

Perceptions and Truism of Climate Variability within Smallholder Farming Communities in Meru County, Kenya

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Authors' contributions

This work was carried out in collaboration between authors MM, JO and FW. Author MM designed the study, conducted data analysis and prepared the manuscript. Authors JO and FW oversaw the whole process as the research advisors. There were exchanges between the authors to prepare and revise the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To assess actual and perceived climate variability within smallholder communities in Meru county.

Study Design: A cross-section survey to obtain data on farmers' perceptions and using Long term hydro-climatic records.

Place and Duration of the Study: Targeted smallholder farmers in the seven major sub-agro ecological zones of Meru County. Rainfall and stream flow records ranging between 1976 and 2011 were used. Household survey and focused groups discussions were conducted in August 2010.

Methodology: A stratified random sampling was used in 7 sub agroecological zones, each zone representing a stratum. Structured questionnaire was administered to 275 household heads. Focus

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group discussions were undertaken to understand the community perspective on climate variability. Data was analysed employing descriptive statistics. Using rainfall data from 3 stations and 1 river gauge, seasonal rainfall and stream flow anomalies were computed. ANOVA was used to determine significant mean differences across represented sub-agroecological zone.

Results: The key indicator of climate variability was variations in rainfall. In the low highland 1, coefficient of variability in rainfall amount for first season was 0.43 and 0.26 for second season. For the upper midland 2 and in the transition zone with upper midland 3 the coefficient of variability for first season was 0.36 and 0.37 respectively. As such the first season was the main determinant of annual agricultural productivity in both upper midland and low highland agro-ecological zones. February and September had highest (0.44) Stream flow coefficient of variability. Majority (91.6%) of respondents concurred that there was climate variability, an indication of the awareness level.

Conclusion: Responses were pegged on perceived forms of climate variability. There was divergence in observed and perceived climate variability parameters necessitating integration of farmers' and scientific approaches in mitigation against effects of climate variability. Planning for effective agricultural productivity needs to be seasonal and agro-ecological zone specific to counter temporal and spatial variations.

Keywords: Agroecological zone; rainfall variability; smallholder farmers' responses.

1. INTRODUCTION

The state of knowledge about the Earth's climate is informed by studies undertaken at individual, national, regional and global institutional levels including the intergovernmental panel on climate change (IPCC). These entities have recommended continued research on the underlying phenomenon [1]. The global circulation model provides a general trend at broad levels without certainties in nature and extent of changes in precipitation, temperature and extreme events [2]. Global prescriptions resulting from modelling or predictions may have little or no relevance to the prevailing local and regional situation [3]. The extent of data deficiency attributable to weaknesses of ground-based (and upper air) observing systems is greatest in Africa and has drawn attention from United Nations Framework Convention on Climate Change [2]. However, global climatic observations suggest existence of seasonal and annual climate variability [4]. Studies done on effects of climate variability have relatively focused on the wider global dimensions, with less intensity on smaller local community interests, individual country and intra country levels. Rainfall projections models and scenarios in Kenya are inconsistent [5,6]. Knowledge of climatic impacts in different locations and their potential responses is still rudimentary [7]. Past efforts focused on dryland ecosystems in identifying impacts of and responses to climate change [8]. The midlands and highlands may be equally affected by climate variability, impressing the need for intensifying climate variability research in all agro-ecological zones.

Existence of information gaps, amidst inadequate knowledge and resources has deepened the challenges of smallholder farmer response to climate variability [9]. Kenya's economic development is characteristically anchored on subsistence smallholder farming [7]. Smallholder farmers have relied on perceptions [10]. Responses to climate variability in rural subsistence farms were associated to perceived climate variability rather than the periodic weather forecast and measured parameters [11]. As Kenya grapple with development of appropriate policies to tackle smallholder farming climatic related challenges it is imperative to ascertain the existence of climate variability, have knowledge on farmers' perception and their response strategies. Meru County forms part of the Eastern slopes of Mount Kenya and a major food and cash crop production area of the country [12]. This study was based on the hypothesis that smallholder farmers in Meru experience climate variability which triggers responses. Taking into account the sub-agroecological zones, presence of climatic variability was investigated based on actual rainfall and stream flow records. This study further assessed smallholder farmers' perceptions on climate variability and their responses.

2. METHODOLOGY

The study targeted smallholder farmers in the seven major sub-agro ecological zones in the four sub-counties; Imenti South, Central, North and Buuri in Meru County Kenya. These zones were LH₁ (tea & dairy zone), UM₁ (Tea/coffee

zone), UM₂ (Main coffee zone), UM₃ (Marginal coffee zone), LM₃ (Cotton zone), LM₄ (Marginal cotton zone) and LM₆ (grazing zone) (Fig. 1).

