	1.9	2	2.4

Notes: the definitions of very bad, bad, good and constant is as perceived by focus group discussants, key informants and questionnaire respondents; **Very bad**—intense sun's heat, high temperatures, erratic/unpredictable rainfalls, poor crop harvests, lack of pasture/grass for livestock—less productive livestock, rampant frostbite, prolonged/persistent droughts for up to 2–4 years, food insecurity, drying rivers; **Bad**—unreliable/unpredictable rainfall, droughts, poor or little farm harvests, less pasture for livestock, drying rivers, food insecurity, persistent droughts, increased winds, increasing human population; **Constant**—no comparable observable change in climate; **Good**—Abundant rainfall accompanied by good farm harvests, plenty of grass/bushes for livestock, Improved rains, crop yields enough for subsistence purposes, piped water.

Figure 2. The course of precipitation (grey line) and the Palmer Drought Severity Index (PDSI) (bold line) and of linear PDSI (dotted line) of Laikipia Air Base Station, Kenya (Trend statistics: y = dependent parameter (PDSI or precipitation); x = independent parameter (number of month in the whole period; R = correlation coefficient; p = probability of R = 0). Source: [69]



Our study is comparable to others in that, for example, some of the perceptions of farmers were termed as vulnerability indicators by studies of Adimo *et al*. [70] in Kenya. In Mount Kenya region, studies by Kauti [4] identified perceptions on crop varieties as determinants of crop varieties for cultivation on farms. In both cases reported by Adimo *et al*. [70] and Kauti [4] from Kenya, hailstorms were not identified by the authors as the case for Umande and Muhonia. Elsewhere, in Ethiopia, farmers reported similar sentiments of reduced rainfalls and changed rainfall patterns [71]. Farmers in Southern Africa region termed perceptions of droughts, floods, reduced rainfalls as stressors [48], although Umande and Muhonia farmers did not mention floods as a perception. Thus as farmers give value of climate perceptions, we interpret their valuing as emphasis of what climate change and variability entirely means to these farmers' agriculture and their livelihoods in general.

Moreover, farmers reported that at present, they are experiencing shorter rain seasons than in the past and sometimes, there were only dry spells with no rains. Discussants from Umande and Muhonia also said that they used to expect the very first rains of every year in February, which were locally referred to as *'maguna ng'ombe'*, meaning 'help for livestock'. *Maguna ng'ombe'*are short rains for about three days, ensured grass would grow to sustain the livestock until the rainy season started in March every year. The farmers said that *maguna ng'ombe* is no longer occurring since the year 2000 and identify this as a remarkable change in their climate. We interpret the lack of *maguna ng'ombe* as a pointer to the needed support of farmers from agricultural ministries, development agencies and NGOs interested in enhancing local agriculture through livestock production.

The majority of farmers also reported increased frequency of droughts (about 96%) and increased frequency of rivers drying out (97%). Perceptions on droughts have been reported from Kenya where the locals perceived droughts as acts of god that could not be controlled [36,72] and as disasters beyond their control [73]. Umande and Muhonia farmers bear similar beliefs although they opt to undertake strategies that help them cope with the drought effects.

3.2. Effects of Climatic Variability in Smallholder Agriculture

Following droughts, increased temperatures, and erratic and unpredictable rainfalls and drying rivers, farmers from Umande and Muhonia report incidences of crop and livestock losses. These were also raised in key informant interviews and focus group discussions as highlighted by one farmer:

> In 1984, there was drought, we lost our livestock and we did not harvest from our crops. Recently, we lost our crops and livestock to a major drought of 2009 (Male key informant No. 4 Umande).

In FGD in both sub locations, farmers concurred that they had experienced severe droughts in several years, although, most farmers recalled year 2009 as a year of most severe droughts that culminated in losses of livestock and crops. Loss of livestock and crops was translated as food shortage and decrease in crop yields by the locals, hence their perception of increased hunger (Table 1). Farmers recognize losses associated to droughts through comparison of numbers of livestock owned before droughts and livestock numbers after droughts. The majority of farmers lost livestock (57.8%), with Muhonia farmers losing more livestock in numbers in year 2009 than Umande in the same year (Table 2). Based on farmers' estimates, the total livestock lost in year 2009 stands at 442 herds in

Umande and 1,169 from Muhonia. Muhonia farmers were hit harder by the drought in the direct comparison with Umande (see Table 2). The losses in crops and livestock noted by farmers in 2009 could mean that farmers were not fully prepared with appropriate strategies to moderate the damage caused by the drought.

