Research Article

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Climate change stressors affecting household food security among Kimandi-Wanyaga smallholder farmers in Murang'a County, Kenya

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Abstract: Climate change hazards including droughts and floods are adversely affecting crop productivity and food security among Kenyan smallholder farmers. This article analyzes rainfall and temperature change effects on household food security in Kimandi-Wanyaga, in Murang'a County, Kenya. Both the meteorological and the community perceptions were analyzed. Monthly rainfall and temperature data for Thika Meteorological Station were analyzed for trends using MAKESENS procedure. The community perceptions data obtained through household survey, key informant interviews, and focus group discussions were analyzed using Statistical Package for Social Sciences (SPSS) and content analysis. The study hypotheses were tested using chi-square tests. The community perceived inadequate rainfall during crop growth (79%), reduced rainfall intensity (77%) and erratic onset and cessation of seasonal rainfall (73%) had interrupted their crop productivity. These disagreed with MAKESENS rainfall trends that showed statistically insignificant rainfall variability ($\alpha > 0.1$). The community's warmer temperature perceptions agreed with observed rising maximum temperature trend at 0.001 significance level. This study observed a significant relationship between the community's perceived local rainfall and temperature changes, and household food security. For robust and strategically designed climate policies and programs for food security, governments need to communicate to policy makers the perceptions of smallholder farmers involved in autonomous climate adaptation.

Keywords: smallholder farmers, crop productivity, indigenous perceptions, rainfall variability, warmer temperatures

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1 Introduction

Sustainable agriculture promotes food security under the sustainable development goal 2 of ending hunger, achieving food security, and improving nutrition [1]. Food security exists when "all people, at all times, have physical, social and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences and is supported by an environment of adequate sanitation, health services and care, allowing for a healthy and active life" [2]. Our diets and nutrition are founded on agriculture. Thus, food production and good nutrition can enhance environmental sustainability, economic development, equity, and inclusion and reduce the burden on health systems [2]. Climate change impacts augment food security risks and threaten to erode the gains made against malnutrition and hunger among the most vulnerable nations and communities [3]. The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes" [4]. Recent studies note that global rising temperatures will lower yields of major crops by 3–13% without accounting for adaptations and CO_2 fertilization [5].

Africa's agriculture and livelihoods are heavily climate dependent with over 95% of Sub-Saharan Africa's

(SSA) total cropland being rain-fed [6,7] and over 60% of the population working in the agricultural sector [8]. In SSA, agriculture contributes approximately 23% of the GDP [9]. About 80% of Africa's agriculture is small scale [10]. Africa risks the 21st-century pervasive disturbances and threats of extreme events because of overdependence on rural livelihoods and climate-sensitive natural resources [11–13], limited economic and institutional adaptive capacity [14], low GDP, and absence of safety nets [15,16]. Food security is particularly susceptible to climate change because crop production relies on relatively predictable year to year temperatures, timing, and amount of rainfall, particularly at critical crop development stages [17]. In SSA, an estimated agricultural loss of 2–7% GDP is predicted by 2100 [18]. In East Africa, the expected widespread rainfall increase is unlikely to improve agricultural productivity due to its spatial-temporal variations [19].

Kenya's climate is mainly driven by the Inter-Tropical Convergence Zone (ITCZ), a broad low-pressure zone, caused by intersection of northeast and southeast trade winds of the two hemispheres [20–22]. Significant spatial-temporal rainfall variations mainly emanate from topography complexity and the presence of many lakes [23–25]. The temperature regime is equatorial characterized by minimal average monthly and annual temperatures closely correlated with altitude. Most areas experience above 0°C and daily temperature variations between 9 and 13°C [26,27]. The economy heavily depends on rain-fed agriculture [28]. Drought cycles in Kenya have shortened [29], resulting in severe food security challenges that render majority of Kenyans unable to access the right food quality and quantity. The Kenya Food Security Steering Group (KFSSG) and Murang'a County Integrated Development Profile [30] note that many Kenyan households are net food consumers while others spend most of their income on food purchase [30,31].

Murang'a County in Kenya faces climate change impacts manifested in frequent droughts, floods, and drying waterways that deteriorate agricultural production and worsen communities' food insecurity. Climate disasters slow down the County's economic development as limited resources are diverted to disaster response and recovery programs. Without adaptation, the situation is bound to worsen vis-à-vis climate change [30,32]. A range of climate studies has been carried out in the County, and much of it focused on County-level climate and landslide occurrence [33], rainfall distribution and crop growing seasons [34], potential evaporation estimation [35], and rainfall variability determination [32]. Given that climate change impacts in developing countries are locally specific and highly uncertain [36], there remains a dearth of knowledge in Murang'a County focused directly on climate stressors and their implications on household-level food security. This study aimed to address the knowledge gap by eliciting an in-depth household-level understanding and scientific evidence of rainfall and temperature variations and their implications on food crop production and food security among smallholder farmers in the County. By understanding, planning for, and adapting to climate change, households can minimize risks from climate-related stresses [37].

This study worked with Kimandi-Wanyaga community in Ndakaini location, Gatanga sub-County in Murang'a County. Residents are predominantly small-scale subsistence rain-fed farmers mainly growing tea under prevailing socio-economic challenges of a soaring population, shrinking land resources, limited livelihood opportunities, and rising food insecurity. They practice minimal food crop production and most of their tea income goes to food purchases. Unpredictable weather patterns also affect their crop productivity, and despite historical coping efforts, the vulnerability of the majority of the smallholder farmers to crop production constraints persists [30,38]. The intersection of prevailing challenges and a changing climate could push the smallholder farmers beyond their coping limits. Rainfall and temperature were the independent variables, and food security indicators were the dependent variables. The food security indicators were as follows: the number of meals that households consumed daily, the number of months in a year households ate own produced foods, the household's meal variety, and the household's meal sizes. The research adopted the following research questions: What are the observed rainfall and temperature trends during the period 1984–2014 in Kimandi-Wanyaga in Murang'a County, Kenya? What are the community's perceived rainfall and temperature changes? What is the relationship between the community's perceived rainfall and temperature changes and their food security during the period 1984–2014? The main aim of the study is to analyze climate stressors, specifically rainfall and temperature, affecting food security among the Kimandi-Wanyaga community in Murang'a County in Kenya. The study's specific objectives are to analyze the observed rainfall and temperature trends for the period 1984–2014; the community's perceived rainfall and temperature changes; and the relationship between perceived rainfall and temperature changes on the community's food security during the period 1984–2014. To achieve the first objective, observed rainfall and temperature data were analyzed using the MAKESENS procedure. To achieve the second and third objectives, the study tested two hypotheses: (1) HO_1: There is no significant relationship between perceived rainfall changes and the household food security among the Kimandi-Wanyaga community in Murang'a County, Kenya. (2) HO_2: There is no significant relationship between perceived temperature change and the household food security among Kimandi-Wanyaga community in Murang'a County, Kenya. The findings would raise awareness on climate change reality and its impacts on food security among the most vulnerable and provide recommendations for policy-makers on climate change adaptation for food security.