This area is inhabited by an estimated population of 0.5 million [13].

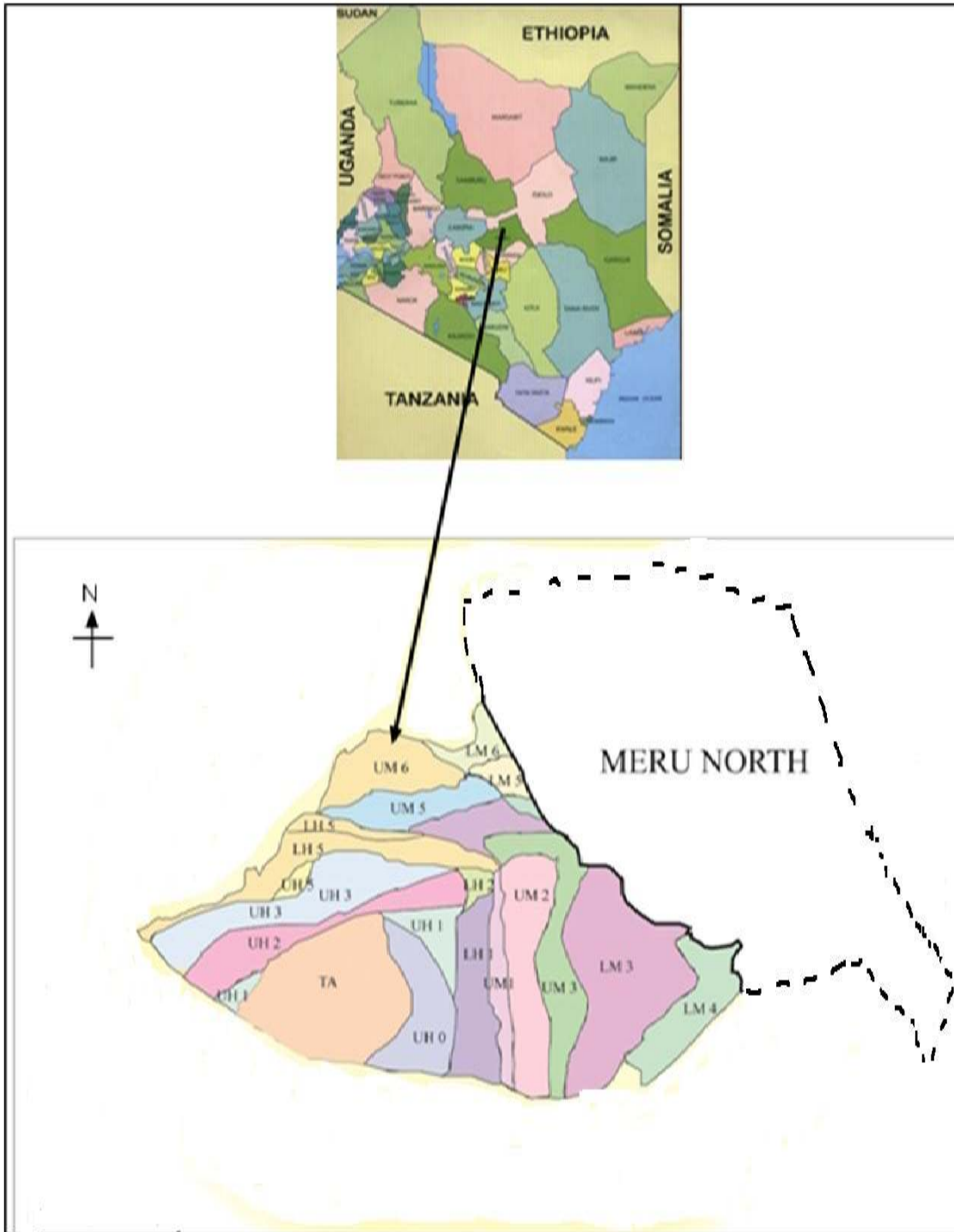


Fig. 1. Location of study area

A stratified random sampling was used and each sub-AEZ represented a stratum. Using a list of administrative units as the sampling frame, one village per sub-AEZ was randomly selected. A larger sample size is believed to generate more reliable data. Therefore, a sample size per unit (Sub-AEZ) of 30% and 60% was deemed appropriate for the large and small target populations respectively culminating to a total of 280 households randomly selected. Structured questionnaire was administered using the local language to 275 household heads. It contained questions on demographic and socio-economic characteristic of the households, assets portfolio, perceptions on climate variability and their effects on smallholder farming. Focus group discussion (FGD) was undertaken to deepen the understanding of the community about climate variability and its effects. The FGD consisted a total of 4 groups each comprising of 8-12 participants. It targeted the most vulnerable/poor, the rich, Key informants and the elderly (above 60 years). This was done through homogeneous sampling. A combination of various participatory techniques was employed including; time line analysis, stakeholder analysis, risk and opportunity analysis.

