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Seasonal climate dynamics, perceptions and multiple risk adaptations: Lessons from Smallholder mixed agro ecosystems in Semi-arid Kenya

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Climate variability is frequently associated with instances of dry spells and droughts, which principally result from highly variable rainfall and increasing temperatures. In mixing agro ecosystems, these phenomena primarily affected crop and livestock practices of smallholder farmers through generating social, economic and environmental losses. Resulting water scarcity, in quality and quantity, at household and landscape level is likely to negatively affect major water dependent livelihoods. In the event of associated and perceived climate variability impacts, households in Wote area of Eastern Kenya at individual level institute adaptations to manage these impacts. The present study used semi structured questionnaires and a focus group discussion to populate household's perceptions and adaptation mechanisms. This study results revealed that households perceived that climatic change and associated impacts are getting more severe. These include instances of higher temperatures and more variable season onset and a wide range of ecosystem deterioration indicators including effects on land health and vegetative cover. Anomalies and means computed from Gridded 10 year rainfall and temperature records from the Climate Research Unit-University of East Anglia (CRU) partially demonstrate similarity to some of these observations. Sampled households employ a wide range of adaptations strategies, principally crop based practices such as cultivation of fast maturing crops and crop diversification. These practices aim at building resilience, taking advantage of new opportunities and can primarily reduce the unforeseen damage and losses resulting from extreme climatic events. Hence, emphasis should be given to crop-based strategies, value addition, forecast based action and financing and localization of water harvesting.

Key words: Climate variability, smallholder, adaptation, Kenya, semi-arid.

INTRODUCTION

Climate change as per the Intergovernmental Panel on Climate Change (IPCC) is as a statistically significant deviation in either the mean of the climate or its variability,

persisting for decades or a longer time scale (IPCC, 2001). The United Nations Framework Convention on Climate Change (UNFCCC) distinguishes climate change

and climate variability with the former being associated with anthropogenic activities leading to alteration of the atmospheric composition: the latter is linked to natural processes (UNFCCC, 2014) including sea surface temperature changes (Lyon and DeWitt, 2012). Smit et al. (2000) in their analysis of adaptation explain there lies a strong relationship between climate change, climate variability and extremes such that adaptation to change necessarily includes adaptation to variability. From these definitions indirect and direct impacts on human wellbeing is quite explicit. In Africa, climate variability is primarily exhibited by intra seasonal, inter-annual and inter-decadal variations, which present a great challenge in understanding and prediction of trends (Hulme et al., 2001; Borona et al., 2015). In Africa, the rain fed agriculture is highly vulnerable to climate variability and change, which is highly dependent on seasonally unreliable rainfall (Challinor et al., 2007). Such rain fed agriculture covers 97% of the cropland and is mainly practiced by rural small-scale farmers (Calzadilla et al., 2009), using rudimentary techniques. Such numbers indicate Africa is indeed highly vulnerable to climate change and variability impacts, a situation that is exacerbated by non-climatic drivers such as high cost of inputs and high population growth rates (Tubiello and Fischer, 2007; Calzadilla et al., 2009).

Climate change and variability are frequently accompanied by instances of dry spells and droughts, which principally result from highly inconsistent rainfall and high temperatures. Dry spells are lengthy instances of absence of rainfall during onset of the growing period, which may gradually develop into droughts when this length is over 40 days (Mkandawire, 2014). As such, dry spells play a role in shortening of the growing season by occurring within the season, for example delaying the onset of the season. Subsequently, there is a high likelihood of crop failure as well as inter-annual yield variability, especially for moisture stress sensitive staple cereals such as maize (Kambire et al., 2010). Instances of dry spells in arid environments largely influence soil-moisture availability (Kisaka et al., 2015) and may contribute to crop-water deficit during key crop growth stages (Igbadun et al., 2005).

In the event of associated and perceived climate change and variability impacts as well as changes in socio economic conditions, farming communities at individual level employ adjustments or adaptations to manage associated impacts. These adaptation strategies are adjustments or responses by affected households in the face of experienced calamities, stressors or stimuli (Smit et al., 2000; O'Brien et al., 2004) and are an important component of assessing vulnerability to climate change and variability (Smit et al., 2000; Mirza, 2003).

Adaptation practices also aim at taking advantage of new opportunities. These adaptations can reduce the unforeseen damage resulting from extreme weather risks and are important in sub Saharan Africa where there is higher vulnerability exacerbated by lower adaptive capacity (Hassan and Nhemachena, 2008). These adaptations assist smallholder households to achieve their food, livelihood and income security in the face of climate risks and non-climatic drivers such as market fluctuations (Kandlikar and Risbey, 2000). The relationship between climate change and food availability is largely dependent on the timing and nature of adaptation mechanisms (Porter et al., 2014). This could be influenced by the effectiveness of employed adaptation mechanisms including the timing. Smit et al. (2000) and Kandlikar and Risbey (2000) add that adaptations could vary with prevailing climate stimuli and economic and institutional arrangements in place at a particular locality. This implies certain socio economic factors influence the nature and choice of adaptation mechanisms that a household employs (Deressa et al., 2009) with certain adaption mechanisms proving beneficial in addressing climate impacts while others fail (Porter et al., 2014).

According to Adger et al. (2009) in their detailed review, emphasize that a wide range of factors including knowledge on future climate, ethics and their manifestation as well as the value given to places and cultures equally influence climate notwithstanding physical and ecological barriers. Kandlikar and Risbey (2000), who indicate that infrastructure, information systems as well as research for development equally play a role in enhancing adaptation, further reiterated this aspect. Absence of these mechanisms in developing countries amplifies their vulnerability. As such, while adaptation mechanisms remain the key drivers of addressing climate-induced risks among many households in rural areas of SSA, there are combinations of forces that hinder these resilience efforts, subsequently increasing household's vulnerability. These forces range from those occurring at the household and community level to those manifested at the national and regional stage. The devastating impacts and complexity associated with the changing climate and associated evolution of farming community perceptions and innovative responses have inspired individual and collaborative research and/or development. In this regard a wide range of perception and climate trends studies have been carried out in sub Saharan Africa including those showing similarities and differences between meteorological records and farmer observations. Simelton et al. (2013) for example demonstrate some similarities between farmer perceptions and

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meteorological data for example inter-annual variability of rainfall at onset.