Table 2. Livestock losses in Umande and Muhonia sub locations of Laikipia, Kenya (n = 106 for Umande sub location and n = 100 for Muhonia sub location; Total n = 206)**.**

Variable	**Year**	**Umande n = 106%**	**Muhonia n = 100%**	**Total n = 206 (%)**
% of farmers with livestock		59.4	71	65.0
No of farmers with livestock losses	1976–2000	8.5	1	4.9
	2007	0.9	0	1.0
	2008	1.9	0	0.5
	2009	**46.2**	**70**	**57.8**
	2010	1.9	0	1.0
Total No. of livestock lost in 2009		442	1169	1611

Notes: livestock in count include cows, goats and sheep.

In literature, droughts are identified as a potential risk and source of losses in agricultural production [8,74–78]. An increase in the frequency of droughts in the region leads to decreased agricultural production [8,16,68,75,79]. Farmers can lose all their livestock and crops from a single drought. Affected farmers are likely to fall into poverty [80]. Drought losses in Umande and Muhonia concur with findings from Northern Kenya [81] and Mount Kenya [70], where drought accounted for high losses in cattle population. Climate change and variability increases farmers' vulnerability as they lose their natural assets (crops and livestock) upon which their livelihoods depend. The foregoing picture of increasing climatic variability in the two sampled sub locations is consistent with descriptions in the literature on climate change and variability in Kenya and Africa in general [8,13]. Therefore, issues resulting from droughts such as livestock and crop losses need to be addressed in order to enhance adaptive capacities of the vulnerable farmers. Nonetheless, apart from climate related factors, there are other factors that discourage adaptive capacity among farmers in Laikipia such as economic instability, trade liberalization, conflicts, poor governance, diseases, limited access to climate and agricultural information and poor institutional and legal frameworks [21] which may require more extensive research than was possible under the remit of this study.

Perceptions of high incidence of animal diseases in Muhonia stand at 76% and 54% in Umande. Examples of diseases associated with climate variability reported in FGD, key informant interviews and questionnaires included heart water, east coast fever (*ngai*), anaplasmosis (*ndigana*) and pneumonia (*mahuri*) (italicized names are diseases and or pests names in Kikuyu). Other diseases and pests mentioned included blindness, babesiosis, worms (*njoka*) and lumpy disease. Similarly, smallholders perceive increased incidences of crop diseases at about 90% in Umande and 95% in Muhonia. Crop diseases mentioned include blight and leaf rust. Crop pests mentioned include spider mite, aphids, millipedes and *muthingiriri* (tiny black ants). The respondents reported that disease prevalence had increased in comparison to the time they settled as a result of increasing temperatures and droughts. These farmers' knowledge compares with the PDSI drought indicator, showing increasing temperatures and less precipitation (see Figure 2). In addition, the farmers' sentiments can be supported by the IPCC reports, citing the increase and burden of some livestock and crops diseases due to increasing temperatures and decreasing water availability caused by climate change [16]. Warmer temperatures may accelerate development rates of some insect species, resulting in a shorter time span between generations [82]. On the contrary, some respondents from both sites in one FGD and some key informants, reported that disease prevalence was a result of increasing numbers of livestock, which was not the case when they settled, when farmers had one or two herds of cattle. Some farmers reasoned that livestock was better adapted to droughts than crops and that there was the possibility of relocating with livestock to other areas when there were droughts. These farmers were able to save some livestock from the droughts. However, some key informants and discussants shared their own experiences where they lost all their livestock, despite relocating to forested areas where grass was assumed abundant. These results confirms that migrating of livestock has proven successful for some but not for all. With many authors predicting a worsening climate in future in terms of frequent droughts and dry spells, inconsistent rains among others [10,16,24,83], Umande and Muhonia farmers are likely to experience tougher challenges from climate change and variability, if their adaptive capacities to the current trend of occurrences are not abated.