The Ministry of Water and the Meteorological Department were the main source of hydro-climatic data. Out of the 20 rainfall stations those were at one time operational, 17 had over one years' data missing thus disqualified. The world meteorological organization standard was applied in selection of appropriate set of data, that one should not fill more than 10% missing monthly data. Githongo Tea factory provided data for the period 1984 to 2011 while both Meru forest station and Meru meteorological stations had data for 1976 to 2011. Thus the three stations qualified. The River Kithino stream flow daily records for the past 30 years were provided by the Ministry of Water.

2.1 Data Analysis Methods

This study applied a combination of qualitative and quantitative approaches. Perceptions on climate variability were analysed using descriptive methods expressed as frequencies and further triangulated with the results of FGD. Component score was used to narrow the number of response strategies to those that were strongly correlated. XL STAT and Excel version 2010 were used to generate the annual average cumulative departure index on seasonal rainfall trends ranging between 20 to 34 years for 3 weather stations. March, April and May

represented the first season rains while for second season; October, November, December and in addition January was considered since its inclusion was valued in previous studies [14,15]. Seasonal rainfall cumulative departure was calculated where mean seasonal values of MAM were considered as 92 days and 123 days for ONDJ. The base period was defined as the entire period of record during which the mean seasonal values computed by this equation are considered to be representative of the long term average conditions. A positive departure of precipitation, for instance, indicates that the rate of precipitation for that season exceeds the long-term average for that season. While, the stream flow departure from normal (1980-2011) was computed by calculating the difference between long term annual mean and yearly mean figures. Determination of rainy season was based on the first 3 to 4 months after the start of a rainy season. ANOVA was carried out to test whether the mean of the seasonal rainfall between sub-AEZs differed significantly. Further a Tukey Post Hoc test was done to identify which Sub-AEZs differed significantly from each other. Stream flow variability was computed using mean and standard deviation derived from Excel for a 30 year period. Daily monthly averages for River Kithino discharge were computed to develop long term trends. Data was also subjected to homogeneity test [16].

3. RESULTS AND DISCUSSION

3.1 Observed and Perceived Climate Variability

The hydro-climatic findings indicated variability of rainfall amounts and stream flow discharge. Majority of the respondents (91.6%) concurred that there was climate variability. This was an indication of increasing awareness of this global threat and hence opportunity for spontaneous community participation in intervention measures.

3.1.1 Rainfall

The trends emanating from actual records depicted in Figs. 2 and 3 illustrate differences in departure from their mean seasonal rainfall amounts among sub-AEZs over time.

Cumulative departure for the station in low highland one (LH₁), upper midland two (UM₂) and the one within transition zone upper midland two to three (UM₂₋₃) for March, April and May (MAM)

depicts coherent rainfall patterns. Rainfall in LH₁ appeared to have a greater increase than UM₂ and UM₂₋₃. There was a tendency for the Peak Cumulative departure index (CDI) to alternate with a depression. There was enhanced rainfall in the years 1977/78, 1997/98 and 2002/03 with CDI of above 6. There was a peak in 1997/98 because during ENSO years there is more rainfall. Considerably more rain fell between October and December in 1997 than proceeding 1998 MAM season. Around year 1984, 1995, 2000 and 2005/06 the CDI was at below -3. Therefore, the area experienced both intermittent droughts and floods. When there was positive departure the higher areas received relatively greater change than the lower areas.

Consequently, the impact of rains during ENSO years are more pronounced in the highlands than low lands hence essential to strengthen counter measures in these areas.

ONDJ is the long rains while, MAM season is considered as the short rains in Meru unlike most parts of Kenya. The two Seasonal rainfall accounts for over 85% of the annual rainfall and ONDJ season receive more rain than MAM season. Test for significance of the mean rainfall differences (at 0.05 confidence level) for the two seasons resulted to a P-value less than 0.05 (P<0.05). Thus the mean rainfall for the two seasons was significantly different in LH₁, UM₂ and UM₂₋₃ (Table 1).