Farmers perceptions are an important aspect in detailing climatic variations because farmers are some of the hardest hit by climate extremes and their knowledge, perceptions and choice of adaptation can further inform on future action and solutions (Maddison, 2007; Gbetibouo, 2009; Morlai et al., 2011). In the face of climatic impacts, smallholder farmers have a wide range of perceptions that include observations on climatic trends. These range from increase to decrease or no observable change of certain climatic and related indicators of vulnerability to the changing climate as well as the surrounding ecosystems. This study demonstrates the importance of farmer perceptions and the wide range of response strategies employed to manage and benefit from climatic risks based on these perceived climatic risks.

Since rainfall changes and agriculture are intimately linked, heavy reliance on rain fed agriculture as the main source of livelihood by small-scale farmers, negates household economic status by increasing poverty when climate extremes strike. Specifically, smallholder farmers in Wote are becoming increasingly vulnerable as their adaptation efforts and key livelihoods such as drought resistant crops are eroded (Ifejika, Speranza et al., 2010; RoK, 2013) by ever severer climate impacts. The farmers were the entry point for this study since understanding climate based risks posed among them will inform appropriate and highly transferable adaptive capacities in mixed crop agro ecosystems. Appropriate crop-based adaptation mechanisms and related strategies may assist small-scale farmers to achieve food security in the face of devastating and recurrent extreme events. This constant duel between farmers and combinations of natural risks and hazards inspired the present study.

Therefore, the principal aim of this study is to characterize the nature of perceptions and adaptation strategies of small-scale farmers for the period of 2003-2013, identify changes in land and vegetative cover and utilization of gridded data to detect similarities and variations to farmer perceptions, especially where meteorological records are unavailable or unreliable.

RESEARCH DATA AND METHODOLOGY

The study was part of an ongoing project "Climate change, agriculture, and food security (CCAFS)" which cuts across the Consultative Group for International Agricultural Research (CGIAR) consortium (CGIAR-CCAFS, 2012). The project's study areas in Kenya include a 10 × 10 Km² block in Wote, Makueni County (CGIAR-CCAFS, 2012). The coordinates of the specific sampling block (Figure 1) are 37°378 E, 1°657 S; 37°298 E, 1°702 S; 37°244 E, 1°624 S; 37°326 E, 1°581 S (Förch et al., 2011). A preceding study selected 200 households based on dominant production systems within the identified block via stratified sampling, with reference to the administrative divisions (sub-locations and villages) aided by village level leaders (Rufino et al., 2013a).

This study purposively sampled 120 farmers who were cultivating the focus crops from 200 households. *Vigna unguiculata* (Cowpeas), *Cajanus Cajan* (Pigeon peas) and *Sorghum bicolor* (Sorghum) (referred to as focus crops, hereafter) are examples of drought tolerant crops and their varieties widely cultivated by small-scale farmers in the Wote area in lower eastern Kenya (RoK, 2013). Data collection techniques included household surveys where semi structured questionnaires were used which were characterized by techniques such as multiple responses and likert scales. The likert scale was chosen since it has an array of merits and is one of the most common attitude or level of agreement to statement scales (Monette et al., 2013). In addition, a 15 member Focus Group Discussion (FGD) was held at the community level involving selected men and women with reliable historical knowledge on climatic dynamics and associated adaptation. The focus group discussion was held to populate general community level information on issues around climate variability and was mainly to supplement information gathered at household level. SPSS and Microsoft excel applications were used in cleaning and analysis of collected results from the household and community level. Descriptive statistics were applied in the analysis. At the time of this study, reliable data from synoptic meteorological stations was not available. This is so since the nearest stations are distant and located in different agro ecologies hence are likely to provide unrealistic trend and anomaly results. High-resolution gridded datasets were thus obtained for the study area from the Climate Research Unit, University of East Anglia (Harris et al., 2014). The latest and improved version (4.00) of this data was used by applying a Google Earth Interface to generate estimates of rainfall and temperature records for the study area. These datasets were used in computation of rainfall anomalies and temperature trends to identify the relationship with farmer's perceptions in the study period.

The study area is largely semi-arid and experiences instances of climate variability. The area's climate is generally semi-arid with the southern part being mainly low-lying grassland, which is suitable for ranching. The mean temperature range is between 20.2 and 24.6°C and is characterized by extreme rainfall variability, which affects farming. Hilly areas receive about 800-1200 mm per annum while the rest of the areas receive about 500mm per annum (RoK, 2013). Further, the existing community mainly practices small-scale rain fed agriculture and livestock rearing. The dominant soils in the study area are luvisols and cambisols (Driessen et al., 2001). Luvisols have favorable physical properties including granular surface soils that are porous and well aerated. Cambisols are characterized by a loamy or clayey soil texture with good water holding capacity and internal drainage. The population density in the larger Makueni constituency, where Wote area lies, is 125 persons per Km² and is projected to rise (RoK, 2013).

RESULTS

Perceptions of farmers on climate variability dynamics and changes in selected environmental change indicators

Weather parameters such as rainfall and temperatures and their variation play a key role in influencing agricultural activities and subsequently livelihoods of Wote households.

