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Contextualizing Climate Variability in Tharaka South Subcounty, Tharaka Nithi County, Kenya

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Abstract: *Climate variability is variation of climate elements from thelongterm mean state. Climate variability may result from natural internal processes within the climate system or from natural or anthropogenic external forces. Kenya's climate system is marked by spatial variations between its regions and temporal variation across all timescales. The nature of climate variability therefore differs along and across different spatial and temporal contexts.Climate variability in the context of Tharaka South Subcounty has however not been studied in detail to enable clear understanding of past and currently prevailing climatic status and trends. No studies have also been done to analyze household's resilience to climate variability in Tharaka South Subcountydespite the fact that climate variability resilience building is site specific. This therefore called for a detailed study aimed at analyzing climate variability in the context of Tharaka South Subcounty. This study is based on the sustainable livelihoods framework and uses a descriptive study design. It employed multi stage sampling design with data being collected from primary and secondary sources. Analysis was done using thematic analysis, descriptive analysis and inferential statistical methods including coefficient of variation and Kendall's tau-b. Household's resilience to climate variability was calculated using a resilience composite index developed using inductive and hierarchical approaches. The study found out that the local climate is becoming increasingly variable with positive trends in climate variability along the years being observed. Local climatic patterns are becoming more erratic and unpredictable as confirmed by local people's perceptions. Climate variability has negative impacts on local people's livelihoods butthey are undertaking various responses to build their resilience. Local households were however observed to have very low resilience to climate variability as determined using the developed resilience index.*

Key words:*Climate variability,household resilience index, livelihood assets, livelihood strategies resilience, sustainable livelihoods framework, vulnerability context*

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I. Introduction

Climate variability is the variationofclimate elements from the longtermmean state on all spatial and temporal scales including: months, seasons, years, decades, centuries, millennia etc. (Ziervogel et al, 2010; Lambrou and Nelson, 2010; Agbo et al, 2015; McCarthy et al, 2001; Win Stanley, 2007; IPCC, 2007; UNFCCC, 1992). Climate variability may result from natural internal processes within the climate system (internal variability) or from natural or anthropogenic external forces (external variability) (Bangladesh Meteorological Department, n.d.). According to (IPCC, 2007), climate change directly affects variations in rainfall and temperature patterns and incidences of droughts and hence causes climate variability.

Kenya has a complex climate that varies significantly between its regions and from season to season, year to year and decade to decade (Parry et al, 2012). The climate pattern in Kenya is influenced mainly by its position relative to the Indian Ocean and Lake Victoria, varied topography, the ITCZ and the ENSO phenomenon (Ojwang et al, 2010). Rainfall is the prime climatic factor in Kenya and has a high degree of spatiotemporal variability although temperature is also significant factor particularly in the highlands, ASALs and near large water bodies (Ojwang et al, 2010).

Despite this spatiotemporal variability,most climate studies make use of global, regional and national level datarather than focus on specific local contexts where effects manifest and responses are undertaken hence the risk ofveiling local level vulnerability in terms of access to capital assetsdue to the problem of aggregation (Deressa et al, 2008; Antwi-Agyei et al, 2012; Eakin and Borjoquez-Tapia, 2008; Morse and Fraser, 2005). Climate variability studies also often don't focus on all timescales. Climate variability however refers to variations in the mean state and other climate statistics on all temporal scales including at the monthly level(Bangladesh Meteorological Department, n.d.; McCarthy et al, 2001; Winstanley, 2007; IPCC, 2007; UNFCCC, 1992).

This is true in the case of Tharaka South Subcounty where no detailed studies have been done to analyze the vulnerability context especially in terms of effect on access to capital assets and hence also on livelihood strategies. More so, no studies have recently been done in the area to define the current status and trends ofclimate variability. Although Recha (2009) did an analysis of climate variability trends in Tharaka, his analysis was up to the year 1994 and thus does not capture the current trends. Climate is however dynamic and context specific which means past climatic metrics cannot absolutely represent conditions in the subsequent temporal continuum. Climate studies in Tharaka South Subcountyhave also not analyzed the status and trends of drought severity and vegetation condition (NDVI) nor their relationship with climate variability.

Past studies on climate variability in Tharaka South Subcountyincluding (Mugi, 2011; Recha, 2009) did not analyzenor attempt to measurethe resilience of household's climate variability. Climate variability resilience building strategies are however site specific and can be best understood and decided at the household level given their minimal standard definitions and inter spatial comparability (Deressa et al, 2008; Alexa et al, 2010; Boru and Koske, 2014; Uy et al, 2011). In addition, studies on the impacts of climate variability in Tharaka South Subcounty have majorly focused on impacts on crop production but not on other aspects e.g. education and health.

Studies undertaken in the past also did not measure climate variability resilience using a multivariable composite index. Most of these studies use a single observable proxy resilience indicator. However, resilience metrics should capture a broader spectrum of key variables other than focus on one dimension. This is because resilience of rural households is defined by multiple ingredientsbased on access to financial, social, human, financial and natural capital assets (IFAD, n.d.). Composite indices should thus be used to measure resilience since they put into consideration multiple variables and provide relative measures that allow ranking of cases from the lowest to the highest level (USAID, 2014).