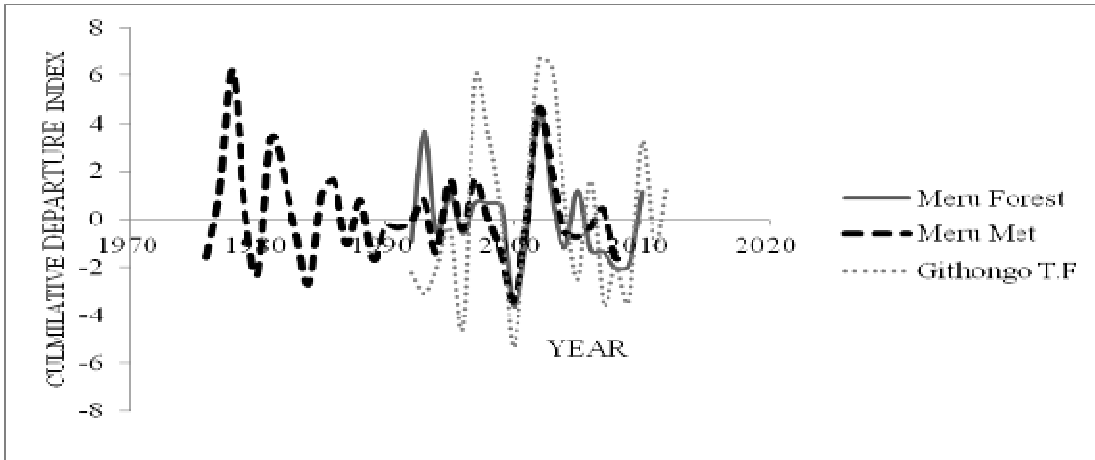


Fig. 2. Rainfall cumulative departure for Githongo (LH₁), meru forest (UM₂₋₃) and meru meteorological stations (UM₂) for MAM

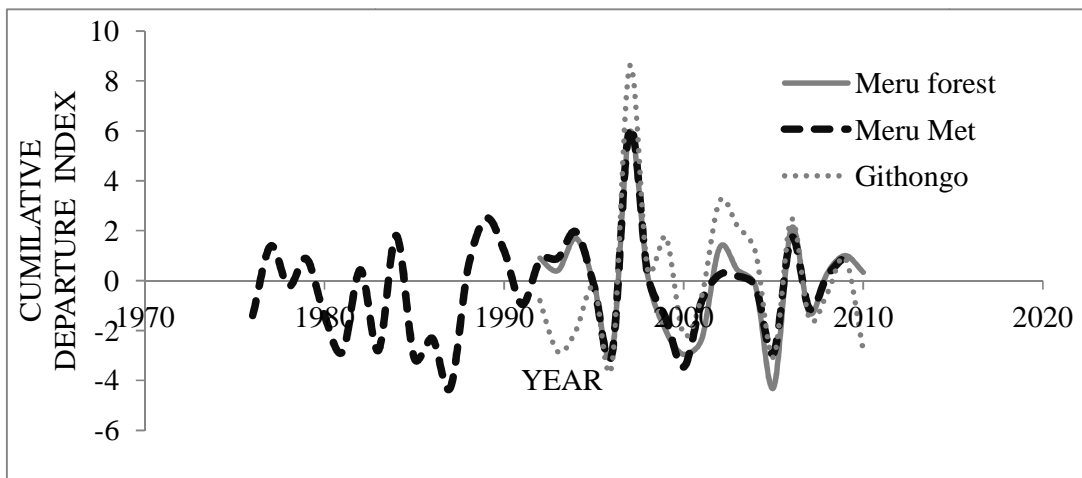


Fig. 3. Rainfall cumulative departure for Githongo (LH₁), meru forest (UM₂₋₃) and meru meteorological stations (UM₂) for ONDJ

Significant differences in mean rainfall amounts exist between the three areas in the same season. It was evident that high amounts are received in ONDJ than MAM season. Rainfall variability changes across Sub-AEZs while the closely related sub-AEZs had approximately or equal coefficient of variation (CV) in both seasons. Both MAM and ONDJ rainfall are variable as showed by the CV (Table 1). Low highland one had CV of 0.43 for MAM season and CV of 0.26 for ONDJ. UM₂ and UM₂₋₃ had equal CV of 0.34 for ONDJ season. MAM CV was 0.36 and 0.37 for UM₂ and UM₂₋₃ respectively. These findings concur with other studies carried out within the lowlands of Eastern Mt Kenya in LM₄, LM₄₋₅ and IL₅ where MAM rainfall season had a CV of between 0.35 and 0.36 while ONDJ had a CV of between 0.36 and 0.44 [15]. MAM rainfall amount was more variable and less stable within the three sub-AEZs. This implies that the performance of ONDJ is a key determinant of the annual crop yield in UM₂ and UM₂₋₃. March April and May season rainfall is more variable in LH₁ than in UM₂ and UM₂₋₃. However, the average seasonal amounts of over 700 mm are adequate for crop production in LH₁. Accordingly, to maximize the benefits there is need to employ meteorological seasonal predictions in planning for MAM season. This would entail availability of appropriate cropping mix, varieties and technologies that would regulate soil moisture. Subsequently, the same would apply for the ONDJ in UM₂ and UM₂₋₃ which is more variable. The trend suggests that rainfall variability increases as you go to lower Sub-AEZ for the MAM and decreases in the ONDJ season. The semi-arid LM₆ is more sensitive to rainfall variability hence need for land use planning. Pastoralism or agro-pastoralism can be confined in the less arid areas.