2 Methods

2.1 Study area

The community occupies Kimandi-Wanyaga sub-location, Ndakaini location, Kariara Ward, Gatanga sub-County in Murang'a County covering approximately 9.169 km^2 (Figure 1). The total population is 3,479 people, 943

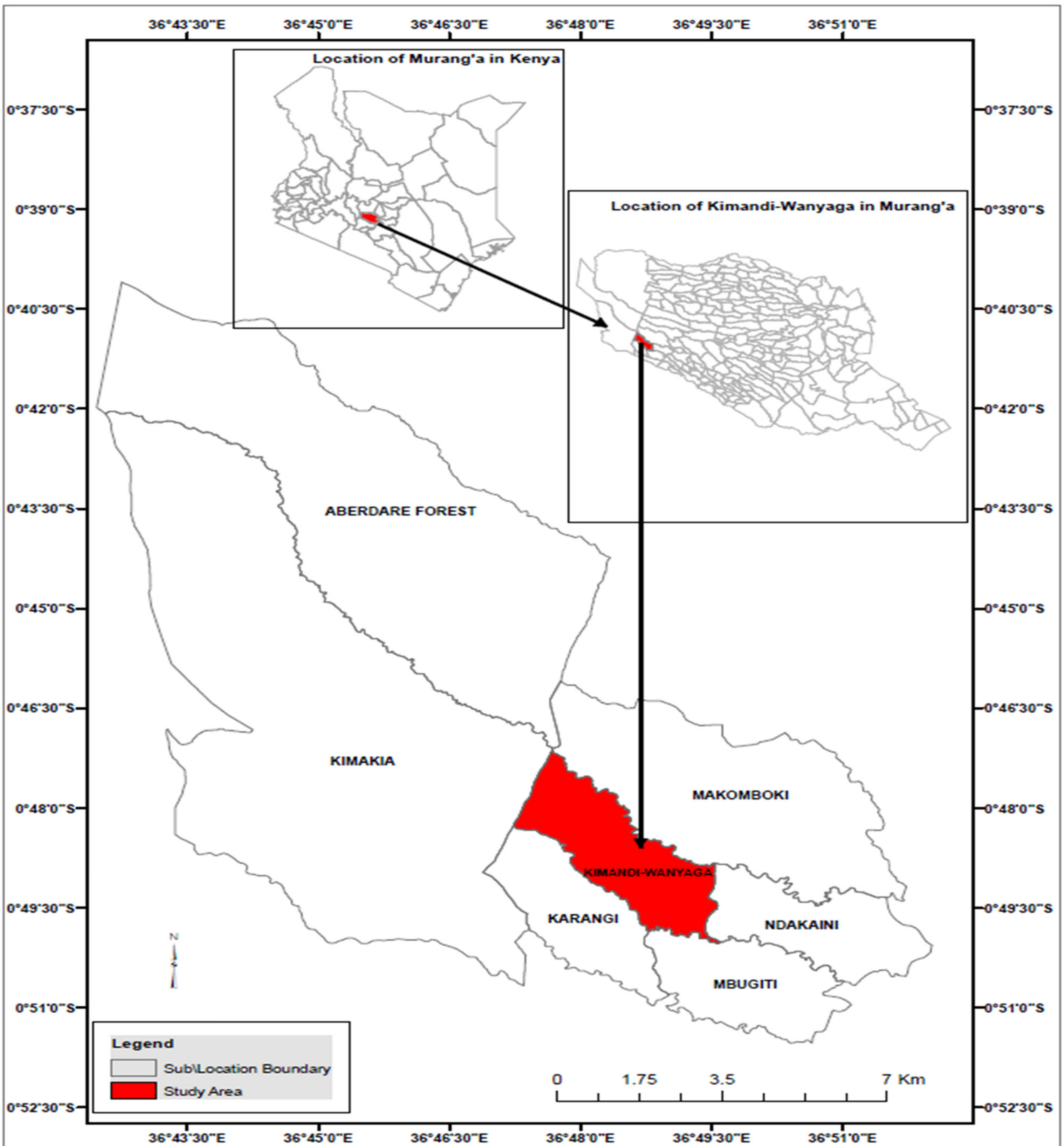

Figure 1: Location map of the study area in Murang'a County, Kenya.

households with a population density of 379 persons per km^2 [39]. It lies at 2,040 m above sea level within lower highland (LH_1) agro-ecological zone (also called Tea-Dairy Zone) characterized by permanent cropping possibilities dividable in a long to very long cropping season followed by a medium one. Proximity to Mt. Aberdares and Mt. Kenya makes the climate generally wet and humid, hence suitable for tea and dairy farming. Mean annual temperatures range from 15 to 18°C with an annual average rainfall of 1,700–2,400 mm. Rainfall distribution is bimodal with long rains falling in March to May (MAM) and short rains from November to early January. April rainfall is highest in amount and reliability [38].

Residents are predominantly smallholder rain-fed farmers. The average household farm size is 1.4 acres. Over 95% of arable land is under tea. Common food crops grown include maize, beans, Irish potatoes, sweet potatoes, cabbages, kales, and avocadoes, which are grown near homesteads and along river valleys. Most farm produce is consumed at home. Livestock reared include cows, goats, chicken, rabbits, and a few sheep [30].

Over 35% of the landscape is steep with fragile soils susceptible to soil erosion and landslides. The volcanic rock system has disconformities and porous beds, which collect and move ground water and regulate water supply from wells and boreholes [38]. Perennial rivers in the area are Kayuyu, Thika, Githika, and Gitabiki draining into Ndakaini Dam. Approximately 60% of the population have piped water, while 40% rely on river and rain water harvesting. The use of tap water for irrigation is prohibited. Currently, the area experiences erratic weather patterns resulting in river flow recession, low crop yields, total crop failure, and food insecurity. The steep relief and fragile soils expose the area to flush floods, soil erosion, environmental degradation, landslides, river and dam siltation, and water eutrophication. Landslides cause human and livestock mortalities and loss of crops and farming land [30].

2.2 Sampling procedure and sample size determination

The study adopted a mixed methods research design. The study population comprised 943 Kimandi-Wanyaga sublocation smallholder subsistence households [39]. The Yamane formula at 95% confidence level [40] was used to derive the household survey sample of 281 households.

Taro Yamane formula:

$$n = \frac{N}{1 + N(e)^2}, \tag{1}$$

where n = sample size, N = number of households in the population, and e = allowable error (%).

Substituting numbers to the formula:

$$n = \frac{943}{1 + 943(0.05)^2},$$
$$n = 280.8637.$$

Rounded off to **281** households.

Sampled households were selected through the systematic sampling method [41]. A probability inclusion range (sampling fraction) was expressed as $= \frac{n}{N}$, where n is the sample size and N is the population size, which was determined as follows:

$$= \frac{281}{943} = 1/3.$$

Thus, one in every three households took part in the study. Respondents were household heads whether male or female. The question on diet diversity was only answered by the person in charge of household meal preparation the previous day. Key informants (KIs) were purposively selected based on knowledge required to meet study objectives.

2.3 Data collection method

Primary data were collected between September and December 2015. Monthly rainfall data (1961–2016) and temperature data (1988–2016) for Thika Meteorological Station were sourced from the Kenya Meteorological Department (KMD) Nairobi. Community perceptions data were collected using semistructured questionnaires in a household survey, KI interviews, and focus group discussions (FGDs). A household was used as the unit of analysis and defined as "a group of people living in the same compound consisting of enclosed set of buildings, eating from the same pot and recognizing one head of household, usually a husband and father or guardian" [39]. Factors underlying the community's food insecurity were based on a number of food security indicators such as number of meals consumed daily, length of time households consumed own produced foods, and diet quality. Diet quality was measured through a Household Dietary Diversity Score (HDDS) [42] to get a snapshot reflection of the households' economic ability to access different foods. A 24 h recall period was used to count the total food groups that a household had consumed in the preceding 24 h. A household dietary diversity questionnaire was adapted to Kimandi-Wanyaga context by having a government nutrition officer and some local women categorize the food group list, translate it into locally available foods, and recognize names for meal, snack, and household. Information gathered included all foods consumed by the household members the previous day and night and all ingredients used in preparing the foods.

2.4 Data analysis

Monthly rainfall data (1961–2016) and temperature data (1988–2016) for Thika Meteorological Station primary data were collected between 2015 and 2017. Meteorological data from local volunteer weather stations were found to contain long periods of missing data and hence considered insufficient for robust conclusions. Therefore, the study used monthly data available at Thika Meteorological Station whose rainfall data (1961–2016) had no missing values. However, the station's only available monthly minimum temperature data were for 29 years (1988–2016), while the monthly maximum temperature data were for the period 1980–2016 with two year's missing data (1997 and 1998). The data were analyzed as they were using Mann–Kendall and Sen's slope analyses commonly referred to as the MAKESENS procedure [43]. The MAKESENS procedure is based on the nonparametric Mann–Kendall test for detecting trends, and the nonparametric Sen's slope estimator, for estimating magnitude of the trends. The Mann–Kendall test detects the presence of decreasing or increasing monotonic trends of annual time series with no seasonal or other cycle, while Sen's method estimates a linear slope for the trends. MAKESENS was mainly developed to detect and estimate trends, in time series of annual values of atmospheric and precipitation concentrations. The approach has been applied in various studies to measure rainfall and temperature trends [44–48]. In this study, MAKESENS approach was found appropriate for the trend analysis because data do not require to conform to particular distribution, it allows for missing data, and the Sen's method is not highly sensitive to outliers or single data errors. The two-tailed test in the MAKESENS analysis is specifically employed at four significance levels symbolized as follows:

*** If trend at $\alpha = 0.001$ level of significance.
** If trend at $\alpha = 0.01$ level of significance.
* If trend at $\alpha = 0.05$ level of significance.
+ If trend at $\alpha = 0.1$ level of significance.
If blank cell, $\alpha > 0.1$ level of significance.
Therefore:

A trend at $\alpha = 0.001$ significance level indicates a high probability of existence of a monotonic trend.