Extremes of such events are indicators of climate variability and change (Blanco-Canqui and Lal, 2008). To understand the changes associated with weather patterns, households in the study area outlined variations

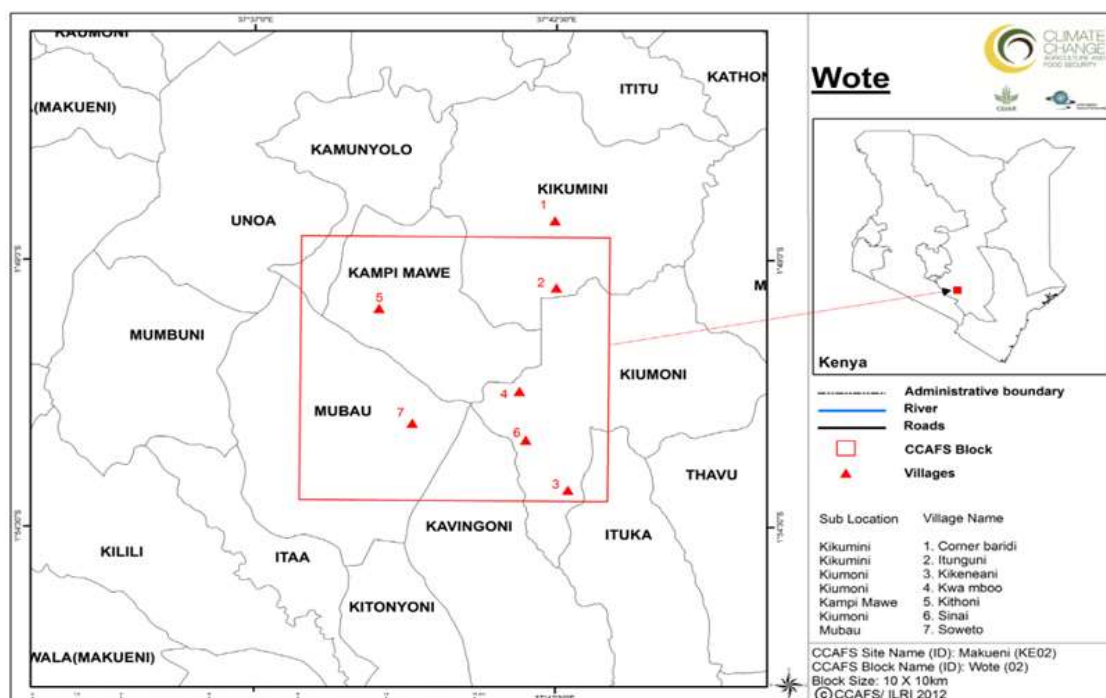


Figure 1. Map showing the study area, Wote, Eastern Kenya.
Source: Förch et al. (2011).

Table 1. Perception on selected weather parameters comparing with 10 years ago as indicated by Wote households.

Variable	Neutral		Slightly agree		Strongly agree		Strongly disagree	
	No	%	No	%	No	%	No	%*
Severer dry season	1	1	4	3	112	93	3	3
Rain prediction difficult			8	7	106	88	6	5
Temperature increased	10	9	10	9	90	85	8	8
Frequent floods	5	4	27	23	6	5	80	67
Higher yields with c. change	3	3	16	13	42	35	59	49
Climate change not big issue	4	3	25	21	74	62	16	13
Get adapted varieties			1	1	117	98	2	2
Dry season shorter			14	12	10	8	94	78
Temperatures decreased	9	8	23	19	9	8	76	63

n=120,*Percentages sum exceed 100% because these are multiple responses.

Source: Authors.

they had observed from the past ten years for specific weather parameters as a measure of perceptions for climate variability. Farmers put forward their perceptions of changes in weather against a four-point likert scale shown on the legend in Table 1 and further noted the direction of selected parameters (Table 2).

The results of the farmer's perceptions in Table 1 indicate that one of the key issues noted by Wote households is severer dry seasons among other risks. A large number of households, 93%, indicated that they strongly agree that there indeed has been a severer dry

season over the past ten years. Further, most of the households, 85%, strongly agreed that over the last ten years temperatures have increased. Table 2 also indicates, 76% of the respondents stated that they had noted an increase in the number of hot days and an even a larger number, 88%, indicating increase in dry months. The responses in Table 1 reveal that most of the households interviewed, 88%, strongly agreed that they had difficulties in predicting the occurrence of rainfall over the last decade. The large percentage indicating the none importance of climate variability, 62%, is perhaps

Table 2. Households perception on changes in selected weather parameters over the last 10 years in Wote.

Parameter	Decrease		Increase		Not different	
	No	%	No	%	No	%*
Total amount of rainfall	115	96	5	4		
Short rain onset	98	82	22	18		
Long rain onset	91	76	15	13	1	1%
Long rain duration	112	93	2	2		
Temperature Intensity	20	17	91	76	7	6%
Number of hot days	25	21	91	76%	4	3%
Dry months in a year	14	12	105	88%		
Incidence of floods	99	83	5	4	14	12%
Ground water table	115	96	3	3		
Length of growing period	84	70	35	29		

n=120,*Percentages sum exceed 100% because these are multiple responses.

because of indicated large adaptation responses such as 98% getting adapted varieties. The survey result also revealed that the majority of respondents (96%) witnessed that the amount of rainfall had a decreasing trend in the last 10 years.

Further, in terms of precipitation volume, Table 2, there had been a decrease in the amount of rainfall as indicated by almost all of the households, 96%, with an almost equal number, 93%, experiencing a notable decrease in the long rain season duration. To further bring out the issue of rainfall failure, 67% of the households strongly disagreed that over the last decade there has been frequent floods and an even larger number, 83% stated there was a decrease in flood events over the last 10 years. Table 1, also outlines that while more than half of the households (62%) do not view climate variability as a great challenge almost all, (98%) strongly agreed they need to obtain varieties that could enable them adapt indicating that climate variability features as a concern in farming decisions. In a related aspect, almost half of the households, 49%, further strongly disagreed they had more yields in their farms with the climate variability phenomenon occurring.

Apart from weather related events, respondents further indicated changes in the natural environment and crop performance (Table 3) to identify the direction and timing of key ecosystem changes over the past decade. Almost all respondents, 91%, had experienced an increase in the incidences of crop failure in the last decade (Table 3). Other key perceptions is decrease in land fertility as noted by 91% of the households and decrease in the level of accessible ground water. In addition, increased incidences related to pests and diseases such as new crop pests and diseases have been experienced by most of the households; 94 and 92%, respectively (Table 3). Examples of diseases include blight, head smut, bacterial wilt and maize rust and pests included caterpillars, aphids, stalk borer and cutworms.