Although the resilience of a household is determined by its access to capital assets including: human, social, natural, physical and financial capital (Oft, 2009; Verner, 2010). No studies have measured climate variability resilience using access to capital assetsas per the sustainable livelihoods framework. Although (Piya et al, 2012; Defiesta & Rapera, 2014; Elasha et al, 2005) measure adaptive capacity and community resilience using the sustainable livelihood approach, their studies had a focus on climate change as opposed to climate variability. Kamaruddin and Samsudin (2014) also use the sustainable livelihood index but as a tool for assessing the ability of the rural poor in receiving entrepreneurial projects. Others, (Hahn et al, 2009; Mbakahya and Ndiema, 2015; Cheb, 2015) used the sustainable livelihoods framework but their studies focused on vulnerability toclimate variability as opposed to resilience.

II. Theoretical framework

The sustainable livelihoods framework was developed by the sustainable rural livelihoods advisory committee of the DFID. It provides an organizing structure for analysis and is the core of the sustainable livelihoods approach. The sustainable livelihoods framework is based on Chambers and Conway (1992) definition of livelihoods i.e. ''A livelihood comprises the capabilities, assets and activities required for a means of living.A livelihood is sustainable when it can cope with and recover from stresses and maintain or enhance its capabilities and assets both now and in the future while not undermining the natural resource base''. Livelihoods essentially highlight understanding of the context within which people live, their assets, the livelihood strategies they pursue through existing structures and processes and the livelihood outcomes they intend to achieve (Scoones, 1998).

The sustainable livelihoods framework sets out to conceptualize how people operate within a vulnerability context which frames the external environment in which they exist (GLOPP, 2008). The vulnerability context is shaped by trends, shocks and seasonality, over which people have little or no control despite having impact on their livelihoods assets and opportunities (Nayak and Maharun, 2013). It is also shaped by the socioeconomic characteristics of a population which determines their capacity to respond effectively hence the degree to which their livelihoods are affected (Aniah et al, 2016). The vulnerability context therefore includes the climatic conditions in the local environment.

Impacts of the vulnerability context on people and communities differ based on socioeconomic inequalities. This means resilience building strategies must address the processes that underlie such structural inequalities in orderto be effective (United Nations, 2016). According to Gentle et al (2014), impacts of climate variability are not uniform but differ based on geographical location and socioeconomic characteristics which shape the structural inequalities that perpetuate vulnerability. Understanding dynamics of people's livelihoods and perceptions of the vulnerability context is therefore key to understanding how they will be affected and how they might respond of which is helpful in developing resilience building strategies (IUCN et al, 2004).

The vulnerability context can be best managed by helping people to build their livelihood assets. Livelihood assets include: human, social, natural, physical and financial capital which are converted through livelihood strategies into livelihood outcomes such as resilience (DFID, 2000). The sustainable livelihoods approach thus seeks to understand people's assets and the strategies that they use to convert assets into livelihood outcomes in a context of shocks, trends and seasonality which affects them (Moser et al, 2011;

Connolly-Boutin and Smit, 2016).Assets endowment does not only determine household's vulnerability but it also influences the choice of livelihood strategies (Kabede and Adana, 2011).

Livelihood strategies are mediated by structures and processes (Chambers and Conway, 1992; Ellis, 2000). Structures and processes operate at all levels from the household level to the international level and in all spheres including the private and public (Petersen and Pedersen, 2010). Processes include decision making processes, social norms, culture and rules which determine operations and interactions of structures through which they are established and implemented (Lowe and Schilderman, 2001). Structures include rural institutions such as membership organizations that define how people interact and act in the community; how assets are accessed, used, controlled and decision making processesand hence determining livelihood strategies (FAO, 2008;DFID, 2000).

Livelihood strategies comprise the range and combination of activities and choices that people make in order to achieve their livelihood outcomes (DFID, 2000). They constitute how people combine and use assets in pursuit of livelihood outcomes that meet their objectives. The viability and effectiveness of livelihood strategies hence livelihood outcomes is influenced by ecological, socioeconomic and institutional factors which determine availability and accessibility of assets (Majale, 2002). Livelihood outcomes include more income, wellbeing, food security, sustainable use of natural resources and reduced vulnerability hence resilience (DFID, 1999).