A trend at $\alpha = 0.1$ significance level indicates the data values are from a random distribution with a 10% probability risk of rejecting the hypothesis of no trend.

The Z statistic is assumed to have a normal distribution and is used to evaluate the presence of a statistically significant trend, where:

A positive value stipulates an upward trend.

A negative value stipulates a downward trend.

2.4.1 Mann–Kendall test

For number of data values exceeding 10, the normal approximation test is used.

$$\begin{aligned}\text{Mann–Kendall statistic}\\ &= \text{Number of positive differences}\\ &\quad - \text{Number of negative differences}.\end{aligned} \tag{2}$$

S variance is calculated using the following equation accounting for any ties present:

$$\text{Variance of Mann–Kendall statistic} = \frac{\text{Average of squared differences}}{\text{Count of data values}}. \tag{3}$$

The test statistic Z is computed using the values of statistic and variance of statistic as follows:

$$\text{Test statistic } Z = \frac{\text{Statistic} - 1}{\text{Square root of variance}}, \quad \text{if statistic is greater than } 0. \tag{4}$$

$$\text{Test statistic } Z = 0, \quad \text{if statistic is equal to } 0. \tag{5}$$

$$\text{Test statistic } Z = \frac{\text{Statistic} + 1}{\text{Square root of variance}}, \quad \text{if statistic is less than } 0. \tag{6}$$

2.4.2 Sen's method

Sen's method estimates the true slope of an existing trend (annual change) assumed to be linear and fitting the equation:

$$\text{True slope} = \text{Slope estimate} + \text{constant}. \tag{7}$$

To get the slope estimate, the data value sets of all slopes are calculated, where:

$$\text{Slope estimate} = \frac{\text{Difference of data values between years}}{\text{Difference between years}}. \tag{8}$$

The median of the number of time periods (between the years) is Sen's estimator of slope.

The number of slope estimates = number of time periods + (number of time periods less 1 divided by 2).

If there are multiple observations in one or more time periods, then number of slope estimates is less than number of observations + (number of observations less 1 divided by 2).

The median of the number of slope estimates is obtained by ranking from smallest to largest as follows:

Slope estimate 1 ≤ slope estimate 2 ≤ slope estimate 3

$$\text{Sen's estimator} = \text{Median slope} \tag{9}$$

= Median of slope estimates if number of slope estimates is odd
= Average of the two middle slope estimates if number of slope estimates is even

The quantitative data obtained from the household survey were analyzed through descriptive statistics using the Statistical Package for Social Sciences (SPSS). The study hypotheses were analyzed using chi-square tests and cross tabulation between different parameters of rainfall and the households' food security indicators. The community's perceived rainfall change parameters were the frequency of drought, adequacy of rainfall during crop growing season, rainfall intensity, and the rainfall season onset and cessation. The temperature parameters were an increase, a decrease, or remained the same. The household food security indicators were as follows: the number of meals consumed daily, length of time households consumed own produced foods, diet quality/variety, and the food rations. The significance of the relationships was assessed using the probability values (where the critical p value was 0.05) associated with the computed chi-square statistics. An associated p value of less than 0.05 led to the rejection of the null hypothesis and vice versa. The findings were presented in tables. Qualitative data were analyzed using the content analysis and presented in direct quote formats.

3 Results

3.1 Characteristics of the survey population

Results of the study (Table 1) show that majority of household heads (76.2%) were male, middle-aged (57.3%), and had attained secondary level education (52.7%). Majority of the farmers (95.3%) owned less than 4.5 acres of land, and most of the arable land was under tea crop (67.34%).

Table 1: Characteristics of the survey population

Characteristic		Percentage
Age (years)	<25	0.4
	25–35	12.1
	36–45	27.8
	46–55	29.5
	56–65	16.4
	66–75	7.8
	76–85	3.9
	>85	2.5
Gender	Male	76.2
	Female	23.8
Formal education level	None	8.9
	Primary	28.8
	Secondary	52.7
	College/University	9.5
Household farm acreage	0–0.5	6.0
	0.51–1.0	19.6
	1.01–1.5	17.8
	1.51–2.0	16.0
	2.01–2.5	16.0
	2.51–3.0	10.3
	3.01–3.5	2.5
	3.51–4.0	5.0
	4.01–4.5	2.1
	4.51–5.0	2.1
	5.01–5.5	1.1
	>5.51	1.4
Household arable farm uses	Tea crop	67.34
	Food crops	20.59
Household head occupation	Farming only	83.3
	Farming and informal employment	8.9
	Farming and formal employment	7.8

3.2 The factors underlying the household's food insecurity

Multiple responses from the household survey indicated that within the year 2013, 62% of respondents had gone hungry, 68% had run out of money to buy food, while 71% had cut the sizes of their meals. About 74% of respondents had skipped a meal, while 76% had reduced the variety of foods eaten. One FGD participant added that:

"Rainfall in this area has changed and it has reduced our crop yields especially maize. This has brought food shortage. In the past, we used to harvest enough maize to store for the whole year. Every home had a granary for storing maize. We dried the maize in the sun and stored it for making *Githeri* (boiled maize and beans) and porridge. We used to cook a lot of foods and store it in the granaries. The granaries were not locked so that all family members and visitors would be able to serve themselves food freely. We shared our food freely because we had a lot of food. We also had many celebrations in a year especially after harvesting our crops. Now we don't have granaries because we have little food to store. We don't have enough to food to keep until the next harvest and we buy most of our foods from the local markets, Thika town or from Nyandarua County. Most of the money we get from tea is used to buy food and pay school fees. Families with small farms don't have enough money to buy food and spend on other things and sometimes they go hungry. They have to work on other people's farms to earn money."

Regarding the length of time households consumed own produced foods, 40.2% of respondents indicated 2 months, 38.8% indicated 1 month, 20.6% indicated 3 months, and 0.4% indicated 6 months. One KI noted that:

"Most of us here do not harvest enough food to use until the next harvest. Families with enough money usually buy food like as Irish potatoes, green peas, cabbages, tomatoes and carrots from our neighboring Counties."

The households' daily food consumption results showed that 71.5% consumed two meals, 27.1% consumed three meals, 9.2% consumed one meal, and 1.4% consumed four meals. The study findings on the qualitative measure of the households' access to various foods analyzed using the HDDS method are presented in Tables 2 and 3.

The results in Table 2 indicate that within the 24 h reference period, more than half of the households had consumed cereals (82.6%), sugar and honey (67.3%), oils and fats (65.5%), vegetables (60.5%), roots and tubers (58.7%), and legumes and nuts (55.5%). The food groups least consumed by the households were fruits (31%), meat and poultry (30.6%), and eggs (23.5%). The average HDDS observed among the study community (Table 3) was about 4.0036.

Table 3: Household dietary diversity score (HDDS)

	N	Minimum	Maximum	Mean	Std. deviation
HDDS	281	2	7	4.0036	1.11323

One KI also asserted that:

"The common foods we eat here are *Githeri* (a mixture of boiled maize [*Zea mays*] and beans [*Phaseolus vulgaris*]) fried with cabbages (*Brassica oleracea*), Irish potatoes (*Solanum tuberosum*) or mashed with pumpkin (*Cucurbita moschata*) leaves, *Ugali* (maize flour cooked with boiled water to a dough-like consistency) eaten with *Sukuma wiki* (*Brassica oleracea* var. *viridis*) or cabbages (*Brassica oleracea*). We also commonly eat rice (*Oryza sativa*), beans (*Phaseolus vulgaris*), arrowroots (*Xanthosoma sagittifolium*), sweet potatoes (*Ipomea batata*) and eggs. Here we don't commonly eat meat and chicken because they are very expensive."