The direction of incidence of weeds was almost equal

with 47% of the respondents reporting increase and 48% indicating decrease. These incidences indicate minimal change associated with weeds. Nevertheless, where weeds occur on farm there is great risk to crop yield quantity and quality and only add to harvest level drops, which magnify impacts from climatic factors. Only a small number of households, 6%, had perceived an increase in forested area and wild vegetation with almost all, 93%, indicating over the last ten years the vegetated area had decreased (Table 3).

Perceptions on significant climatic and non-climatic changes

In addition to identifying the direction of selected weather and aspects such as land fertility, pests and vegetation loss, households also indicated which of those changes had largely. This approach was also applied by a vulnerability study in the Lake Victoria basin (LVBC, 2011). This is to underline the importance of such climatic and non-climatic deviations to on farm activities. Such significance was noted by denoting a value of one (1) on the respective aspect(s) in this study by the respective household. This was to identify which parameter(s) has/have changed largely, such that the farming household's livelihoods are affected mostly. Changes in the total amount of rainfall were experienced in most, 72 %, of the households (Table 4). Another key change noted is incidences and/or outbreak of pests and diseases as reported by 47% of the respondents. Land fertility was identified as a key change affecting households with most of the households, 71% indicating there was a significant change.

Community perceptions on key calamities and ranking of Key calamities in Wote

At the community FGD, it was also evident the Wote area

Table 3. Responses on perceived changes in selected ecosystem change indicators over the last decades as observed by Wote households.

Indicator	Decrease		Increase		Not different/change	
	No.	%	No.	%	No.	%*
Forest and vegetation cover	112	93	7	6	1	1
Wild animal species	112	93	7	6		
Incidences of crop failure	10	8	109	91		
Incidence of weeds	58	48	56	47	4	3
Outbreak of pests and diseases	6	5	110	92	1	1
Resistance to pests	76	63	40	33	1	1
New crop pests	3	3	113	94	1	1
New crop disease	5	4	110	92	2	2
Ground water table	115	96	3	3		
Land fertility	109	91	8	7	1	1

n=120, *Percentages sum exceed 100% because these are multiple responses.

Table 4. Most significant weather and related changes by count by Wote households.

Environmental change	No.	%*
Total rain amount	86	72
Land fertility	85	71
Outbreak pests and diseases	56	47
Incidence crop failure	31	26
Forest and vegetation cover	28	23
Resistance to pests	21	1
New crop diseases	7	6
New crop pests	6	5
Length of growing period	5	4
Weeds occurrence	5	4

n=120, *Percentages sum exceed 100% because these are multiple responses.

did not experience heavy rainfall related impacts over the past five decades. This gives more evidence of the area being semi-arid though there are some instances such as the el-Niño rains of 1997 reported in Table 5 during the focus group discussion. The results tended to align with the household survey results, Table 5, that most of the community has mainly experienced drought conditions over the last five decades in the years; 1964, 1965, 1974, 1975, 1980-1984, 2009 and 2010. To bring further calamities to perspective households were asked to rank the three key calamities they had experienced with the value of one representing the calamity that had affected them most. The ranking in Table 6 still indicates drought is the major climate related event affecting the households where ($\bar{x}=1$).

Observation in changes in rainfall and temperature from gridded rainfall and temperature data

Figures 2 and 3 demonstrate a characteristic inter-annual

variation in rainfall with more years recording below the average values of the study period. Rainfall anomalies and seasonal average temperatures were computed using anomaly and temperature average equations as applied by Borona et al. (2016). There was an increasing trend in mean temperatures for both the short and long seasons. Absolute values indicate the highest seasonal rainfall records were in the year 2006. The MAM and OND were used as these are the long and short rain seasons in Wote. Furthermore, the period between 2003 and 2013 was applied to represent the 10 years prior to the study, the same period for the perceptions.

Responses to major climatic and non-climatic changes

Adaptation against drought and instances of unreliable or unpredictable rainfall within the growing season

Drought was ranked as a key calamity in the study area

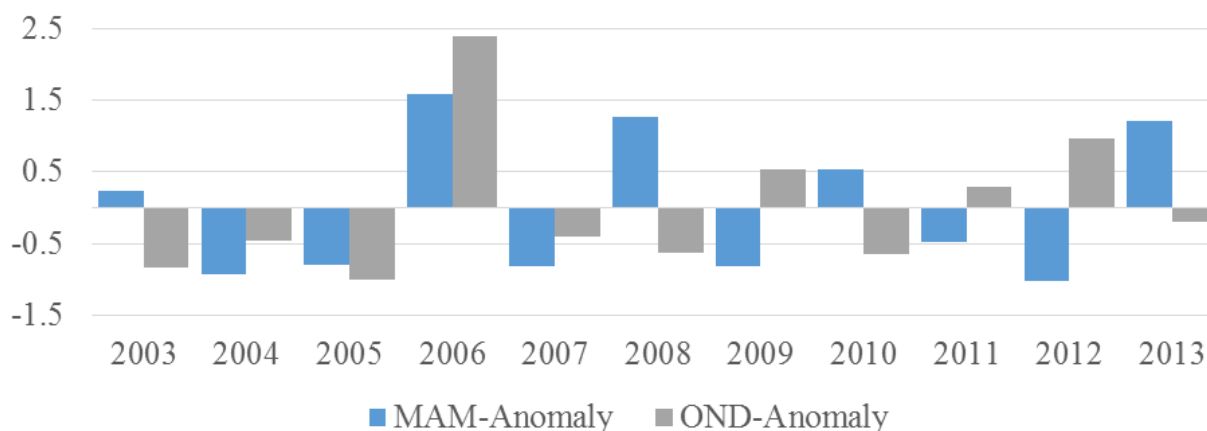
Table 5. Major calamities in the last fifty years at the community level (Focus group discussion-Wote).

Period	Description of event
1961 and 1997	There was torrential rainfall known as el-Niño .The 1997 above normal el nino floods forced migration of people living along <i>Kaiti</i> river
1964 - 1965	There was a drought " <i>Atta</i> " implying the brown flour they received then as relief
1974-1975	Which they called " <i>Longosa</i> " signifying the minimal movement of Livestock as there was scarce pasture
1980-1984	The drought was known as " <i>Nikuvaa ngurete</i> " -"don't depend on me".
2009-2010.	Most recent drought

Table 6. Ranking of Key calamities in Wote.