3.1.2 Stream flow

There was reduction in stream discharge as signified by the CV and the mean monthly discharge. The CV ranged between 0.40 in February and September to 0.22 April and December (Table 2).

September and February are generally the driest/hottest months with minimal precipitation. The increased rainfall fluctuation in January and August/ September causes variability during these months. River Kithino is the main water supply and originates from the slopes of Mt Kenya. This enhances runoff and sedimentation during rainy seasons. Further, in the drier months, irrigation increases exploitation of water upstream. High rainfall led to increased river discharge due to surface runoff, raised water table, precipitation, reduced evaporation and decreased irrigation. Other studies concur that there is a relationship between increases in heavy precipitation and changes in high stream flow [17]. Significant and coherent signal of increasing stream flows attributable to heavy precipitation were detected [18]. This negates the effects of hydrological cycle in maintaining stable environmental conditions.

Stream flow discharge decreased from 1980 to 2010 as signified by the slope (-0.0097). The river discharge was above normal between 1982 and 1994. However, there was a depression in 1995, 2004 and 2009 (Fig. 4). This suggests that either or both natural and human activities have intensified in the recent years. Irrigation was believed to be a major contributor of the low stream discharge during the dry months. Kithino River was one of the most significant sources of water for irrigation and domestic use in the Imenti south sub county. The ease of establishing a gravitation watering system led to over-abstraction along River Kithino. Over 53 water projects were authorized to abstract water from this river including some of the large schemes in the region like Nguru ngakero Irrigation and Ciomucogia. Results further indicated that 34.3% of respondents practiced irrigation. However, 87% of those who practiced irrigation indicated that unreliable rainfall was the main reason for venturing into irrigation. Other reasons were; meeting market demands and maximizing returns per unit land. This implies that erratic rainfall led to expansion of irrigated area. Stream flow dynamics and seasonal climatic variations are intertwined. Several studies have linked trends of stream flow discharge to climate variability [19-21].

Table 1. Computed CV and P-value for the three rainfall stations seasonal rainfall

Station	Sub-AEZ	MAM	p-value	CV	ONDJ	p-value	CV
Githongo T.F	LH ₁	744.7	0.00	0.43	1329.9	0.00	0.26
Meru Forest	UM ₂₋₃	478.1	0.00	0.37	811.2	0.00	0.34
Meru Met.	UM ₂	466.2	0.00	0.36	789.5	0.00	0.34