3.3 The rainfall trend analysis during the period 1984–2014

Station-based rainfall data for Thika Meteorological Station (1961–2016) were analyzed using the MAKESENS procedure to detect seasonal and annual rainfall trends

Table 2: Percent of households consuming each food group within the reference 24 h period

Food categories	No		Yes		Total	
	Count	Percent	Count	Percent	Count	Percent
Cereals	49	17.4	232	82.6	281	100.0
Fish	264	94.0	17	6.0	281	100.0
Root and tubers	116	41.3	165	58.7	281	100.0
Legumes/nuts	125	44.5	156	55.5	281	100.0
Vegetables	111	39.5	170	60.5	281	100.0
Milk and milk products	158	56.2	123	43.8	281	100.0
Fruits	194	69.0	87	31.0	281	100.0
Oil/fats	97	34.5	184	65.5	281	100.0
Meat/poultry	195	69.4	86	30.6	281	100.0
Sugar/honey	92	32.7	189	67.3	281	100.0
Eggs	215	76.5	66	23.5	281	100.0
Miscellaneous food items	133	47.3	148	52.7	281	100.0

Table 4: The annual and seasonal rainfall trends

	Annual rainfall				MAM rainfall				OND rainfall			
N	Test *Z*	Sig.	*Q*	% change	Test *Z*	Sig.	*Q*	% change	Test *Z*	Sig.	*Q*	% change
56	0.01		0.063	0.37334	−0.37		−0.747	−9.4188	1.1		1.195	18.8865

N: the number of annual values in the calculation excluding missing values. Test *Z*: the test statistic *Z*. Sig: if blank cell, α > 0.1 level of significance. *Q*: Sen's estimator for the true slope of linear trend (change per unit time). % change: calculated as: ((Sen's slope × length of period)/mean) × 100.

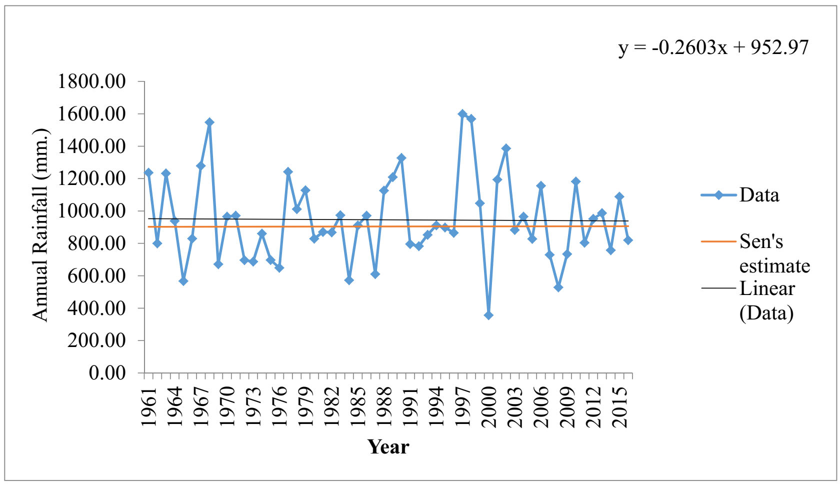

Figure 2: The annual rainfall trend.

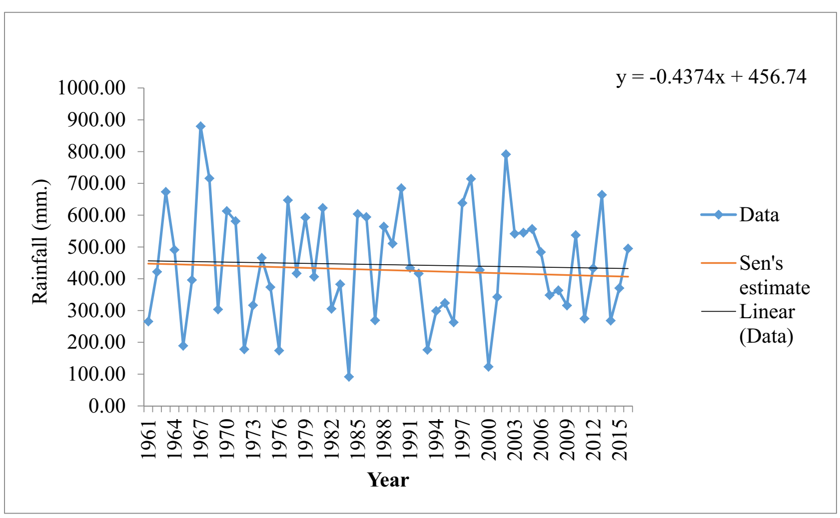

Figure 3: Long season (March–May) rainfall trend.

in the study area. The results are stipulated in Table 4 and Figures 2–4.

Results of the seasonal rainfall trend (Table 4) indicate that the long season rainfall of MAM had decreased by 9.4188% at a magnitude of –0.747 and the short season rainfall of October to December (OND) had increased by 18.8865% at a magnitude of 1.195. Annual rainfall shows an increase of 0.37335% at a magnitude of 0.063. However, the significance level was greater than 0.1, indicating a higher than 10% probability risk of rejecting

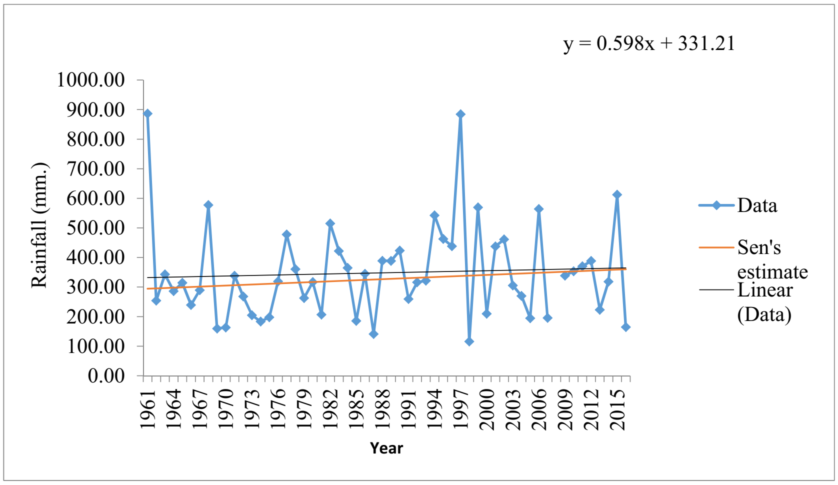

Figure 4: Short season (October–December) rainfall trend.

Table 5: The monthly maximum and minimum temperature trends

T_{MIN}					T_{MAX}				
N	**Test *Z***	**Sig.**	***Q***	**% change**	***N***	**Test *Z***	**Sig.**	***Q***	**% change**
29	1.44		0.016	4.011	35	3.82	***	0.040	9.745

N: the number of annual values in the calculation excluding missing values. Test *Z*: the test statistic *Z*. Sig: *** if trend at $\alpha = 0.001$ level of significance. *Q*: Sen's estimator for the true slope of linear trend (change per unit time). % change: calculated as: ((Sen's slope × length of period)/mean) × 100.

the H_0 hypothesis of no trend. Therefore, the annual and seasonal rainfall trends in the study area during the study period 1984–2014 were not statistically significant ($\alpha > 0.1$) as also illustrated in Figures 2–4. The study area is characterized by the bimodal rainfall pattern of long rains (MAM) and short rains (OND), which drive crop production cycles. Despite the statistically insignificant annual and seasonal rainfall trends, the study does not presume that rainfall did not vary during the un-analyzed June–July–August (JJA) season.

3.4 Temperature trend analysis during the period 1984–2014

The maximum monthly temperature (1980–2016) and minimum monthly temperature (1988–2016) data for Thika Meteorological Station were analyzed for trends using the MAKESENS procedure. The results are illustrated in Table 5 and Figures 5 and 6.

The MAKESENS trend analysis results (Table 5) showed that the monthly minimum temperature had increased by 4.011% at a magnitude of 0.016, a trend that was statistically insignificant ($\alpha > 0.1$). The monthly maximum temperature trend showed an increasing change of 9.745% at a magnitude of 0.04%, a trend that was statistically significant (*** if trend at $\alpha = 0.001$ significance level). This implied that the study area had significantly warmed during the period 1984–2014.