Calamity	Household number*	Median($\tilde{x}$)
Drought ranking	110	1
Floods ranking	4	2
Erratic rain ranking	51	2
Frost ranking	2	1.5
Wind ranking	16	3
Crop disease rank	82	2
Crop pest rank	85	3
n=120	*Multiple responses	

Due to the ordinal nature of the data, the median ($\tilde{x}$) is the more useful measure of central tendency indicating the most occurring calamity (Huizingh, 2007, Harvey et al., 2014). Other events scoring highly in the ranking order include erratic rains ($\tilde{x}=2$), floods ($\tilde{x}=2$) and crop diseases ($\tilde{x}=2$).

**Figure 2.** Rainfall anomalies, March, April, May (MAM) and October, November, December (OND), seasons for the period 2003 to 2013, Wote.

affecting most of the households over the years. As such, households engaged in an array of mechanisms to adjust to the frequent occurrences of drought events. Most response mechanisms revolve around farming, Table 7. Most of the households, 65%, have engaged in cultivation of drought resistant crops and varieties, 13% practicing crop diversification and 28% setting up terraces. Households in Wote have made efforts to adjust to erratic

rains through several adaptation mechanisms, from Table 8 most of the households, 39%, established terraces with 18% cultivating cover crops to manage instances of erratic rains.

A few households employed related mechanisms such as contour ploughing, 4%, agro forestry, 8% and water catchment, 6%. Crop based mechanisms of adaptation also feature, though in smaller numbers, in adaptation to

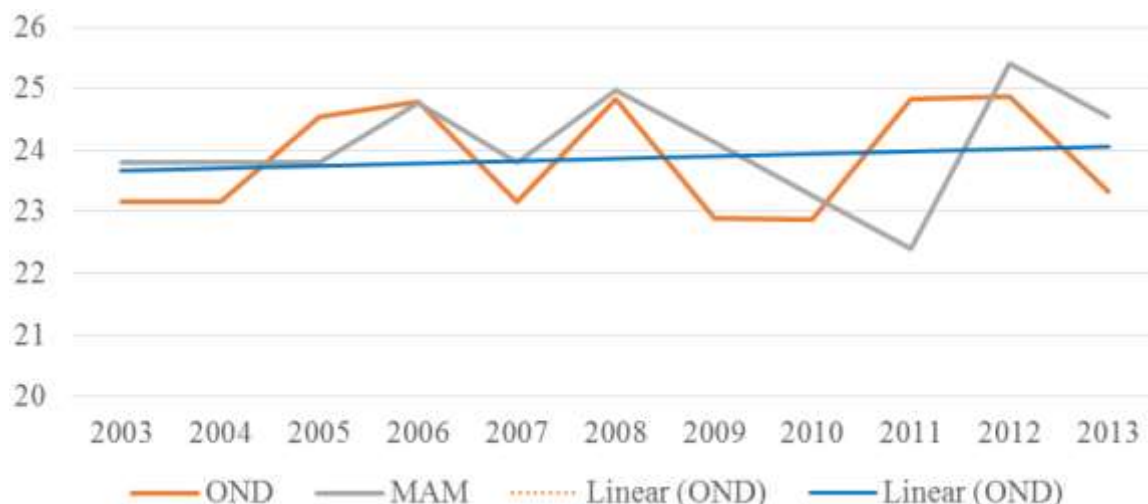


Figure 3. Mean temperature trends, March, April, May (MAM) and October, November, December (OND), seasons for the period 2003 to 2013, Wote.

erratic rains as shown in Table 8 just as they feature prominently in drought adaptation. In response to erratic or irregular rains, there is minimal cultivation of drought resistant crops perhaps there is a focus on moisture retention through terracing and cover crops.

Adaptations to crop pests and diseases in Wote

To adjust to the effects of crop pests and diseases households in the study area employed an array of mechanisms notably application of pesticides by most of the households, 88 and 65% respectively, Table 9. Potential mechanisms such as intercropping and cultural methods such as push-pull featured minimally as adaption means.

A small number of households responded to crop pests' instances by cultivating resistant crops, 7% and crop rotation 5%. Adaptation mechanisms aimed at adjusting to crop disease attacks, Table 9, are very similar to crop disease responses. Households, 13%, Table 9, indicated that they cultivated disease resistant crops in their farms as a means of curbing crop diseases a choice also featuring highly in crop pest responses.

Adaptations to changes in land fertility and vegetative cover changes in Wote

Households in Wote employ two main adaptation mechanisms to manage soil fertility including application of manure, 68% and inorganic fertilizer, 16%, Table 10. Vegetative cover provides a wide range of ecosystem goods and services such as soil erosion control vital for the sustenance of farming households in Wote. Loss of this cover implies loss of several vital ecosystem

functions. To adapt to such changes in vegetative cover households engaged in an array of mechanisms including cultivation of cover crops, 11% and a few, 8% practicing agro forestry, Table 10.

Access to weather and calamities information as an adaptation mechanism in and selected adaptation mechanisms in Wote

Weather as well as pests and disease outbreak information access among vulnerable communities is important. Such information assists in informed adaptation decisions while engaging in farming especially when to purchase inputs and start land preparation. Households mentioned which specific weather information they had received over the last two years, which denoted the actual access to weather, and calamities information as a mechanism of adaptation. From Table 11, a larger number of the households, 81% had received weather information on extreme events forecast as well as forecast for the start of the rains. An equally larger number of the households, 73% had received information on occurrence of pests and diseases.

DISCUSSION

Perceptions to the changing climate and environment

Recent studies in the sub Saharan region have demonstrated the usefulness and importance of perceptions in climate variability and change studies among farming households including, Hassan and Nhemachena (2008), Deressa et al. (2009), Mertz et al.

Table 7. Drought adaptation mechanisms by households in Wote.