III. Materials and methods

Study Area

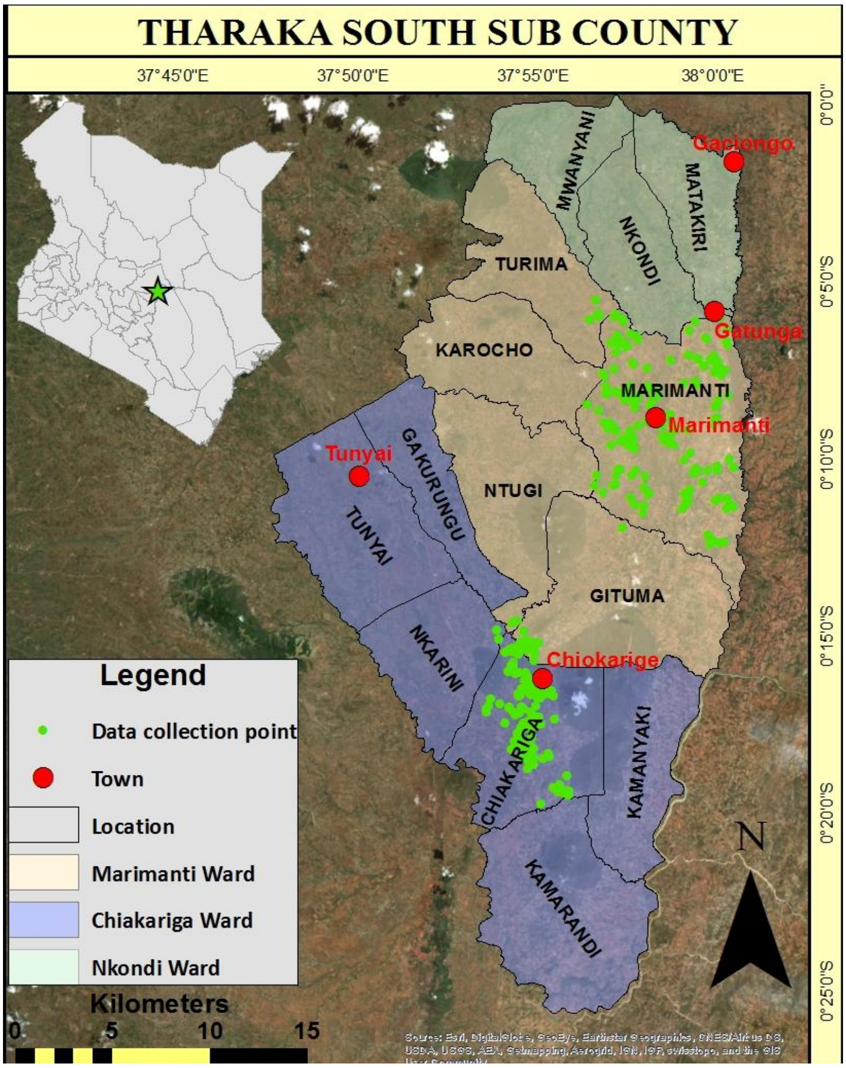

Figure 1: Map of Tharaka South Sub County

Tharaka South Sub County is part of Tharaka Nithi County and lies to the East of Mount Kenya. It covers a surface area of 689 KM^2(GoK, 2010). Tharaka South Sub County is subdivided into three wards namely: Nkondi, Chiakariga and Marimanti (GoK 2012b). Tharaka South Sub County has a total population of 80,122 people of whom 38,653 are male while 41,464 are female. The sub county has 17,111 households and a population density of 116 people per KM^2 (GoK 2010b).The sub county has three main livelihood zones namely the mixed farming zone, marginal mixed farming zone and the rain fed farming zone (Government of Kenya, 2008). The people are largely agro pastoralists with farming and animal husbandry accounting for over 70% of their income (Kirraine et al, 2012). The sub county is marked by inadequate access to formal financial institutions with the main source of credit being informal microfinance institutions.

The sub county experiences unusual climate variability due to climate change (GoK, 2012b) and also due to the fact that it is semi-arid. The sub county mainly receives low, unreliable and poorly distributed rainfall (GoK, 2016). Rainfall has a bimodal pattern and fluctuates between 500 to 800 mm per annum (GoK, n.d.). Temperatures range between 24 to 37 degrees centigrade (GoK, n.d.) but at times rising up to 40 degrees centigrade (Kabui, 2012). The sub county falls in the dry/savannah climatic zone according to the Koppen-Geiger climate classification.Proximity of the area to Mount Kenya means that the local climate is influenced by the El Nino southern oscillation, inter tropical convergence zone, latitude and altitude and sea surface temperatures among other factors (Odingo et al, 2002).

IV. Data collection

The study used a descriptive study design. It employed multi stage sampling design. Two Locations i.e. Marimanti and Chiakariga were first selected randomly. An inventory of informal microfinance groups was then created indicating the sub locations where they are based. 18 groups proportionately spread across sub locations in each of the locations were then selected. 11 respondents were then chosen systematically from the lists of the selected informal microfinance groups to form the study sample.The studys' sample size was determined using Cochrans' (1963) Equation 1 and a sample size of 385 respondents arrived at.

Secondary data was obtained through review of existing literature. Primary data was collected through: focused group discussions, key informant interviews, observation and household questionnaire survey. Data collection was done with the assistance of a mobile based georeferenced data management system called kMACHO. Methodological triangulation was used to cross verify, validate and harmonize data from different data collection methods. This helped increase the credibility and validity of the results.

Pilot testing of the data collection instruments was done to check for weaknesses in design and instrumentation. The data collection instruments were evaluated for validity through expert consultation. The instruments were tested for reliability using the Cronbach Alpha method to test the degree to degree of internal consistency between items in a research instrument. A Cronbach alpha of 0.774 was arrived at indicating good reliability.

V. Data analysis

To analyze climate variability in Tharaka Sub County. Rainfall including at monthly, seasonal and annual scales was used as an indicator. Rainfall data was sourced from Climate Hazards InfraRed Precipitation with Station data (CHIRPS) i.e. **ftp://ftp.chg.ucsb.edu/pub/org/chg/products/CHIRPS-2.0/README-CHIRPS.txt**. CHIRPS incorporates 0.05^o resolution satellite imagery with in-situ station data to create gridded rainfall time series for trend analysis and seasonal drought monitoring. Climate variability in the study area was quantitatively analyzed using the coefficient of variation of annual rainfall of the last 38 years. This gave the intraannual, intraseasonal and monthly climate variability for the period.Drought severity was measured using percentage of normal precipitation.