3.5 The perceived rainfall changes (1984–2014)

Approximately 91% of the study respondents reported that they had observed changes in local rainfall and 72.2% reported an increase in drought frequency during the period 1984–2014. The majority of respondents (72.2%) also reported rise in drought frequency. One KI reiterated that:

> "Here in this area, rains have reduced and we have been staying for long periods of time without rains compared to what used to happen long ago. This has made our animals to lack food. Our tea and crop harvests have also gone down."

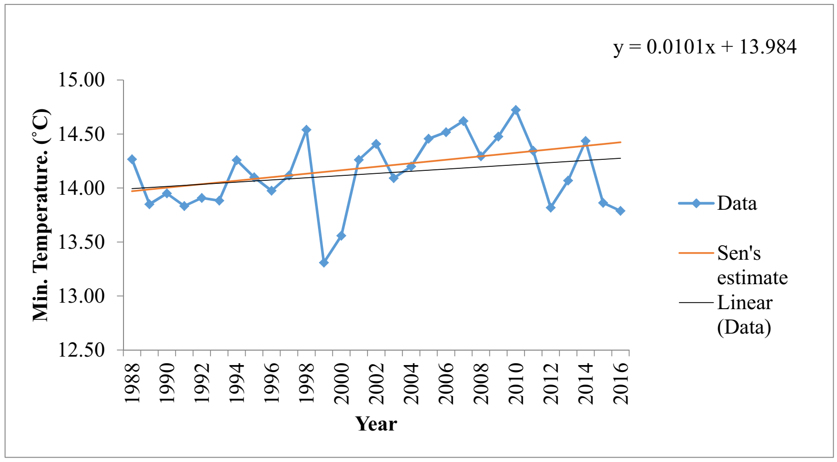

Figure 5: Monthly minimum temperature trend.

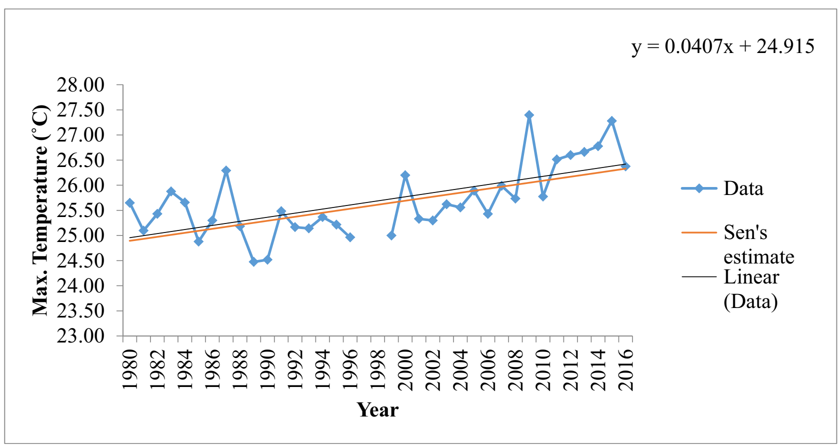

Figure 6: Monthly maximum temperature trend.

About 75.3% of the study respondents also reported a decrease in floods frequency. One FGD participant added that:

> "Here we don't get floods because our land has many hills. When it rains heavily, our farms which area near the rivers get flooded and this covers our crops such as vegetables and arrowroots (*Xanthosoma sagittifolium*)."

Approximately 79.4% of the study respondents indicated that they had noted a decrease in adequacy of rainfall during crop growing seasons, while about 77.2% of the respondents perceived reduction in rainfall intensity. The FGDs participants noted that sometimes the rains were heavy, while other times they were very light and below crops needs. One KI added that:

> "In the past, rainfall used to be plentiful and predictable such that we knew when to dig our farms and when to plant our crops. Nowadays, we are not sure when it will rain. If we plant crops at the beginning of rains, most of the rains fall quickly and end quickly making the days we have rains to be few compared to what used happen a long time ago. Sometimes the rains stop when crops are still growing making our crops to give low harvests. Sometimes all our crops dry up due to lack of rains."

3.6 The perceived impacts of rainfall changes on the households' food security

The following null hypothesis was tested:

> *HO_1: There is no significant relationship between the perceived rainfall changes and the household food security among Kimandi-Wanyaga community in Murang'a County, Kenya.*

Table 6: Cross-tabulation analysis between the perceived changes in drought frequency and the household's food security

Frequency of drought	Number of meals households consumed daily					
	Two n (%)	Three n (%)	Four n (%)	Total n (%)	χ^2	*p*-value
No change	42 (67.70)	20 (32.30)	0 (0.00)	62 (22.06)	73.807[a]	0.000
Decreased	5 (31.20)	7 (43.80)	4 (25.00)	16 (5.69)		
Increased	155 (76.40)	48 (23.60)	0 (0.00)	203 (72.24)		
Total	202 (71.90)	75 (26.70)	4 (1.40)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.23.

Frequency of drought	Number of months in a year household ate own-produced foods						
	1 month n (%)	2 months n (%)	3 months n (%)	6 months n (%)	Total n (%)	χ^2	*p*-value
No change	12 (19.40)	30 (48.40)	20 (32.30)	0 (0.00)	62 (22.06)	53.951[a]	0.000
Decreased	2 (12.50)	3 (18.80)	10 (62.50)	1 (6.20)	16 (5.69)		
Increased	95 (46.80)	80 (39.40)	28 (13.80)	0 (0.00)	203 (72.24)		
Total	109 (38.80)	113 (40.20)	58 (20.60)	1 (0.40)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.06.

Frequency of drought	Households reduced meal variety because food was not enough				
	Yes n (%)	No n (%)	Total n (%)	χ^2	*p*-value
No change	38 (61.30)	24 (38.70)	62 (22.06)	31.411[a]	0.000
Decreased	5 (31.20)	11 (68.80)	16 (5.69)		
Increased	170 (83.70)	33 (16.30)	203 (72.24)		
Total	213 (75.80)	68 (24.20)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 4.87.

Frequency of drought	Cut the size of meals in the past year (2014) because food was not enough				
	Yes n (%)	No n (%)	Total n (%)	χ^2	*p*-value
No change	26 (41.90)	36 (58.10)	62 (22.06)	53.333[a]	0.000
Decreased	4 (25.00)	12 (75.00)	16 (5.69)		
Increased	167 (82.30)	36 (17.70)	203 (72.24)		
Total	197 (70.10)	84 (29.90)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.78.

The results of a chi-square test on the relationship between the perceived changes in drought frequency and the households' food security are presented in Table 6.

The computed *p*-value of 0.000 (Table 6) was less than 0.05, an indication that the drought frequency was significantly related with the number of meals households consumed daily ($\chi^2 = 73.807^a$, $p = 0.000$), the length of time households consumed own-produced foods ($\chi^2 = 53.951^a$, $p = 0.000$), the households' meal variety ($\chi^2 = 31.411^a$, $p = 0.000$), and the households' food rations in the year 2014 ($\chi^2 = 53.333^a$, $p = 0.000$). The results implied that increased drought frequency had reduced the number of households' daily meals, the length of time households consumed own-produced foods, and the households' meal variety and rations.

The study results of the cross-tabulation analysis between rainfall adequacy during the crops growing season and the household's food security are presented in Table 7.

From the study results (Table 7), rainfall adequacy during crop growing season was significantly related to the number of meals households consumed daily ($\chi^2 = 43.265^a$, $p = 0.000$), the number of months in a year that households consumed own-produced foods ($\chi^2 = 29.430^a$,

Table 7: Cross-tabulation analysis between the perceived changes in the rainfall adequacy during the crops growing season and the household's food security

Rainfall adequacy during crop growing season	Number of meals households consumed daily					
	Two n (%)	Three n (%)	Four n (%)	Total n (%)	χ^2	p-value
Decreased	172 (77.10)	51 (22.90)	0 (0.00)	223 (79.36)	43.265[a]	0.000
No change	10 (58.80)	7 (41.20)	0 (0.00)	17 (6.05)		
Increased	7 (35.00)	10 (50.00)	3 (15.00)	20 (7.12)		
Undecided	13 (61.90)	7 (33.30)	1 (4.80)	21 (7.47)		
Total	202 (71.90)	75 (26.70)	4 (1.40)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.30.