Adaptation means	No.	%*
Drought resistant crops	78	65
Terracing	34	28
Crop diversification	16	13
Early planting	9	8
Building wells	7	6
Early land preparation	6	5
Fast maturing crops	5	4
Off farm income	5	4
Agroforestry	3	3
Irrigation	3	3

n=120, *Percentages sum exceed 100% because these are multiple responses.

Table 8. Adaptation against erratic rains by households in Wote.

Adaptation mechanism	No.	%*
Terracing	47	39
Cover crops	22	18
Agroforestry	9	8
Water catchment	7	6
Contour ploughing	5	4
Drought resistant crops	5	4
Fast maturing crops	5	4
Manure	3	3

n=120, *Percentages sum exceed 100% because these are multiple responses.

Table 9. Adaptation to crop pests and diseases in Wote.

Adaptation mechanism against crop pests	No.	%*
Pesticides	105	88
Resistant crops	8	7
Crop rotation	6	5
Early planting	5	4
Weeding	2	2
Adaptation mechanism against crop diseases		
Pesticides	76	63
Resistant crops	16	13
Crop diversification	1	1
Fast maturing crops	1	1
Increasing acreage	1	1

n=120, *Percentages sum exceed 100% because these are multiple responses.

(2009), Apata et al. (2009), Simelton et al. (2011), Morlai et al. (2011) and Nizam (2013). In the present study, households mentioned that it was getting warmer over the study period. This increase in temperature is

characterized with higher intensity and longer warm days and months. This scenario has implications on evaporation demand in the already semi-arid Wote area ecological profile. This could contribute to water stress

Table 10. Adaptations to land fertility and vegetative cover loss in Wote.

Adaptations to land fertility	No.	%*
Manure	79	68
Fertilizer	19	16
Terracing	8	7
Adaptable crops	5	4
Crop rotation	4	3
Adaptation to vegetative cover loss		
Cover crops	13	11
Agroforestry	10	8
Destocking	3	3
Buying fodder	2	2

n=120, *Percentages sum exceed 100% because these are multiple responses.

Table 11. Weather and calamities information received over the last two years by Wote Households.

Information received	No.	%*
Drought forecast	97	81
Start of rain forecast	97	81
Pests and disease forecast	88	73
Forecast for 24hrs or next 3 days	58	48
Weather for next 2 to 3 Months forecast	46	38

n=120, *Percentages sum exceed 100% because these are multiple responses.

even to the popular drought hard cereals. As the households mentioned, effects of temperature increase because of climate variability and change, have had an effect on crop growth and subsequent yields as well as livestock productivity with eventual contribution to food scarcity and assets loss. These trends have been discussed by related work exploring perceptions on climate change in ASALs in east Africa with reference to the same period, such as Mary and Majule (2009) in Tanzania and Macharia et al. (2012) in Kenya. Indeed temperatures are a key driver of crop growth and development and variations do negatively affect crop growth and production by altering soil water balance (Blanco-Canqui and Lal, 2008). Studies also show that temperature variation and intensity influence crop yields in several ways especially when such parameter is on an upward trajectory, increasing in intensity is experienced for lengthy times (World-Bank, 2013). For example, by altering organic matter content of soils (Letcher, 2009) which is critical for soil health. Temperature changes also affect crop growth and yield by influencing evapotranspiration (Datta et al., 2008) and more so by coinciding with sensitive crop growth stages (Lin et al., 2008). Datta et al. (2008) also argue that spatial-temporal changes in temperature among other weather parameters can also influence farmers on farm decisions on input use

as well as crop management, which eventually affects the yield.

Rainfall distribution/regularity as reported by households has been exhibiting an unpredictable and erratic behavior. In particular, there is a worrying trend associated with late onsets and early cessations subsequently shortening the critical growing season length even during the more reliable longer rain season. Intra-seasonal distribution has an amplifying effect on this impact and this could be the reason households identified a decrease in rainfall volume perhaps due to fewer rainy days. This decreasing volume could even be more impacted by the higher temperatures leading to loss of and inadequacy of the scarce water resource above and below the soil.

Rainfall failure and poor distribution leads to dry spells, which are a precursor of drought conditions, which severely affects farming activities by causing crop failure (Zezeza, 1997) or bringing about low yield quality. Macharia et al. (2012), in a perception to climate change and variability study among farmers in arid and semi-arid areas of eastern Kenya, also found out that changes in rainfall patterns and increased drought instances or more frequent drought spells. Related perception studies in arid and semi-arid areas of East Africa have similarly shown a similar trend in reduction of rainfall amount and distribution (Mary and Majule, 2009; Mongi et al., 2010)

including instances of erratic rainfall in several African countries (Simelton et al., 2011). Erratic or unpredictable rains are associated with delayed and inconsistent onset, shorter duration and even consecutive rainy days characterized by intense downpour within the onset and cessation window (Simelton et al., 2011). Such erratic rains are a concern in arid and semi-arid environments such as Wote, as the households emphasized. This is because erratic rains negatively affect farming activities particularly making prediction of the start of rains difficult for farmers subsequently contributing to ill-timed and inadequate land preparation.

Significant changes in weather and other key elements in Wote

Since variation in rainfall occurs in Wote as a key change, households are at risk of effects resulting from such key determinant of crop development and more so livelihoods largely dependent on farming. In particular, households mentioned the total rainfall amount has decreased and this trend could be contributing to incidences of crop failure as a direct or indirect impact. Perhaps households experienced lower rainfall volume because of shorter rainfall duration and inconsistency in the number of rainy days or rainfall intensity. In addition, household's livelihoods are largely dependent on crop and livestock keeping hence the likely paying of attention to and observation of rainfall changes.

Rainfall indeed is a key source of water, a precious commodity in farming households used in crop cultivation, household chores as well as watering of livestock. Inadequacy and variation of such rainfall and by extension climate variability (Wallace, 2000), has been linked to crop failure, livestock death or disposal and food insecurity around SSA (Haile, 2005). Severe crop failure could have far-reaching implications on the households in the study area because of the heavy reliance on farming as a primary livelihood strategy. Kurukulasuriya et al. (2006) in their marginal climate impacts study, note eventual effects of crop failure on household revenues on affected households, more so in the drier areas of Africa. Studies have also pointed out that yields can be sustained or even increased in severe climate events, when appropriate adaptation measures are employed (Dinar and Mendelsohn, 2011). This could explain why some households identify climate variability not being a key concern. Nevertheless, this study reveals that climate variability is a risk to reckon with as households are compelled to institute a wide range of adaptation mechanisms.