Climatic trendsbased on rainfall as an indicator were also analyzed over the last thirty eight years, 1981-2018. This was done using Mann-Kendall statistical test. The method does not require the data to be normally distributed. It's a non-parametric test and is best suited for analysis of weather data which is often not normally distributed and is subject to abrupt breaks caused by a heterogeneous time series. The analysis was done at monthly, seasonal and annual scales at95% level ofsignificance. This included analysis of trends in rainfall amounts, within and between period's variability,Percentage of Normal Precipitation (PNP)and Average annual Normalized Difference Vegetation Index(NDVI). The NDVI values werederived from surface reflectance data acquired by the Advanced Very High Resolution Radiometer (AVHRR) satellite having a 1KM resolution.

Local peoples' perceptions to climate variability were analyzed through thematic analysis and descriptive statistics. This included perceptions on extent of change, how climatic patterns have changed, causes and impacts of climate variability on rural livelihoods. Local people's response action for addressing the impacts of climate variabilitywere also analyzed using thematic analysis and descriptive statistics.

Household's resilience to climate variability was measured based on the sustainable livelihoods framework.The sustainable livelihoods framework is concerned with how people use a range of assets to devise livelihood strategies with an aim of achieving positive livelihood outcomes i.e. resilience to climate variability (Connoley-Boutin and Smit, 2016). In doing this a household's access to capital assets was measured in terms of the total expenditure incurred in accessing them. This included household expenditure on access to education and health care, and on inputs of crop production and livestock production as indicators. These were then used to construct household's resilience composite index.

Calculation of the resilience composite indices employed inductive and hierarchical approaches. In doing this, the negative oriented values i.e. community health status for each the last 38 years were first adjusted for directionality using multiplicative inverse adjustment to ensure higher values always indicate higher resilience i.e.

$x_i = 1/x_u$

Where:

x_i = Adjusted value of x

x_u = Unadjusted value of x

The variables were then be normalized to ensure comparability of indicators bearing different measurement units and scales. This was done using the Min-Max normalization to yield a standard index value with relative positions in the range of zero to one for each indicator i.e.

$z_i = x_i - \min(x)/\max(x) - \min(x)$

Where:

Z_i = Normalized value of x_i

min(x) = Minimum value of x

max(x) = Maximum value of x

These indicators were then weighted to avoid uncertainty of equal weights given their diversity. This entailed subjecting the variables to a joint participatory weighting process using a pairwise ranking matrix. This allocated weights to according to the number of times a variable was chosen as being more important.

The composite indices were then calculated using the formula;

$CI = \sum (w_i x_i)/n$

Where:

CI = Composite index

w_i = Weight of variable

x_i = Variable value

n = Number of variables

The composite indices were tested for accuracy and robustness through uncertainty and sensitivity analysis. Uncertainty analysis was done using the propagation of standard errors approach i.e. based on uncertainties of index components. This involved adding their standard errors as a weighted sum in quadrature (squared, weighted, added and then square rooted) as in Kirchner (2001) i.e.

$U = \sqrt{\sum} (w_i S_i)^2$

Where:

U = Uncertainty

w_i = Variable weight

S_i = Standard error of component

Sensitivity analysis was done using multiple regression analysis to determine how components constituting the indices influence them as in Hamby (1995). In doing this the coefficient of determination (R^2) gave an indication of the amount of variation in the composite index which can be explained by the model's components.

VI. Results

Analysis of Monthly climate variability

Analysis of monthly rainfall was as shown in table 1.

Table 1: Analysis of monthly rainfall

Analysis of Monthly rainfall												
Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average rainfall (Normal precipitation)	27.71	15.76	84.18	286.04	99.28	5.10	9.00	7.18	2.85	113.70	269.24	105.96
Minimum rainfall observed	6.52	5.21	12.18	89.28	23.04	1.96	2.61	3.09	0.82	5.62	36.63	21.96
Maximum rainfall	167.25	59.68	262.74	563.27	271.08	23.04	16.66	13.35	8.29	275.52	673.81	266.71

observed												
Trends in rainfall amounts	0.033	0.081	-0.018	-0.081	-0.166	-0.279*	-0.294**	-0.117	-0.314**	-0.078	0.061	-0.050
Climate variability	1.140	0.814	0.733	0.359	0.552	0.021	0.367	0.363	0.556	0.618	0.043	0.617
Percentage of months with below normal precipitation (%)	71.05	65.79	55.26	52.63	57.89	73.68	55.26	55.26	57.89	60.53	60.53	52.63
Minimum percentage of normal precipitation (%)	20.5	33.00	14.50	31.2	23.20	38.50	29.00	43.00	28.80	4.90	13.60	20.00
Maximum percentage of normal precipitation (%)	54.91	37.83	31.21	196.9	273.10	452.20	185.1	185.90	291.30	242.30	250.30	251.70
Trends in percentage of normal precipitation	0.033	0.081	-0.018	-0.081	-0.166	-0.279*	-0.294**	-0.117	-0.314**	-0.078	0.043	0.617