Rainfall adequacy during crop growing season	Number of months in a year that households consumed own-produced foods						
	1 month n (%)	2 months n (%)	3 months n (%)	6 months n (%)	Total n (%)	χ^2	p-value
Decreased	96 (43.00)	88 (39.50)	39 (17.50)	0 (0.00)	223 (79.36)	29.430[a]	0.001
No change	6 (35.30)	8 (47.10)	3 (17.60)	0 (0.00)	17 (6.05)		
Increased	1 (5.00)	10 (50.00)	8 (40.00)	1 (5.00)	20 (7.12)		
Undecided	6 (28.60)	7 (33.30)	8 (38.10)	0 (0.00)	21 (7.47)		
Total	109 (38.80)	113 (40.20)	58 (20.60)	1 (0.40)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.47.

Rainfall adequacy during crop growing season	Ate a smaller variety of foods than usual because food was not enough				
	Yes n (%)	No n (%)	Total n (%)	χ^2	p-value
Decreased	184 (82.50)	39 (17.50)	223 (79.36)	31.045[a]	0.000
No change	11 (64.70)	6 (35.30)	17 (6.05)		
Increased	7 (35.00)	13 (65.00)	20 (7.12)		
Undecided	11 (52.40)	10 (47.60)	21 (7.47)		
Total	213 (75.80)	68 (24.20)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.11.

Rainfall adequacy during crop growing season	Cut the size of meals in the past year (2014) because food was not enough				
	Yes n (%)	No n (%)	Total n (%)	χ^2	p-value
Decreased	181 (81.20)	42 (18.80)	223 (79.36)	75.860[a]	0.000
No change	9 (52.90)	8 (47.10)	17 (6.05)		
Increased	0 (0.00)	20 (100.0)	20 (7.12)		
Undecided	7 (33.30)	14 (66.70)	21 (7.47)		
Total	197 (70.10)	84 (29.90)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.08.

$p = 0.000$), the variety of households' meals ($\chi^2 = 31.045^a$, $p = 0.000$), and the size of meals households consumed in the year 2014 ($\chi^2 = 75.860^a$, $p = 0.000$). Therefore, the rainfall adequacy during crops growing season was associated with the number of meals households consumed daily, the period of time households consumed own-produced foods, and the households' diet variety and rations.

The results of the cross-tabulation analysis of rainfall intensity and household food security are provided in Table 8.

The results of this study (Table 8) indicated a significant relationship between the rainfall intensity and the number of meals that the households consumed daily ($\chi^2 = 69.170^a$, $p = 0.000$), the period of time the

Table 8: Cross-tabulation analysis between the perceived rainfall intensity and the household's food security

Rainfall intensity	Number of meals households consumed daily					
	Two n (%)	Three n (%)	Four n (%)	Total n (%)	χ^2	p-value
Decreased	172 (79.30)	45 (20.70)	0 (0.00)	217 (77.23)	69.170[a]	0.000
No change	8 (50.00)	8 (50.00)	0 (0.00)	16 (5.69)		
Increased	6 (22.20)	17 (63.00)	4 (14.80)	27 (9.61)		
Undecided	16 (76.20)	5 (23.80)	0 (0.00)	21 (7.47)		
Total	202 (71.90)	75 (26.70)	4 (1.40)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 4.23.

Rainfall intensity	Number of months in a year that households consumed own-produced foods						
	1 month n (%)	2 months n (%)	3 months n (%)	6 months n (%)	Total n (%)	χ^2	p-value
Decreased	99 (45.60)	85 (39.20)	33 (15.20)	0 (0.00)	217 (77.23)	44.119[a]	0.000
No change	5 (31.20)	7 (43.80)	4 (25.00)	0 (0.00)	16 (5.69)		
Increased	2 (7.40)	9 (33.30)	15 (55.60)	1 (3.70)	27 (9.61)		
Undecided	3 (14.30)	12 (57.10)	6 (28.60)	0 (0.00)	21 (7.47)		
Total	109 (38.80)	113 (40.20)	58 (20.60)	1 (0.40)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.06.

Rainfall intensity	Ate a smaller variety of foods than usual because food was not enough				
	Yes n (%)	No n (%)	Total n (%)	χ^2	p-value
Decreased	178 (82.00)	39 (18.00)	217 (77.23)	22.555[a]	0.000
No change	11 (68.80)	5 (31.20)	16 (5.69)		
Increased	14 (51.90)	13 (48.10)	27 (9.61)		
Undecided	10 (47.60)	11 (52.40)	21 (7.47)		
Total	213 (75.80)	68 (24.20)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 4.87.

Rainfall intensity	Cut the size of meals in the past year (2014) because food was not enough				
	Yes n (%)	No n (%)	Total n (%)	χ^2	p-value
Decreased	165 (76.00)	52 (24.00)	217 (77.23)	20.136[a]	0.000
No change	11 (68.80)	5 (31.20)	16 (5.69)		
Increased	13 (48.10)	14 (51.90)	27 (9.61)		
Undecided	8 (38.10)	13 (61.90)	21 (7.47)		
Total	197 (70.10)	84 (29.90)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.78.

households consumed own-produced foods ($\chi^2 = 44.119^a$, $p = 0.000$), the households' meals variety ($\chi^2 = 22.555^a$, $p = 0.000$), and the households' meal rations consumed in the year 2014 ($\chi^2 = 20.136^a$, $p = 0.000$). Therefore, the rainfall intensity was associated with the number of meals households consumed daily, the period of time households consumed own-produced foods, and the households' diet variety and rations.

The results of the relationship between rainfall onset and the household's food security are presented in Table 9.

The results of this study (Table 9) indicated a significant relationship between the rainfall season onset and the number of meals the households consumed daily ($\chi^2 = 31.715^a$, $p = 0.000$), the period of time the households consumed own-produced foods ($\chi^2 = 33.905^a$,

Table 9: Cross-tabulation analysis of the perceived changes in the onset of the rainfall season and the household's food security

Seasonal rainfall onset	Number of meals the households consumed daily					
	Two n (%)	Three n (%)	Four n (%)	Total n (%)	χ^2	p-value
Changed	161 (73.50)	58 (26.50)	0 (0.00)	219 (77.94)	31.715[a]	0.000
No change	20 (52.60)	14 (36.80)	4 (10.50)	38 (13.52)		
Undecided	21 (87.50)	3 (12.50)	0 (0.00)	24 (8.54)		
Total	202 (71.90)	75 (26.70)	4 (1.40)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.06.

Seasonal rainfall onset	Number of months in a year that households consumed own-produced foods						
	1 month n (%)	2 months n (%)	3 months n (%)	6 months n (%)	Total n (%)	χ^2	p-value
Changed	100 (45.70)	85 (38.80)	34 (15.50)	0 (0.00)	219 (77.94)	33.905[a]	0.000
No change	4 (10.50)	16 (42.10)	17 (44.70)	1 (2.60)	38 (13.52)		
Undecided	5 (20.80)	12 (50.00)	7 (29.20)	0 (0.00)	24 (8.54)		
Total	109 (38.80)	113 (40.20)	58 (20.60)	1 (0.40)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 9.14.

Seasonal rainfall onset	Ate a smaller variety of foods than usual because food was not enough				
	Yes n (%)	No n (%)	Total n (%)	χ^2	p-value
Changed	171 (78.10)	48 (21.90)	219 (77.94)	3.403[a]	0.182
No change	27 (71.10)	11 (28.90)	38 (13.52)		
Undecided	15 (62.50)	9 (37.50)	24 (8.54)		
Total	213 (75.80)	68 (24.20)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 9.14.

Seasonal rainfall onset	Cut the size of meals in the past year (2014) because food was not enough				
	Yes n (%)	No n (%)	Total n (%)	χ^2	p-value
Changed	161 (73.50)	58 (26.50)	219 (77.94)	6.887[a]	0.032
No change	20 (52.60)	18 (47.40)	38 (13.52)		
Undecided	16 (66.70)	8 (33.30)	24 (8.54)		
Total	197 (70.10)	84 (29.90)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 7.17.

p = 0.000), and the size of household meals in the year 2014 (χ^2 = 6.887[a], p = 0.000). However, the study found no statistically significant relationship between the seasonal rainfall onset and the variety of foods consumed by the households as indicated by the chi-square statistic of χ^2 = 3.403[a] and p = 0.182 that was greater than 0.05.