Other than rainfall variation, the experienced decrease in land fertility could be partly attributed to repeated cultivation of land over the years due to land scarcity; the focus group discussion participants mentioned this. In addition, the increase in population, leads to reduced

land sizes and reduced fallow intervals where land is not taken out of production for nutrient replenishment. This contribution resulting from rise in population numbers is also mentioned in other studies such as Bekunda et al. (1997) and Gruhn et al. (2000). Loss of fertility could further contribute to loss in other on-farm resources such as less fodder, less firewood and less crop residues and an array of other ecosystem goods (Sanchez et al., 1997; Sanchez, 2000). In addition, since most of the households are small holders there is a high likelihood, they have minimal investments to purchase inorganic fertilizers. Other potential drivers could include; variable and inadequate rainfall and rapid evaporation that induces soil erosion and insecure land ownership rights that curb soil fertility investments (Gruhn et al., 2000).

Relating farmer perceptions to rainfall and temperature records

Analysis of CRU rainfall records for the study period (2003-2013) demonstrated a trend of drier years more than wet years. The resulting anomalies such as highest rainfall records in the year 2006, 334 mm (MAM) and 734 mm (OND) depict observations made by NASA in 2006 and 2007 (NASA, 2007). Rainfall anomalies indicate that the long (March-April-May) and short (October-November-December) seasons include 6 and 7 years respectively with below average records in the MAM and OND seasons (Figure 2). These records demonstrate similarities with some key farmer observations relating to rainfall distribution. This scenario could perhaps be resulting from, as farmers put it, rainfall amount has decreased, and the season onset and cessation have become late and early respectively. Subsequently the rain or growing season has shortened. It is also likely farmers experienced less number of rainy days hence the observations such as increase in the number of dry days and months and fewer records of floods. The semi-arid environment of the study area can also be a causal factor of these observations.

Figure 3 demonstrates inter annual variation in seasonal mean temperatures for the short and long seasons. We used a linear trend line to detect any monotonic trend (Increase or decrease). The linear trend line indicates an overall rise in seasonal temperature means during the study period. This observation exhibits some similarity with the farmers observations in particular the perception that the number of hot days and months and subsequent temperature intensity has increased over the years. Observed similarity between farmer perceptions with rainfall and temperature records, demonstrates a method of understanding intra seasonal trends in climatic parameters in particular where instances of limited data are prevailing. In addition, observed similarity outlines the value and importance of including both resident farmer perceptions and climate records in climate variability

studies to generate valid inferences and insights. This combination is also useful where both data sources and options exhibit limitations.

Other studies such as Jiri et al. (2015) and Shisanya and Mafongoya (2017) show that farmers had experienced increased temperature and reduced rainfall volumes which were positively reflected by meteorological records. Mamba et al. (2015) on the other hand demonstrate how correct perceptions on weather variability as compared to rainfall records informed adaptations that aided in investment decision making which facilitates better yields and food security. These studies indeed show farmers largely make correct and reliable observations that can be equated to or compared with meteorological data. These observations are important as they inform appropriate policy, which leads to fitting adaptation steps. In addition, the importance and usefulness of meteorological data and farmer perceptions is complementary as each has its own strengths and weaknesses.

Response strategies against climatic and other environmental changes

A large number of households in the semi-arid Wote area cultivate crops and varieties that target the prevalent drought in the area. These crops and varieties include certain varieties of cowpeas, pigeon peas and sorghum. These crops and their varieties have demonstrated physiological characteristics that make it conducive to thrive in the soils in this area and more so withstand the prevalent moisture stress. Cultivation of these legumes guarantees the households a source of food, fodder and income even in instances of extreme drier conditions. Combining these strategies with related adaptation approaches such as early planting, cultivation of fast maturing crops and early land preparation even further assures of robust resilience even when multiple extreme conditions strike. Crop based drought and erratic rains response mechanisms are widespread as described in adaptation studies involving smallholder households. These include growing of drought tolerant crops and varieties (Mahu et al., 2011; Mwang'ombe et al., 2011; Rufino et al., 2013b) and crop diversification (Woodfine, 2009).

Another popular crop based response intervention is crop diversification targeting to address drought conditions. Smallholder farmers in Wote cultivate different focus crops within the same plot in the same growing season. In other instances, the level of diversification goes a notch higher to include different varieties. It is likely that few of the households in Wote that involved in crop diversification aim at reducing the risk of extreme events where all crops fail. Agroforestry is widely applied in farming communities and involves cultivation of certain multipurpose legumes to minimize loss of available soil

moisture and ensure water availability for crop growth. Agroforestry, which involves on farm cultivation of certain multipurpose trees and shrubs such as mangoes, is also a key strategy that offers farmers in Wote the wide range of products and services. In particular, this highly beneficial mechanism facilitates control of soil erosion in the face of erratic rains and is a concurrent source of food, income, fodder and firewood. Related studies similarly demonstrate that an approach such as crop diversification is a popular means adopted against climate extremes among farmers in other areas of sub Saharan Africa (Deressa et al., 2009; Mertz et al., 2009; Bizuneh, 2013) including semi-arid parts of Kenya (Recha, 2011).

A more labour intensive avenue in response to erratic rains is establishment of terraces. This demonstrates commendable efforts by households to institute radical interventions to capture and control runoff in the prevailing dry agro ecology. Terracing aims to conserve elusive soil moisture in arid and semi-arid areas (Mwang'ombe et al., 2011). Terraces are classified as structural interventions or modifications of original land topography in sloppy landscapes aiming at soil erosion control and enhancement of soil moisture retention (Blanco-Canqui and Lal, 2008). This soil water management benefit could be the same driver informing some of the farmers to respond to erratic rainfall by adopting contour ploughing. In a further effort to capture, the scarce water resource households set up water catchments. These establishments have a high adaptation potential and include certain water harvesting systems aiming at capturing precipitation in semi-arid environments as Woodfine (2009) mentions.