3.3. Overview of Climate from 1975 to 2010 of Laikipia District of Kenya and Relationship with Smallholder Perceptions

At Laikipia weather station, the PDSI shows a significant linear trend towards more dryness during the past 35 years, however, with distinct variations between years (Figure 2). For example, the periods 2000 to 2003 show as low as −5 (extreme drought) that slightly improves to −3 (tending to extreme droughts) in 2003. In 2008, the PDSI shows moderate to extreme drought conditions over the Laikipia region, with the drought conditions getting worse at PDSI of −4 in year 2010. The results agree with the general trends in the global model predictions of variable climate in some parts of Africa [14,16,84]. Studies by Herrero *et al*. [8] reported that Kenya in general would get wetter as a result of climate change and few places would receive decreased rainfalls. Muhonia and Umande constitute the few areas with reducing rainfalls. The farmers' observations match with data from Laikipia Air Base station. For example, farmers mentioned that the years 1984 and 2009 (see statement of key informant No. 4, Umande) were characterized by severe droughts matches with Figure 2 where PDSI of 1984 and 2009 stand at −2.5 (tending to extreme droughts). The drought years identified by farmers match with drought years highlighted in studies from Kenya by Herrero *et al*. [8]. However, extreme drought years such as 2001 (PDSI −4.8), 1986 (PDSI −4.0) and 1981 (PDSI −3.7), although mentioned in questionnaire and FGD, were not emphasized as major drought years according to interviewees. These extreme drought years, however, could constitute the interpretation of 'very bad' climates by farmers where persistent droughts of 2–4 years were reported (see explanations below Table 1). We deduce that interviewees are keen to emphasize years they lost their assets badly to droughts. However, we acknowledge this as potential area for further research and debate. The PDSI drought indicator shows a stronger decreasing trend than precipitation (no significant decreasing linear trend over the whole period), due to the increasing temperatures (significant linear trend over the whole period, not shown), which leads to higher evapotranspiration and therefore increasing drought conditions.

The KMD often gives reports on expected long and short rains through the daily newspapers and radio for farmers to be alert on rains or droughts of the season [85]. However, these reports often exclude some key critical details of occurrences in seasons such as *maguna ng'ombe,* expected prevalent diseases that are considered important by farmers. We argue that farmers' knowledge and perceptions give in-depth explanations of rainfalls, temperatures, droughts and diseases that often lack in the meteorological reports given by the KMD. Farmers can easily follow the KMD reports if they are written in an understandable way suited for farmers' [13]. Therefore, the acceptability of KMD reports by farmers can be improved if they include local knowledge as part and parcel of these reports. These results provide evidence for increasing risk of droughts over Laikipia. Increase in frequency of droughts will add further pressure on smallholder agriculture and lead to greater losses [15].

3.4. Coping and Adapting to Climate Change and Variability

Faced with unpredictable climatic variables, farmers from Umande and Muhonia adopt different responses to cope. Much of this response is reactive, in the sense that it is triggered by past or current events (e.g., drought occurrences) but it is also anticipatory in the sense that it is based on some assessment of conditions in the future (e.g., rainfall occurrences). Adaptations may already be practiced before droughts while others are activated as drought evolves [67]. Such adaptive changes at household farming level have been argued by Darnhofer *et al*. [86] as mostly undertaken due to uncertainties faced by farmers.

To cope with decreasing rainfalls, farmers juggle with mixing long cycle crops and short cycle crops on their farms in both sub locations reflected in the following narrative:

> We plant maize, beans and potatoes, we mix both long and short season crops, because of the rains, it rains sometimes and sometimes it doesn't, when we have long rains, we harvest the long season crops and short season crops with little rains (male participant in FGD 1 Muhonia).

Discussants know which crop varieties they cultivate based on rain seasons. The long season signifies more rains and thus, crops that take long to mature are cultivated, the short seasons signifies less rain and crops that take a short time to mature are cultivated. However, discussants point the mixing of long and short cycle varieties to ensure some harvests as highlighted in the following informant's quote:

> In 1980, we used to cultivate 614 maize, now we still plant 614 because we saw it yields highly, the variety also waits for the rains and you get some little harvests with little rains, 513 maize does not survive for long, it's affected by *mbaa* (*mbaa* means frost in Kikuyu) (key informant No. 4 Muhonia).