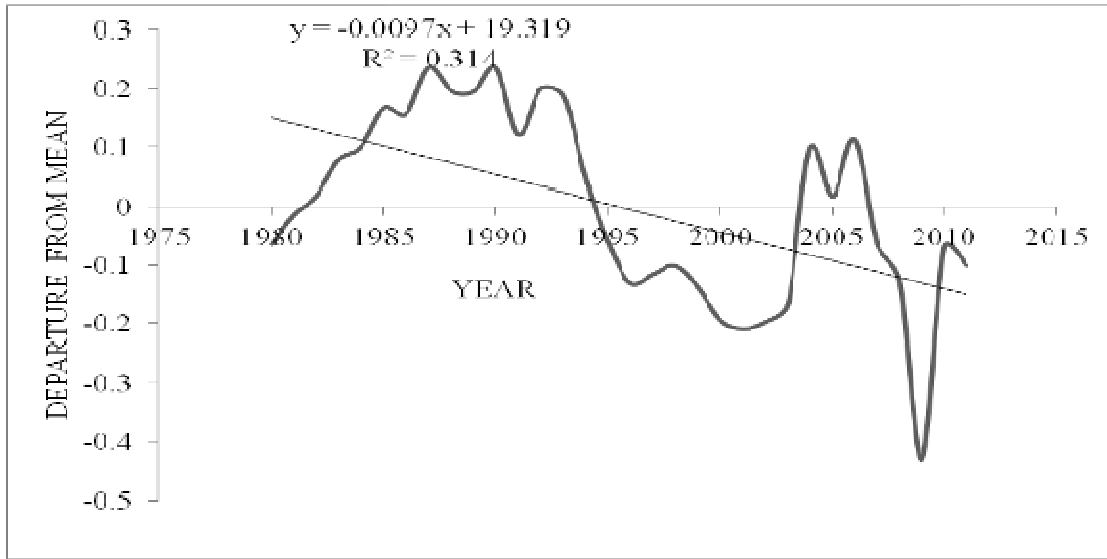


Fig. 4. Trend of cumulative departure of Kithino River

Table 2. River kithino stream discharge \bar{X} , SD and C.V

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	0.87	0.77	0.81	0.87	0.95	0.82	0.82	0.67	0.63	0.79	0.85	0.90
SD	0.25	0.31	0.20	0.19	0.31	0.21	0.32	0.22	0.25	0.27	0.20	0.20
C.V	0.27	0.40	0.25	0.22	0.33	0.26	0.39	0.33	0.40	0.34	0.24	0.22

3.2 Perceived Climate Variability

Majority of the respondents (74.5%) indicated climate variability existed due to presence of prolonged and intense drought. Further, 7.3% suggested it was because of seasonal fluctuation and 6.5% of respondents pointed out that it was as a result of prevalent excessive and intense rainfall. An insignificant proportion (0.4%) indicated presence of excess heat or increased temperature while 11.3% were unresponsive (Fig. 5). Contrary to empirical findings that rains were adequate most respondents associated climate variability to occurrence of drought. Despite evidence of seasonal rainfall variability only a minority reported seasonal fluctuations. These findings were based on the respondent memory. Dependency on rain-fed farming makes deviation of rainfall below or above normal not escapes the minds of the respondents because exposure to drought directly and detrimentally affects their livelihoods. Perceived variability was predominately linked to rainfall anomalies while a meagre proportion of respondents (0.4%) associated it to temperature. Needs of the peoples are often conceived as a form of benchmark when they compare seasonal farm productivity [22]. A good season is associated to

adequate rainfall probably because cropping seasons are defined by presence or absence of rainfall but rarely are temperatures considered. Challenges are important in shaping individuals' perceptions, in terms of seasonality, with previous experiences of poor seasons bringing in memories and being responsible for how farmers may tend to react "perception is a necessary prerequisite for response". This implies that, the community will tend to identify with those interventions towards climate variability that manipulate rainfall. Other studies agree that perceived climate variability influences personal and community values and goals [10].

3.2.1 Response to seasonal rainfall fluctuations

Multiple response strategies were concurrently used within a farm. Five response strategies were employed to cope with unexpected seasonal rainfall fluctuations. These were: Planting 1 – 2 months prior to rain onset under irrigation, crop diversification with adaptable varieties/cultivars, Irrigation, livelihood diversification, change of land use from crop farming (Table 3). Most (82.3%) of the farmers employed more than one coping strategy with

62.9% diversifying crop by use of varieties or cultivars that are more adaptable to moisture stress such as sorghum and dry land maize varieties, dolicus beans, dry beans, pigeon peas, cowpeas, millets and indigenous vegetables. Early planting was another widely used measure based on the rain onset dates since these dates have always been traditionally believed to be 15th March for the first season and 15th October for second season. Respondents (55.3%) planted 1-2 months under irrigation prior to rain on set to cushion against depressed rain. Such that crops were already established at rain set. In absence of irrigation the early planted would enjoy nitrogen flush leading to faster growth, development and more importantly improved yields.

Subjecting the five “unexpected seasonal rainfall fluctuations response strategies” to principle component analysis to narrow them to three; planting 1-2 months prior to rain set date under irrigation, shifting from crop farming and diversification with adaptable crop varieties or cultivars were strongly correlated (Table 4). The proportion of respondents undertaking Irrigation and livelihood diversification in managing the rainfall fluctuations indicated insignificant correlation. Irrigation meant none reliant to rainfed cropping. In the past the priority has been clean drinking water, however, the need to feed the growing population is drumming support for irrigated agriculture. Irrigation requires heavy investment; therefore, limited external support curtails attaining the full potential. Smallholder farming is predominately rainfed and tends to grow annual crops whose production cycle synchronizes with seasonality. These findings imply that, if the diversification occurred to crops only, the households would be more vulnerable to climate variability; but would be less vulnerable if non-agricultural activities are incorporated. It is therefore imperative that these results are only considered on on-farm coping strategies basis and not holistic. Other studies have identified similar coping strategies in Meru County [23,24].