Analysis was done for specific months for the last 38 years rainfall for the study area. The least rainfall amount is observed in the month of September 2015 with 0.82 mm while the highest rainfall amount is observed in the month of November 1997 an Elnino year with 673.81 mm. The total rainfall amounts for January were observed to be on an increasing trend although not significant ($\alpha>0.05$). February and November also have a positive increasing trend as appertains to rainfall amounts although also not significant ($\alpha>0.05$). Most of the months have a negative decreasing trend for rainfall amounts including: March, April, May, August and October whose trends are not significant ($\alpha>0.05$). The months of June, July and September have decreasing significant trends ($\alpha<0.05$). January has the highest rainfall variability with June showing the least variability. Most of the months along the years depict rainfall amounts that are below the normal precipitation level. April and December have the least percentage of months with below normal precipitation levels i.e. 52.63% and June has the highest percentage of having rainfall amounts that are below normal precipitation i.e. 73.68%.

The lowest percentage of normal precipitation is observed in the month of January 2017 with 20.5% while the highest being observed in the month of June 2013 with 452.2%. The months of January, February, November and December have an increasing trend ($\alpha>0.05$) as appertains to percentage of normal precipitation along the years which indicates decreasing severity of drought conditions experienced. However, the rest of the months of March, April, May, August, September and October have a decreasing non-significant trends ($\alpha>0.05$) as appertains to percentage of normal precipitation with June and July having a decreasing significant trend ($\alpha<0.05$). A negative non-significant trend is an indication of increasing drought severity.

Analysis of seasonal climate variability

Analysis of seasonal rainfall was as shown in table 2.

Table 2: Analysis of seasonal rainfall

Variable	**MAM Season (Long rains)**	**OND Season (Short rains)**	**JF Season (Dry season)**	**JJAS Season (Dry season)**
Average rainfall (Normal precipitation)	469.50	487.82	143.18	27.12
Minimum rainfall observed	216.33	232.44	11.80	11.93
Maximum rainfall observed	886.62	188.72	214.67	37.81

Trends in rainfall amounts	-0.155	-0.007	0.084	-0.323*
Inter seasonal Climate variability	0.312	0.401	0.929	0.276
Minimum intraseasonal climate variability	0.276	0.185	0.019	0.265
Maximum intraseasonal climate variability	1.18	1.390	1.078	0.998
Trends in intraseasonal climate variability	0.084	0.185	0.037	0.255*
Percentage of seasons with below normal precipitation	55.26%	57.89	71.05	55.26
Minimum percentage of normal precipitation	46.08%	47.70	27.33	49.5
Maximum percentage of normal precipitation	188.84%	242.93	497.15	156.8
Trends in percentage of normal precipitation	-0.158	-.010	0.087	-0.323*

MAM (Long rains) season

This season occurs in the months of March, April and May. The mean seasonal rainfall for the long rains season from 1981-2018 was 469.50 mm with the lowest amount of rainfall for season being observed in year 2000 i.e. 216.33 mm and the highest being observed in 2018 i.e. 886.62 mm. The rainfall amounts for the MAM season depict a negative decreasing non-significant trend (α>0.05). Inter seasonal climate variability for the MAM season along the study period i.e. 1981-2018 was found to be 0.312. The minimum intra seasonal climate variability for the season was observed in 1981 i.e. 0.276 while the highest intra seasonal climate variability was observed in 1997 i.e. 1.18. The season was found to have a positive increasing non-significant trend (α>0.05) for intra seasonal climate variability of 0.084 meaning the climate cannot be easily predicted. 55.26% of the seasons from 1981-2018 were observed to have received below normal seasonal rainfalls. The minimum percentage of normal precipitation for the MAM season was observed in year 2000 i.e. 46.08% while the highest percentage of normal precipitation was observed in year 2018 i.e. 188.4%. The percentage of normal precipitation for the MAM season for 1981-2018 was observed to have a negative decreasing non-significant trend (α>0.05). This means droughts are gradually getting more severe.

OND (Short rains) season

This season occurs in the months of October, November and December. The mean seasonal rainfall for the short rains season from 1981-2018 was 469.50 mm with the lowest amount of rainfall for season being observed in year 1998 (a La Nina year) i.e. 232.44 mm and the highest being observed in 1997 (an El Niño year) i.e. 1188.72 mm. The rainfall amounts for the OND season depict a negative decreasing non-significant trend (α>0.05). Inter seasonal climate variability for the OND season along the study period i.e. 1981-2018 was found to be 0.401. The minimum intra seasonal climate variability for the season was observed in 1995 i.e. 0.185 while the highest intra seasonal climate variability was observed in 2016 i.e. 1.39. The season was found to have a positive increasing non-significant trend (α>0.05) for intra seasonal climate variability of 0.185 meaning the climate cannot be easily predicted. 57.89% of the seasons from 1981-2018 were observed to have received below normal seasonal rainfalls. The minimum percentage of normal precipitation for the OND season was observed in year 1998 i.e. 47.7% while the highest percentage of normal precipitation was observed in year 1997 i.e. 242.93%. The percentage of normal precipitation for the OND season for 1981-2018 was observed to have a positive increasing non-significant trend (α>0.05). This means droughts are gradually getting more severe in the season.