The large number of households utilizing pesticides indicates access to such chemicals and more so knowledge on modern farming techniques in response to crop pests and diseases occurrence. The farmers however did mention, during the focus group discussion, that they would welcome support in form of information on the appropriate chemicals and application procedures or dosage to use in pest control through farm demonstrations and exchanges with support from private or public extension services. This indicates that while smallholder farmers are able to access pesticides sold at local agro veterinary centers they may not have the necessary knowledge on dosage and appropriate application times and products. In other cases, they may violate the restricted entry interval or appropriate time to visit crops once agro chemicals are applied (WSDA, 2009). This could increase their vulnerability since uninformed utilization of such pesticides may influence their health and safety. Further, unintended abuse of agro chemicals can result in resistance by pests as well as destruction of ecologically useful parasites and predators (Lenné, 2000). Nevertheless, pesticides play a big role in alleviating hunger resulting from crop yield losses when used appropriately.

As instituted by a few of smallholder farmers in Wote, early or timely planting as a means of avoiding pests is primarily to ensure crops are past sensitive growth stages before pests strike. Crop rotation on the other hand controls pests by ensuring crops are not cultivated in a specific plot of land over long periods of time, a state that encourages pest concentration and constant attack and possible massive crop failure. These results further show there is an opportunity in investing in and focus on strategies against crop pests and diseases that are crop based.

Application of manure to manage soil health is commonly practiced because of the availability of the product within households and is mostly obtained from reared livestock albeit in smaller quantities. This manure is a substitute to the more costly inorganic fertilizer and primarily promotes soil fertility and subsequent improved crop performance. The importance of manure cannot be underestimated as this input plays a part in ensuring food sufficiency by improving crop yields. In most instances, manure is applied just before planting is done or continuously as crops grow with the aim of maximizing plant yields. Manure does indeed contribute to the improvement of soil fertility by addition of key nutrients (Nitrogen, Potassium and Phosphates) to soils when applied appropriately (Woodfine, 2009). Most smallholder farming communities are unable to access the inorganic fertilizers because of their high costs, though there are proposed solutions with potential benefits such as integrated soil fertility management (ISFM) (Vanlauwe, 2002). Further as Muyanga and Jayne (2006) mention farmer behavior could also inform soil health management" less endowed farmers are risk-averse and are less likely to spend on new technologies rather they exhibit the 'wait and see' mentality".

Among households in the study area, natural vegetation plays a big role in the provision of a wide range of environmental services and goods including; soil erosion control, food, fodder and fuel wood. Destruction and/or modification of vegetative cover will hence bring about loss of such products and services, which are vital for the livelihoods of the households. Cultivation of cover crops as pertains to adaptation to vegetative cover loss aims at reducing open soil surface, which encourages soil erosion and eventual crop loss. These cover crops also contribute in reducing the exposure of seedlings to high temperatures at sensitive crop growth stages. The mechanism is mentioned in other studies related to adaptation such as land degradation studies in Ghana by Mahu et al. (2011). Agro forestry on the other hand in response to vegetative cover improvement aims at ensuring farming communities restore vegetative cover through planting of multipurpose trees and shrubs on farm. This ensures households benefit from an array of environmental goods and services including raising the value of land. As such, institution of agroforestry practices is a noble adaptation strategy that ensures

constant supply of key environmental benefits including in periods when extreme events prevail. Establishment of agro forestry systems is also an important shelter from effects of wind and water erosion at landscape level; plants roots anchor the soil and subsequently reduce runoff (Blanco-Canquis and Lal, 2008).

Weather as well as pests and disease outbreak information access among vulnerable farming communities is important. Such information assists in informed adaptation decisions while engaging in farming such as when to start farming with regard to the start of rains. Ranking of extreme weather information such as drought indicates the exposure and sensitivity of the households to drought, which has been noted as the key calamity, by households in Wote. Information on the start of rains is equally key since rainfall greatly influences land preparation dates as well as start of planting and subsequent performance of crops in arid and semi-arid areas. Rainfall also influences several other household aspects such as pasture availability and subsequent livestock productivity. Households equally showed importance to weather information for the next 24 h to three days. Such ranking indicates that households prefer weather information into the near future. Weather information for one to three days plays a key role in averting sudden climate extremes notably flash floods and dry spells which could severely affect household's wellbeing. Access to forecasts of varied composition and timing including drought forecasts in appropriate lead times, provides an avenue for informed and participatory forecast based action to avert impacts (Ingram et al., 2002; Roncoli et al., 2009).

Conclusions

This study demonstrates that smallholder households in the Wote area of eastern Kenya perceive that there has been changes in the local climatic conditions over the last decade. These observations tally with some climatic estimates generated from CRU gridded rainfall and temperature records. There is a wide range of changes in climatic parameters as experienced by the farming households. These changes include instances of increased temperatures as well as more dry days and months. Furthermore, there are perceived instances of change in the amount of rainfall as well as late onset and early cessation of the growing season. Farmers experience other environmental change indicators partly resulting from, their own land use activities and climatic factors. These environmental change indicators include loss of vegetative cover and deterioration of soil fertility. These wide ranges of climatic and non-climatic changes have prompted a plethora of responses with the motivation of cushioning and accruing benefits from occurring impacts. Crop based strategies are primary responses among the households and include strategies

also identified by related studies in Africa.

The study forms a platform for informing action aiming at supporting smallholder farmers in mixed crop agro ecosystems. To this end, the study identifies principal entry points that can effectively support such households including more emphasis on the crop based strategies including but not limited to drought resistant varieties. Furthermore, novel-farming techniques can be encouraged or supported, with more emphasis on farm value addition and improved farming systems appropriately blending the use of organic and inorganic fertilizers. In addition, in the face of unpredictable climate variation forecast based action and financing methods come in handy. This effort can be accompanied by localization of climate adaptation policies with incentives that inculcate the culture of water harvesting.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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