Table 3. Response strategies to seasonal rainfall fluctuations

Strategy	%
Planting 1 – 2 months prior to rain onset	55.3
Crop diversification with adaptable varieties/cultivars	62.9
Irrigation	10.5
Livelihood Diversification	10.5
Change from crop farming	10.5

Source: Field Survey; 2010; (n=273)

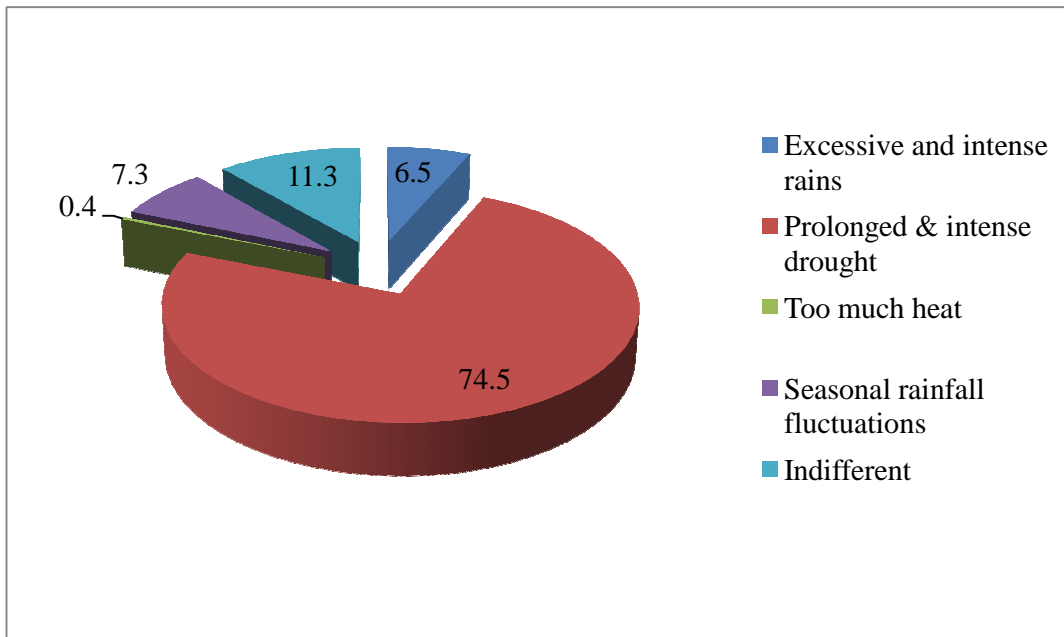


Fig. 5. Perceived climate variability
(Source: field survey, 2010, n=275)

3.2.2 Response to drought

Reduced dependence on agriculture, decreased livestock units, seeking other sources of livelihood and migration to less drought prone areas were the drought coping strategies employed by respondents (Table 5). The two drought coping strategies that scored significantly were decreased dependence on agriculture and migration to less drought prone areas which had a coefficient score of 0.894 and 0.884 respectively. Migration to wetter areas was an option in high drought risk areas; leeward side of Mount Kenya. Information collected during this study suggested that in every 10 years, major droughts occurred once in LH and UM and twice in LM₃ and LM₄ but twice every 5 years in LM₆.

Table 4. Component score matrix for rainfall fluctuations coping strategies

Coping strategies	1	2	3
Planting 1-2 months prior to rain set date	.513	.824	.171
Irrigation	.909	.081	-.026
Change from crop farming	.928	-.049	-.215
Diversify livelihood	.830	-.294	-.352
Crop diversification with adaptable varieties/cultivars	.591	-.350	.723

Table 5. Component score matrix for drought coping strategies

Coping strategies	1	2
Decrease farming/dependence on agriculture	0.354	0.894
Decreased livestock units	0.683	0.066
Migration to less drought prone areas	0.884	0.033
Seeking other sources of livelihood/diversify	0.750	-0.520

3.2.3 Response to intense rainfall

The strategies employed to deal with effects of prolonged intense rainfall were predominately planned in adverse. Majority (94%) of the farms applied soil and water conservation measures to counter runoff (Fig. 5). However, soil and water conservation methods adopted by farmers varied across the Sub-AEZ and depended on the gradient of the farmland. The embankment strength of the structure was proportional to the magnitude of slope for instance in the highlands LH₁ and UM₁: Tea and nappier cover crops, mulch, contour cropping, agro forestry, cut off

drains and terraces were prevalent while in the lowlands LM₄; ridges, trash lines, cover crops and contour cropping were the most preferred. Stone lines were predominant in LM₆, but for those cultivating used trash lines, and grass strips, though the area is a designated grazing zone. Other cultural practices that aided in soil and water conservation across the sub-AEZ included; crop rotation, use of farm yard manure, Intercropping and riverbanks protection. The importance of soil and water conservation in the development of sustainable natural resource and mitigating effects of intense rainfall is crucial as demonstrated in other studies [25,26]. Fifty eight percent of respondents indicated increased crop protection. There has been increased pest and disease damage [1]. Therefore farmers are obliged to protect their crop. Agrochemical related risks demand safe use of pesticides to avoid environmental pollution.