Maize variety 614 was cultivated by farmers at the time of settlement. Currently, the variety is still cultivated in addition of other varieties, which is embraced by all farmers because it is reported to work for them. Farmers can tell the difference between the responses of various maize varieties they cultivate through previous random observation of their crops seasonally. For example, maize variety 614 is considered a long season variety because it takes about six to nine months to mature, while maize variety 513 takes four to five months to mature. Farmers are able to tell the difference in terms of survival and tolerance of these varieties to the lack of rains and *mbaa* (frosts). Interestingly, farmers prefer maize variety 614. Farmers argue that the variety 614 takes long to mature and therefore, there is higher probability of rainfall within the 9 months, which can salvage the crop and guarantee the farmers some little harvest. In contrast, to the maize variety 513 that may not survive beyond 5 months with lack of rains and susceptibility to frosts attacks. Many studies have shown that farmers have mixed long and short season crops systematically over years to cope with climatic variability [87–89]. Umande and Muhonia farmers confirm other studies that showed farmers prefer long cycle and short cycle varieties for a variety of reasons such as superior taste and high yields, tolerance to the drought conditions [4,87]. We argue that Umande and Muhonia prefer both long and short cycle crops to enable them to manage uncertainty of variable weather in terms of rainfalls, droughts and frosts. Crop breeders can thus work together with farmers to determine crop varieties that suit smallholders' perceptions in order to reduce uncertainty of variable weather at local levels.

When droughts occur within Umande and Muhonia, farmers use a number of coping strategies identified from FGD and key informant interviews (see Table 3).

Table 3. Coping and adaptation strategies to local perceptions of climate change and variability from Umande and Muhonia sub locations of Laikipia, Kenya.

Perception of climate change/variability variable	**Perceived effects on humans, livestock, crops**	**Range of responses Rapid (coping) and longer-term (adaptation)**	
		Crops	**Livestock**
Decreasing Rainfall, unpredictable rainfalls, breaks in rainy seasons early rains late rains	• Humans: hunger, food insecurity, loss of livelihoods • Livestock: Lack of fodder, livestock deaths • crops: loss of crops, loss of seeds	Use early maturing crop varieties e.g. 511, 513; DHO4, DHO2) use late maturing crop varieties such as 614, 628, 611 early planting late planting planting whenever a spell of rains is determined) continuous planting rain harvesting into manually dug water pans irrigation from water pans seed preservation using local innovative techniques e.g. wood ash and use of expired batteries making shallow basins around every crop	crop residues used as livestock feeds grass growing for sale during droughts livestock watering from water pans

Table 3. *Cont.*

Perception of climate change/variability variable	**Perceived effects on humans, livestock, crops**	**Range of responses Rapid (coping) and longer-term (adaptation)**	
		Crops	**Livestock**
Increasing temperatures	• Humans: hunger, food insecurity, loss of livelihoods • Livestock: drying of pasture and grass leads to lack of fodder, death of livestock • crops: loss of crops, loss of seeds	Mulching to reduce loss of water from soils Irrigation from water pans	Shifting from crop production to livestock keeping
Increasing wind	• crops: falling of cultivated crops	Intercropping maize, beans, potatoes; growing castor oil plant (*Ricinus communis*) (locally referred to as *mbariki*) around the farm/plot	
Increasing frequency of droughts	• Humans: hunger, food insecurity, loss of livelihoods • Livestock: Lack of fodder, death of livestock • crops: loss of crops, loss of seeds	Use early maturing crop varieties e.g. 511, 513 DHO4, DHO2) use late maturing crop varieties such as 614, 628, 611 use of certified seeds conservation agriculture planting in shallow trenches mulching relocating to river banks to access river water for irrigation cultivation of commercial horticultural crops (tomatoes, peas, cabbages)	Migrating with livestock to forests Sale of livestock Buy feed for livestock
Increasing frosts	• Humans: frostbites • crops: frostbites	Planting *Ricinus communi* around the farm/plot Planting frost resistant crops e.g. 614	
Increase incidence of crop pests, diseases, animal pests and diseases	• Humans: sickness • Livestock: poor livestock health, low production, death of livestock • crops: poor yields, loss of crops	Seek agricultural extension services, use local knowledge such as wood ash to destroy pests	Seek veterinary services, use of local knowledge to treat diseases (hot rod to burn swollen lymph nodes)

Most farmers preferred multiple options, which were used in combination at the same time. The most practiced adaptation on most farms was the diversification and use of various crop varieties. Diversification has been identified as a potential farm-level adaptation to climatic variability [90–92]. Studies done by Gajanana and Sharma (1990) in Tumkur district, Karnataka, India, quoted in Speranza [92] found that many crops were cultivated simultaneously by farmers in Karnataka. However, limitations associated with cultivating crops simultaneously are low yield as a result of limited time, labor and capital. Many crops limit the scope for diversification of more crop enterprises [92]. Farmers in Umande and Muhonia cultivate many crop varieties simultaneously, thus practicing crop diversification, increasing the number of crops varieties to reduce the susceptibility of agriculture to micro-climatic events that might result in crop failure [90–93]. For farmers in Umande and Muhonia, crop diversification does, to an extent, guarantee small harvests; however, there are years in which farmers report total crop losses. Adaptation policies that target such farmers should be worked out consultatively with farmers to ensure that feasible farmer adaptations are promoted and supported in policies.