The results of the relationship between the perceived changes in the seasonal rainfall cessation and the household's food security are provided in Table 10.

The study results (Table 10) indicated a significant relationship between the seasonal rainfall cessation and the number of meals the households consumed daily (χ^2 = 17.851[a], p = 0.001), number of months in a year that the households ate own-produced foods (χ^2 = 13.186[a], p = 0.040), the households' meal variety (χ^2 = 11.100[a], p = 0.004), and the households' meal sizes during the year 2014 (χ^2 = 13.116[a], p = 0.001).

Results from the chi-square and cross-tabulation analysis implied that the study community's perceived rainfall changes and the households' food security were significantly related. Based on these findings, the null hypothesis (HO_1) of no significant association between the perceived rainfall changes and household food security among the study community was rejected. The study can

Table 10: Cross-tabulation analysis of the perceived changes in the seasonal rainfall cessation and the household's food security

Rainfall cessation	Number of meals consumed daily					
	Two *n* (%)	Three *n* (%)	Four *n* (%)	Total *n* (%)	χ^2	*p*-value
Changed	153 (74.30)	53 (25.70)	0 (0.00)	206 (73.31)	17.851[a]	0.001
No change	34 (63.00)	16 (29.60)	4 (7.40)	54 (19.22)		
Undecided	15 (71.40)	6 (28.60)	0 (0.00)	21 (7.47)		
Total	202 (71.90)	75 (26.70)	4 (1.40)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.31.

Rainfall cessation	Number of months in a year that family consumed own-produced foods						
	1 month *n* (%)	2 months *n* (%)	3 months *n* (%)	6 months *n* (%)	Total *n* (%)	χ^2	*p*-value
Changed	90 (43.70)	80 (38.80)	36 (17.50)	0 (0.00)	206 (73.31)	13.186[a]	0.040
No change	13 (24.10)	24 (44.40)	16 (29.60)	1 (1.90)	54 (19.22)		
Undecided	6 (28.60)	9 (42.90)	6 (28.60)	0 (0.00)	21 (7.47)		
Total	109 (38.80)	113 (40.20)	58 (20.60)	1 (0.40)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.28.

Rainfall cessation	Ate a smaller variety of foods than usual because food was not enough				
	Yes *n* (%)	No *n* (%)	Total *n* (%)	χ^2	*p*-value
Changed	164 (79.60)	42 (20.40)	206 (73.31)	11.100[a]	0.004
No change	39 (72.20)	15 (27.80)	54 (19.22)		
Undecided	10 (47.60)	11 (52.40)	21 (7.47)		
Total	213 (75.80)	68 (24.20)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.08.

Rainfall cessation	Cut the size of meals in the past year (2014) because food was not enough				
	Yes *n* (%)	No *n* (%)	Total *n* (%)	χ^2	*p*-value
Changed	154 (74.80)	52 (25.20)	206 (73.31)	13.116[a]	0.001
No change	35 (64.80)	19 (35.20)	54 (19.22)		
Undecided	8 (38.10)	13 (61.9)	21 (7.47)		
Total	197 (70.10)	84 (29.90)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.28.

therefore deduce that the community's perceived rainfall changes were significantly related with the level of the households' food security.

3.7 The community's perceived temperature changes (1984–2014)

About 59.8% of respondents reported that local temperatures were rising temperatures. The FGDs participants concurred that temperatures had become unpredictable citing that, in the past, July that was the coldest month of the year had become warmer, while the month of August that used to be warm had become the coldest month of the year. One elderly KI opined that:

> "Our usual crop planting times have really changed. Temperatures have changed a lot. We cannot tell when it will be warm or cold or when the cold season will start or end. Sometimes it gets too hot while other times it gets too cold. A day can start warm and end up very cold. Sometimes it's too hot that our crops dry out."

Table 11: Cross-tabulation analysis of the perceived temperature changes and the household's food security

Temperature changes	Number of meals households consumed daily					
	Two *n* (%)	Three *n* (%)	Four *n* (%)	Total *n* (%)	χ^2	*p*-value
Decreased	42 (70.00)	18 (30.00)	0 (0.00)	60 (21.35)	27.498[a]	0.000
No change	6 (60.00)	2 (20.00)	2 (20.00)	10 (3.56)		
Increased	121 (72.00)	46 (27.40)	1 (0.60)	168 (59.79)		
No response	33 (76.70)	9 (20.90)	1 (2.30)	43 (15.30)		
Total	202 (71.90)	75 (26.70)	4 (1.40)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.14.

Temperature changes	Number of months in a year that households consumed own-produced foods						
	1 month *n* (%)	2 months *n* (%)	3 months *n* (%)	6 months *n* (%)	Total *n* (%)	χ^2	*p*-value
Decreased	27 (45.00)	19 (31.70)	14 (23.30)	0 (0.00)	60 (21.35)	34.549[a]	0.000
No change	1 (10.00)	4 (40.00)	4 (40.00)	1 (10.00)	10 (3.56)		
Increased	67 (39.90)	71 (42.30)	30 (17.90)	0 (0.00)	168 (59.79)		
No response	14 (32.60)	19 (44.20)	10 (23.30)	0 (0.00)	43 (15.30)		
Total	109 (38.80)	113 (40.20)	58 (20.60)	1 (0.40)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.04.

Temperature changes	Ate a smaller variety of foods than usual because food was not enough				
	Yes *n* (%)	No *n* (%)	Total *n* (%)	χ^2	*p*-value
Decreased	42 (70.00)	18 (30.00)	60 (21.35)	22.555[a]	0.000
No change	3 (30.00)	7 (70.00)	10 (3.56)		
Increased	141 (83.90)	27 (16.10)	168 (59.79)		
No response	27 (62.80)	16 (37.20)	43 (15.30)		
Total	213 (75.80)	68 (24.20)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 4.42.

Temperature changes	Cut the size of meals in the past year (2014) because food was not enough				
	Yes *n* (%)	No *n* (%)	Total *n* (%)	χ^2	*p*-value
Decreased	42 (70.00)	18 (30.00)	60 (21.35)	21.922[a]	0.000
No change	3 (30.00)	7 (70.00)	10 (3.56)		
Increased	131 (78.00)	37 (22.00)	168 (59.79)		
No response	21 (48.80)	22 (51.20)	43 (15.30)		
Total	197 (70.10)	84 (29.90)	281 (100.0)		

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 4.99.

3.8 The relationship between perceived temperature changes and the households' food security (1984–2014)

The following null hypothesis was tested:

HO_2: There is no significant relationship between the perceived temperature changes and the household food security among Kimandi-Wanyaga community in Murang'a County, Kenya.

A chi-square test was conducted to test the null hypothesis (HO_2) of no significant relationship between the two variables. The results of the chi-square test and cross-tabulation between the perceived temperature changes and the households' food security are presented in Table 11.

The study results (Table 11) indicate that temperature changes were significantly related with the number of households' daily meals (χ^2 = 27.498[a], p = 0.000), the number of months in a year that the households consumed own-produced foods (χ^2 = 34.549[a], p = 0.000), the households' meal variety (χ^2 = 22.555[a], p = 0.000), and the households' meal sizes during the year 2014 (χ^2 = 21.922[a], p = 0.000). The study results indicated a significant relationship between temperature changes and the household's food security. Thus, the null hypothesis (HO_2) of no significant relationship between the perceived temperature changes and the households' food security in the study area was rejected. The study can therefore deduce that the community's perceived temperature changes were significantly related with the level of the households' food security.

4 Discussion

Results of the study (Table 1) show that majority of household heads were males (76.2%) and middle-aged (57.3%). Studies show that male household heads have a higher probability of perceiving climate change than female household heads, owing to their higher accessibility to new information. Older farmers are also more likely to perceive climate change than younger farmers because long farming experience increases their agronomic superiority [49,50]. High literacy levels were observed among the study community since about 52.7% of respondents had attained secondary level education. Higher education exposes farmers to new climate change insights raising the likelihood of more educated farmers to perceive climate change compared to less-educated farmers [49,50]. The majority of the farmers (95.3%) owned less than 4.5 acres of land. Smallholder farmers are defined as those owning less than 2.0 hectares (equivalent to 4.94 acres) [51]. Most of the community's arable land was under tea crop (67.34%) confirming Murang'a County report [30].