JF (Dry) season

This is the dry season that occurs in January and February. The mean seasonal rainfall for the JF dry season from 1981-2018 was 143.18 mm with the lowest amount of rainfall for season being observed in year 1987 i.e. 11.8 mm and the highest being observed in 1998 i.e. 214.67 mm. The rainfall amounts for the JF season depict a positive increasing non-significant trend (α>0.05). Inter seasonal climate variability for the JF season along the study period i.e. 1981-2018 was found to be 0.929. The minimum intra seasonal climate variability for the season was observed in 1983 i.e. 0.019 while the highest intra seasonal climate variability was observed in 2001 i.e. 1.078. The season was found to have a positive increasing non-significant trend (α>0.05) for intra seasonal climate variability of 0.037 meaning the climate cannot be easily predicted. 71.05% of the seasons from 1981-2018 were observed to have received below normal seasonal rainfalls. The minimum percentage of normal precipitation for the JF season was observed in year 1987 i.e. 27.33% while the highest percentage of normal precipitation was observed in year 1998 i.e. 497.15%. The percentage of normal precipitation for the JF season for 1981-2018 was observed to have a negative decreasing significant trend (α>0.05). This means droughts are gradually becoming less severe for the season.

JJAS (Dry) season

This is the dry season that occurs in June, July, August and September. The mean seasonal rainfall for the JJAS dry season from 1981-2018 was 27.12 mm with the lowest amount of rainfall for season being observed in year 2009 i.e. 11.93 mm and the highest being observed in 1981 i.e. 37.81 mm. The rainfall amounts for the JJAS season depict a negative decreasing significant trend ($\alpha>0.05$). Inter seasonal climate variability for the JJAS season along the study period i.e. 1981-2018 was found to be 0.276. The minimum intra seasonal climate variability for the season was observed in 1982 i.e. 0.265 while the highest intra seasonal climate variability was observed in 2015 i.e. 0.998. The season was found to have a positive increasing significant trend ($\alpha>0.05$) for intra seasonal climate variability of 0.255^{*}. 55.26% of the seasons from 1981-2018 were observed to have received below normal seasonal rainfalls. The minimum percentage of normal precipitation for the JJAS season was observed in year 2009 i.e. 49.5% while the highest percentage of normal precipitation was observed in year 1981 i.e. 156.8%. The percentage of normal precipitation for the JJAS season for 1981-2018 was observed to have a negative decreasing significant trend ($\alpha>0.05$). This means droughts are gradually becoming less severe for the season.

Analysis of annual climate variability

Analysis of annual rainfall was as shown in table 3.

Table 3: Analysis of annual rainfall

Variable	38 Year period (1981 – 2018)
Average rainfall (Normal precipitation)	1026.17
Minimum rainfall observed	653.47
Maximum rainfall observed	1918.93
Trends in rainfall amounts	-0.107
Inter annual Climate variability	0.243
Minimum intra annual climate variability	1.009
Maximum intra annual climate variability	1.831
Trends in intra annual climate variability	0.174
Percentage of years with below normal precipitation	63.16%
Minimum percentage of normal precipitation	63.42%
Maximum percentage of normal precipitation	186.25%
Trends in percentage of normal precipitation	-0.107
Average NDVI	0.2529
Minimum NDVI	0.0315
Maximum NDVI	0.537
Trends in NDVI	0.400**

The mean annual rainfall i.e. normal precipitation for the area was observed to be 1026.17 mm with least rainfall in one year being observed in year 2000 i.e. 653.47 mm and the highest in 1997 (an Elnino Year) i.e. 1918.83 mm. Annual rainfall amounts depict a decreasing negative non-significant trend ($\alpha>0.05$) meaning that rainfall amounts are decreasing over time although the trends can't be clearly predicted. The inter-annual climate variability for 1981—2018 is 0.25 i.e. 25% from the mean. This depicts a high inter-annual climate variability. The area is marked by high intra annual climate variability due to the bimodal rainfall pattern with minimum intra annual climate variability is observed in 1993 i.e. 1.009 and the highest in 2016 i.e. 1.655. The area has a positive increasing non-significant trend for intra annual climate variability ($\alpha>0.05$). 63.16% of the years are marked by below normal precipitation amounts.

The lowest percentage of normal precipitation was observed in year 2000 i.e. 63.42% and the maximum in year 1997 i.e. 186.25 mm. A non-significant negative decreasing trend ($\alpha>0.05$) is observed for percentage of normal precipitation along the years indicating increasing severity of drought.The average NDVI for 1981-2018 is 0.2529. The lowest NDVI was observed in the year 1986 i.e. 0.0315 and the maximum in the year 2016 i.e. 0.537. The NDVI shows a significant positive trend along the years ($\alpha<0.05$). 42% of the years have above average NDVI. 69% of the years having above average NDVI fall in the latter half of the study period i.e. 2000-2018. 67% of the years in the 2010s depict an above average NDVI. These observation explain the positive trend in NDVI.

Relationship between climate variability and rainfall

A Kendall's tau-b correlation was run to determine the relationship between intra annual rainfall variability and annual total rainfall amounts for the period 1981-2018 in Tharaka South Sub County. There was a negative relationship between intra annual rainfall variability and total annual rainfall amount which was not statistically significant ($\tau_b = -0.014$, p=0.90).