The cultivation of short cycle crops and long cycle crop varieties shows the tendency of farmers to take advantage of the different maturing times of crops, to strengthen their resilience to impacts associated with variable unpredictable rainfalls and drier conditions, in order to increase chances of harvesting a crop during the drier and wetter seasons. These findings agree with the case of Kenyan farmers from Makueni [46,94] and Namibian farmers who cultivated early maturing crops to cope with drier conditions [38,47].

From FGD, key informants and questionnaire interviewees coupled with participant observation confirmed that farmers from both sub locations have various preferences for particular crop varieties, although other crop varieties were grown at a smaller scale on farms. We argue that farmers maybe are trying out experiential learning on their farms to determine which varieties will suit them. Planners, breeders and farmers can use this experimentation attitude of farmers to develop crop varieties that incorporate local needs and knowledge of farmers in order to make such varieties easily attractive to farmers.

Crop and animal diseases were managed by access to agricultural extension services and veterinary services in combination with local knowledge, where finances were limited. For example, farmers from both sub-locations sought veterinary services to treat livestock diseases e.g., east coast fever (ECF); however, some farmers used a hot rod to burn the swollen nodes on the animal before seeking veterinary services. Some farmers from Muhonia explained their use of local knowledge to treat livestock as a result of their long distance from the veterinary services in comparison to Umande. As a result, Muhonia farmers considered lack of veterinary services as an impediment to their adapting. We interpret this to mean that, while farmers use their local knowledge to cope and adapt, they also appreciate the need for other external sources of knowledge (e.g., veterinary) that would integrate with their knowledge to enhance their adaptive capacities.

Table 4 shows additional coping/adaptation strategies of farmers and statistical significance in comparison to their drought perceptions.

About 80% of Muhonia farmers and 68% of Umande depend on relief food. Although farmers mentioned relief food as coping strategy, farmers confirmed that the relief food was unreliable as it occurred spontaneously during very drought years based on what the government interpreted as “very dry" period of the year. In addition, there were special rules attached to who is entitled to the relief food. Provision of relief food, often delivered by the government in collaboration with World Food Programme (WFP) could be an indication that farmers from Muhonia tend to be worse hit by droughts in comparison to Umande. Reliance on relief food could be an indicator of increasing vulnerability during droughts. 84% of Muhonia farmers sell livestock, whereas in Umande only 56% do so. This difference could be due to higher livestock stocking rates in Muhonia than in Umande. Sale of tree products occurs in Umande at 4.7%. Umande farmers' ability to sell tree products such as charcoal and firewood could be attributed to their proximity to the administrative Nanyuki town in comparison to Muhonia, which is distant from the town. Accessibility to administrative and shopping centers expose communities to more opportunities for non-farm activities [4]. The finding on sale of tree products by Umande farmers agrees with studies from central Kenya [4] and Makueni district of Kenya [92], where the sale of tree products was considered as adaptation particularly during drought periods.

Table 4. Coping/adaptation strategies to total crop failure in drought years in Umande and Muhonia sub locations of Laikipia, Kenya (n = 106 for Umande sub location and n = 100 for Muhonia sub location; Total n = 206).

Strategy	**Umande Sub location n=106 (%)**	**Muhonia Sub location n=100 (%)**	**Overall n=206** (%)	**Pearson chi-square Value**	**df**	**Asymp. Sig. (2-sided)**
Purchased new inputs for next season	12.3	1.9	7.3	8.030(b)	1	0.005 *
Received government relief food	67.9	80.2	76.2	8.329(b)	1	0.004 *
Sale of tree products (charcoal, wood, timber)	4.7	0.0	2.4	0.078(b)	1	0.780
Migration/sought employment elsewhere	39.6	35.8	38.8	6.434(b)	1	0.011 *
Borrowed from neighbors and relatives	0.0	1.9	1.0	0.371(b)	1	0.542
Sold our livestock (large and small)	56.6	84.0	72.3	15.462(b)	1	0.000 *

Notes: significant at confidence interval at 95% (0.05).