3.2.4 Gender sensitive response strategies

Other findings of this study indicated some coping strategies were preferred by one gender than the other. Though, women and men tended to participate in all strategies a higher proportion of women were involved in self-help groups and small vegetable/fruits business. Seeking casual jobs and improving management on their farms were men preferences (Table 6).

Table 6. Ratio of men to women preferring use of the strategy

Coping strategy	Men :	Women
By seeking additional jobs	3	2
By improved farm management	3	2
By diversification of food sources	1	17
Involve in other income generating activities	1	2
By self help group interventions	1	33
Small vegetable/fruits business	1	40

Source: Field Survey; 2010

Therefore, it implies that any prescriptions geared towards supporting certain strategies would benefit the dominant gender more than the other. For instance development practitioners advocate group approach. Chances are that more women will get empowered through self help groups than men [27,28] Interventions undertaken by men were biased towards raising

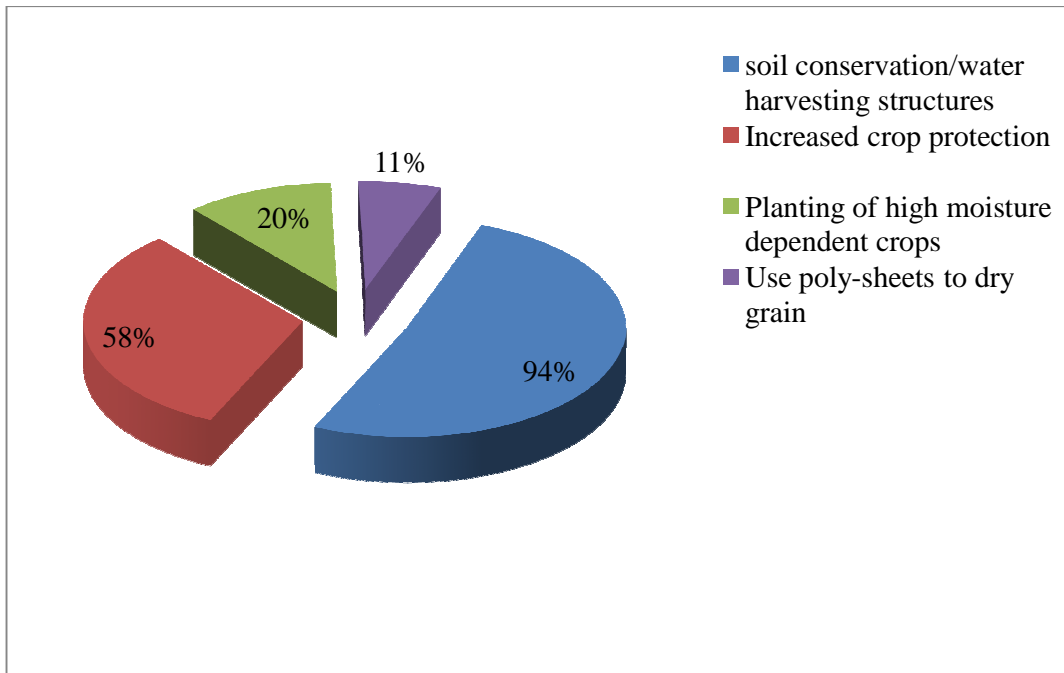


Fig. 6. Strategies to cope with prolonged intense rains

(Source: Field Survey; 2010)

income hence the reason why they preferred strategies that dwelt on seeking additional jobs and improving farm management. On the contrary, women being traditionally home managers preferred those activities that may not demand being away from the home vicinity.

4. CONCLUSIONS

Climatic variability is a reality. Changes in rainfall remain the key indicator of climatic variability among farmers. Variations in climatic parameters were agroecological specific. Perceptions on climate variability are vital in triggering responses and therefore a determinant of what responses a farmer adopts. These perceptions drives farm management decisions and have the potential to influence climate variability and change adaption strategies. There is need for policies geared towards mitigation and adaption to effects of climate variability to consider the perceptions of the target community. Divergence between community perceptions and empirical findings would undermine development of solutions against declining agricultural productivity. Therefore, for enhanced responses to climate variability farmers' perceptions would be integrated with the empirical findings while considering gender issues.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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