A Kendall's tau-b correlation was run to determine the relationship between intra seasonal rainfall variability for the MAM (Long rains) season and MAM seasonal total rainfall amounts for the period 1981-2018 in Tharaka South Sub County. There was a negative relationship between intra seasonal rainfall variability for the MAM (Long rains) season and MAM seasonal total rainfall amounts which was not statistically significant (τ_b = -0.013, p=0.91).

A Kendall's tau-b correlation was run to determine the relationship between intra seasonal rainfall variability for the OND (Short rains) season and OND seasonal total rainfall amounts for the period 1981-2018 in Tharaka South Sub County. There was a negative relationship between intra seasonal rainfall variability for the OND (Short rains) season and OND seasonal total rainfall amounts which was not statistically significant (τ_b = -0.256**, p=0.024).

A Kendall's tau-b correlation was run to determine the relationship between intra seasonal rainfall variability for the JF Dry season and JF seasonal total rainfall amounts for the period 1981-2018 in Tharaka South Sub County. There was a negative relationship between intra seasonal rainfall variability for the JF (Dry) season and JF seasonal total rainfall amounts which was statistically significant (τ_b = 0.256**, p=0.024).

A Kendall's tau-b correlation was run to determine the relationship between intra seasonal rainfall variability for the JJASDry season and JJAS seasonal total rainfall amounts for the period 1981-2018 in Tharaka South Sub County. There was a negative relationship between intra seasonal rainfall variability for the JJASDry season and JJAS seasonal total rainfall amounts which was statistically significant (τ_b = 0.081**, p=0.474).

Relationship between climate variability and drought severity (PNP)

A Kendall's tau-b correlation was run to determine the relationship between intra annual rainfall variability and annual Percentage of normal precipitation for the period 1981-2018 in Tharaka South Sub County. There was a negative relationship between intra annual rainfall variability and annual Percentage of normal precipitation which was not statistically significant (τ_b = -0.014, p=0.90).

A Kendall's tau-b correlation was run to determine the relationship between intra seasonal rainfall variability for the MAM (Long rains) season and MAM seasonal Percentage of normal precipitation for the period 1981-2018 in Tharaka South Sub County. There was a negative relationship between intra seasonal rainfall variability for the MAM (Long rains) season and MAM seasonal Percentage of normal precipitation which was not statistically significant (τ_b = -0.016, p=0.89).

A Kendall's tau-b correlation was run to determine the relationship between intra seasonal rainfall variability for the OND (Short rains) season and OND seasonal Percentage of normal precipitation for the period 1981-2018 in Tharaka South Sub County. There was a negative relationship between intra seasonal rainfall variability for the OND (Short rains) season and OND seasonal Percentage of normal precipitation which was not statistically significant (τ_b = -0.253**, p=0.025).

A Kendall's tau-b correlation was run to determine the relationship between intra seasonal rainfall variability for the JF (Dry) season and JF seasonal Percentage of normal precipitation for the period 1981-2018 in Tharaka South Sub County. There was a negative relationship between intra seasonal rainfall variability for the JF Dry season and JF seasonal Percentage of normal precipitation which was statistically significant (τ_b = 0.259**, p=0.022).

A Kendall's tau-b correlation was run to determine the relationship between intra seasonal rainfall variability for the JJAS (Dry) season and JJAS seasonal Percentage of normal precipitation for the period 1981-2018 in Tharaka South Sub County. There was a negative relationship between intra seasonal rainfall variability for the JJAS Dry season and JJAS seasonal Percentage of normal precipitation which was statistically significant (τ_b = 0.081,p=0.474).

Relationship between climate variability and vegetation condition (NDVI)

A Kendall's tau-b correlation was run to determine the relationship between intra annual rainfall variability and Average annual NDVI for the period 1981-2018 in Tharaka South Sub County. There was a negative relationship between intra annual rainfall variability and Average annual NDVI which was not statistically significant (τ_b = - 0.088, p=0.436).

Local people's perceptions of climate variability

Local people in the study are have experienced climate variability as confirmed by 86.5% of the respondents who said local climatic patterns have changed to a high extent.Changes in the local climatic patterns that have been observed include: increase in extreme temperature events andunpredictability in temperature regimes such that periods expected to be cool end up being hot and vice versa. 5.2% said they had observed an increase in local temperatures. Rainfall distribution has become unpredictable and inconsistent and is often marked by long mid-season cessation. Unpredictable rainfall onset and offset dates have also been observed as rainfall patterns in the area have become increasingly erratic. 38.7% of the respondents said that the rainfall patterns had become unpredictable.

There is increased frequency of rainfall seasons having very low and below normal precipitation. In addition, there has been an increasein frequency, length and severity of drought seasons.55.6% of the respondents observed that there has been a reduction in rainfall amounts. Increased drought intensity andincreasingly hotter conditions has led to increase in evapotranspiration rates as witnessed by scenarios whereby the landscape returns dries up very fast after rainfall events as opposed to the past. There has also been increased frequency and erraticity of intensewind activities in the area.

Local people mainly attribute climate variability to environmental degradation whichcauses changes in the local climatic systems from the norm hence change in climatic patterns. 71.9% of the respondents said climate variability was caused by deforestationwhile 1.6% said it was because of poor environmental conservation practices. 1.6% of the respondents attributed climate variabilityto climate change.