There is a statistical relationship between some coping/adaptations strategies used by farmers and their drought perceptions (Table 4). For example, purchase of new inputs such as planting seeds and fertilizer were related to drought perceptions (0.005) where the confidence interval stands at 95% or 0.05, hence (0.005 < 0.05) is significant. In contrast to sale of wood (0.780 > 0.05); and borrowing from neighbors (0.542 > 0.05); these that are not related to drought perceptions are insignificant. Borrowing from farmers, for example, confirms farmers' reports that they depend on their neighbors in one way or the other all through the year, with rains or with droughts. Similar analysis have been used by Eriksen *et al*. [67] to show relationships between droughts and adaptations of farmers in Tanzania and Kenya.

The subject of adaptations and adaptive capacity of farmers is subject to various debates. For example, acknowledging that different regions and areas exhibit varying degrees of temporal variability [13,14], means that different areas may require different appropriate adaptations befitting the locals. Eignenauer [33] argues that scientists and planners often place emphasis on the extrapolation from one set of coping and adaptation practices, rather than taking lessons from the variability and diversity of farmers' coping and adaptation practices. Policies and development oriented programs stand to succeed in enhancing adaptive capacity of the vulnerable farmers if they support and implement adaptation strategies that are currently being practiced by farmers [68]. The local knowledge of Umande and Muhonia farmers is fundamental to enhancing the adaptive capacities of these vulnerable farmers, who show differences in preferences for adapting. Ideas seen in the context of existing practices of farmers can be easily accepted and embraced by farmers [13]. Since farmers use their perceptions to make decisions on coping and adapting, through local knowledge, policy makers can understand what smallholders perceive and adapt to, before they design policies on how best to prepare and respond to climatic variability. Adaptation policies that integrate farmers' knowledge will improve smallholders' agriculture through promotion of farmer friendly adaptations.

4. Conclusions

This paper has attempted to characterize the understanding of climate change and variability in the context of local perceptions, historical climate data, coping and adaptation strategies from the perspective of Umande and Muhonia smallholder farmers. The PDSI provides evidence for increasing risk of droughts in Laikipia district over the last four decades. The views of smallholders match the historical climate data. As evidenced by the PDSI, we conclude that droughts put pressure on smallholder agriculture, and make them more vulnerable to climatic variability.

The research findings underline the importance and need for local knowledge in several ways:

- Smallholders do perceive their microclimate variations and are able to cope and adapt. There is an urgent need for the integration of local knowledge in critical climate policies to improve agricultural practices. For example, smallholders adapt to drought through an array of adaptations such as crop diversification, sale of livestock, construction of water pans, migration and search of employment. The views of the farmers suggest that people's perceptions and their agricultural practices provide insights to what smallholders really need and prefer in adapting their agriculture to climatic variability. Smallholders' knowledge points out what needs to be improved to enhance adaptive capacity, for example, access to veterinary services. However, the study did not explicitly elaborate on who adapts to climatic variability. For this reason, we propose econometric analysis in order to determine who exactly adapts to climate change and variability. Such analysis may give insights on the direction of local adaptations in future.
- Because the natural and social systems of different geographical regions are heterogeneous, local knowledge can be a critical ingredient to solving local problems because it is time specific, area specific and culturally acceptable. Although Umande and Muhonia share similar climate, the coping and adaptation strategies vary amongst the farmers. Such differences in strategies

can be well taken care of, if local knowledge is regarded in policies. However, local knowledge will not work in exclusion. External knowledge from various development experts targeting vulnerable farmers, should find leverage points of integrating local knowledge for the benefit of smallholders. For example, where farmers would adapt to climatic variability by depending on *maguna ng'ombe* rains for feed for livestock*,* during droughts *'maguna ng'ombe'* is no more. This illustrates a vacuum for appropriate adaptations to substitute *maguna ngombe*. However, such adaptations need to be consultatively looked for by all the actors (farmers, NGOs, government).

- Lastly, local knowledge integration into climate policies on one hand is likely to increase legitimacy of the decision making process of the farmers. On the other hand, it helps to give policy more consistency and steadiness into agricultural practices that attempt to bring about change in farming practices at local levels. This may demand that adaptation interventions search for solutions together with farmers rather than prescribing solutions, which farmers may not view as feasible or attractive.

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Conflict of interest

The authors declare no conflict of interest.

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