Results of the study show that the community was undergoing food availability challenges. Gaps of food availability between seasons was evident since food produced by most households (80%) hardly lasted to the next season. Also evident was food inaccessibility among the households as manifested in financial difficulties that led to rationing or lowering of meal quality as some households stayed hungry due to food shortage. The HDDS results also revealed that most of the households' diets were packed with energy dense food groups such as cereals, sugar, honey, oils, and fats and low in micronutrient dense food groups such as fruits, meat, poultry, and eggs. One KI reported that meat and poultry were not commonly consumed because they were expensive. It is noted that fats and oils do not contribute to the micronutrient density of diets but they improve energy density and absorption of fat-soluble vitamins and plant carotenoids. Low consumption of micronutrients on a given day may indicate seriously inadequate diets that may cause micronutrients deficiency-related morbidity. From a potential score range of 0–12, the households mean HDDS score of 4.0036 indicated inadequate dietary diversity. Low dietary diversity levels also indicate a likelihood of low per capita consumption levels and caloric availability and hence low food access [52,53]. Recently, it has been argued that climate change can alter the micronutrient availability particularly among low-income countries [54]. Micronutrient deficiency prevalence among populations in Kenya has been reported [55]. In Ghana and Tanzania, climate-induced food unavailability was also observed among agriculture-based households [56]. In Madagascar farming, households were reported to ration food and use wild foods to cope with climate-induced food insecurity [57].

Results of the study indicated that the community perceived irregularities in rainfall amount, intensity, frequency, and timing during the period 1984–2014 with adverse impacts on their crop productivity. According to them, rainfall irregularities had interrupted their predictable traditional cropping calendars determined by two rainfall seasons of long rains (MAM) and short rains (OND). The perceived seasons unpredictability and rainfall inadequacy delayed crop planting making farmers to lose seeds if they dry-planted in anticipation for the rains. Those who planted at rainfall onset lost their crops if the rains stopped earlier, fell for a short time, or stopped at the peak of crop growth. They alleged that, as planting times became highly uncertain, crops got stunted, yields fell drastically, and more expenses were incurred as weeding times increased. Their perceptions underpinned the importance of rainfall in determining their food security. The community's perceptions agreed with the results of the chi-square test and cross-tabulation analysis involving the perceived rainfall changes and their impacts on the household's food security. The results indicated a significant relationship between rainfall changes and the community's food security. Similar findings have been reported among farming communities. Farmer's perceptions on declining rainfall and its adverse impacts on food security have been reported [13,14,58].

Conversely, the community perceptions on rainfall decline were not supported by meteorological rainfall data. The MAKESENS test rainfall results yielded statistically insignificant trends (α > 0.1), indicating normal annual and seasonal rainfall distribution in the study area during the period 1984–2014. A range of studies concur that discrepancies can occur between community perceptions and actual observed meteorological data [58–62]. The community misperceptions of rainfall variability may have been compounded by other factors such as inability to decouple the synergistic effects of climate change and nonclimate stressors on crop productivity such as habitat change, introduction of exotic species, overharvesting/over extraction, pollution, and soil pH [58,63–66]. Other studies argue that farmers' perceptions are mainly based on their recent experiences with drought episodes. This makes dialogue and partnership necessary in dealing with the complications of a changing climate make. Precision and reliability of a forecasting system determines its creditability and acceptance by users to proactively incorporate it in their decision-making information processes [61,66]. To avoid maladaptation, choice of adaptation interventions should therefore be broad based without relying on one information source [67,68].

Results of the study show that majority of respondents had experienced increasing temperatures during the period 1984–2014, which had adversely affected crop productivity. Their perceptions agreed with the chi-square test and cross-tabulation analysis results, which indicated a significant relationship between temperature changes and the community's food security. The community perceptions results were supported by observed increasing monthly maximum temperature trend, indicating that the study area was warming. This conforms with other similar studies [69–71]. Africa is also warmer than a decade ago, and the trend is predicted to continue or accelerate in the next three decades [27,72,73].

It is predicted that higher temperatures will reduce crop productivity in Africa due to increased crop moisture stress leading to increased drying, sun-scotch, and wilting of crops [13,74–76]. Climate change impacts will also affect reliability of crop growing seasons and communities' livelihoods [77]. A wide range of studies have established the impacts of changing rainfall and temperatures on crops. For example, crop growth is most vulnerable to adverse weather such as excess or low rainfall and high temperatures at early developmental stages resulting in seedling diseases or death. At reproductive stage, high temperatures, low soil moisture, and waterlogging lower grain formation in corn and soybeans and depress potato bulking. Waterlogging at later stages causes rotting, fungal development, and high disease attacks. Heavy rainfall also lowers maize dry matter yields [78–81]. Water deficits favor aflatoxin concentration in maize [82]. Less than 60% of soil water content reduces plant height, internode length, and stem diameter in tomatoes [83]. Continuous extreme high and low temperatures damage crop leaves [84]. A 3°C global temperature rise is expected to change vegetation character [85]. Intense rains cause floods and landslides that destroy homes, croplands, and trees and also causing human and animal fatalities. Excessive wet years reduce yields due to waterlogging and pest proliferation [86–88]. In Kenya, yields of cowpea were found to be reduced by pests, diseases, and drought [89]. In the absence of effective adaptation, genetic improvement, and fertilization, 1°C increase in global average temperature is likely to lower global yields of maize by 7.4%, rice by 3.2%, wheat by 6.0%, and soybean by 3.1% [90].

Significant losses of up to 40% in tea yields are predicted in SSA due to increased temperatures. In Kenya, a negative future for smallholder farmers particularly tea growers is predicted. Evidence of frost damage on tea indicate that tea has high hazard and sensitivity characteristics to frost. The situation will be exacerbated by climate-induced ailments that curtail employment opportunities and labor productivity [91,92]. This paints a negative future for the smallholder farmers in the study area whose main source of livelihood is tea farming.

5 Conclusion

This study results revealed that the long season rainfall of MAM had decreased by 9.42%, the short season rainfall of OND had increased by 18.89%, and the annual rainfall had increased by 0.37335%. The rainfall trends were statistically insignificant ($\alpha > 0.1$), indicating normal annual and seasonal rainfall trends in the study area during the period 1984–2014. A discrepancy arose between the observed rainfall trends and the community's rainfall change perceptions. The majority of the respondents and a KI perceived rise in drought frequency and prolonged dry spells causing low crop yields and sometimes famine, which led to reliance on food aid. The HDDS results also indicated low household dietary diversity among the community. Results of the chi-square and cross-tabulation of the perceived rainfall changes indicated a significant relationship between the rainfall changes and the household's food security. The results indicated that scientists and farmers measure, observe, and interpret rainfall and its impacts on crop production differently. Although climate scientists judged rainfall trends based on the calculated statistical means, the farmers judged rainfall trends based on its adequacy to meet their crop-water needs. Concerning temperature changes, the majority of the respondents perceived an increasing trend. This was supported by observed temperature data, the chi-square test, and the cross-tabulation analysis results involving perceived rainfall changes and the household's food security. This implied that the study area was warming similar to other regions in the world posing a threat to the community's food security.

6 Recommendations

To achieve robust and strategically designed climate policies and programs, there is a need for governments to communicate to policymakers the perceptions of rural smallholder farmers heavily dependent on climate-sensitive resources and involved in autonomous climate adaptation. The study recommends improved access to prompt and reliable current climate change information, prediction, and response mechanisms through dialogue between farmers' experiential wisdom and scientific knowledge. These are achievable through improved knowledge sharing channels between farmers and climate scientists such as Climate Field Schools (CFS). Participatory research approaches are needed to strengthen smallholder farmers' adaptive capacity through enhanced access to modern irrigation technologies, implementation of water harvesting and conservation measures, use of soil conservation measures such as agroforestry and terracing, proper fertilizer application, and enhanced access to prompt and reliable climate warning information to guide the planning of seasons.

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