The local people also attribute climate variability to drivers of environmental degradation. This includes poor governance which impedes proper enforcement of environmental laws and regulations. 0.3% of the respondents cited poor enforcement of forestry laws as being the cause of climate variability. They also say climate variabilityis caused by poor environmental management and unsustainable natural resource use; increasing population pressure on local resources; poor land use practices; andlack of diverse livelihood strategies hence high direct dependence on the natural resource base. Climate variability is also attributed to low capacity to address the causes; lack of political will to invest in and undertake environmental conservation activitiesand erosion of traditional systems for environmental governance.

Impacts of climate variability on local livelihoods

Climate variability was found to have various impacts including: increasing degradation of natural habitat e.g. forests including important indigenous plant species occasioned by increasing pressure hence unsustainable use as people encroach during droughts in search of alternative livelihood sources. Droughts impede plant growth either through natural regeneration and drying up of trees planted through restoration activities. Indigenous crop species are also fast disappearing due to low crop production levels and frequent crop failures.

There is decrease in quantity and quality of crop production caused by crops drying up and lack of irrigation water as sources dry up. Climate variability leads to drying up of planted crops due to poor rainfall distribution marked by late onset and midseason cessation of rainfall. Cropse.g. sorghum and green grams also rotand others are destroyed during extreme rainfall events marked by late offset and flash floods. Extreme climate events also lead to increase in crop pests and diseases. Diseases and pests caused by drought in crops in the area include: fall army worms outbreak, maize lethal necrosis and fusarium diseases such as root rot. Extreme high rainfall events also lead to crop diseases that are associated with wetness including bacterial and fungal diseases. Decrease in crop production means farmers earn less income hence are unable to access adequate good quality inputs including agrochemicals.

Farmers are increasingly being unable to properly make the right decisions on what to plant as climatic patterns become more unpredictable. This is as this unpredictabilityreduces ability of the local community to forecast climatic conditions using traditional methods as since prevailing trends that are not in tandem with the longterm norms. The erratic nature of local climatic conditions also reduces the probability thus accuracy and reliability of weather advisories issued based on scientific weather forecasting methods

96.9% of the respondents said climate variability has an impact on their crop production. 3.1% said it didn't have an impact. Among those who said climate variability has an impact on crop production, 74.5% said it caused low crop production due to low rainfalls. 4.4% said it led to reduced incomes. 1.3% said it brought about lack of adequate water while 11.4% said it caused unfavorable weather conditions. More so 0.3% said climate variability caused increased temperature levels that were unfavorable for crop production. Another 1.0% said climate variability caused rotting of crops during excess rainfall events while 16.9% said it caused drying of crops when there is insufficient rainfall. 8.8% said that climate variability led to stunted growth of crops with 2.6% saying it brought about poor crop growth hence resulting in poor quality products. In addition, 1.3% said climate variability led to increased outbreak in crops pests. 2.9% said climate variability caused total crop failure, 1.8% said it led to crop losses while 0.5% it made crops to take longer to mature.

There is decrease in quality and quantity of livestock production due to scarcity of pasture in quality and quantity, poor livestock body conditions lack of water and livestock deaths. Pests and diseases may increase due todroughts and heavy rainfall events.During drought infectious diseases are easily transmitted due to increased animal movements and due to high temperatures promoting existence and spread of disease vectors. Diseases that increase in the area during drought include tick borne diseases such as East Coast Fever, tsetse fly borne nagana, anthrax caused by spores from contaminated dry soils and viral borne pestis des petits ruminant.Heavy rainfall events cause Rift valley fever, bovine pluropneumounia, foot rot and foot and mouth disease among others. Decrease in livestock production reduces incomes hence inability to access quality inputs including meeting medical costs for animals

Climate variability was also found to have an impact on livestock production by 93% of the respondents. Of those who said climate variability has an impact on livestock production, 70.4% said it led to lack of pastures while 25.5% said it led to lack of water for livestock. 4.7% said climate variability leads to reduced market value for livestock, 18.2% said it causes to low livestock production and 2.9% said it brings about reduction in livestock numbers. 6.8% said climate variability leads to livestock diseases with 10.6% saying it leads to poor livestock health status. 3.6% said it leads to reduction in grazing land, 1.6% that it causes low quality livestock products and 6.5% that it leads to loss of livestock through death. In addition, 0.5% observed that climate variability causes increase in livestock pests while 9.4% said it leads to unfavorable weather conditions for livestock production.

Due to frequent crop failures, low crop yields and negative effects on livestock production caused by climate variability. Local are losing morale to invest in agriculture which further impacts on local incomes and food security. Negative impacts of climate variability on crop and livestock production also necessitates commitment of higher financial investment towards agricultural production due to costs associated with on coping, adaptation and mitigation activities which makes production more expensive hence reduced profitability. This further reduces the morale of local communities to invest in crop and animal production.

Negative impacts on crop and livestock production leads to food and nutritional insecurity. This is caused by decrease in food availability and lack of adequate income to purchase foodstuffs. Crop based foodstuffs become more expensive due to inadequate local production hence increased demand leading to unaffordability hence inaccessibility.26.9% of the respondents said climate variability led to food shortages.

Negative impacts of climate variability leading to lower incomes hence increased poverty forces local people to sell their assets including physical assets, land and livestock often at very low prices as a coping strategy leading to assets erosion and more poverty. Climate variability impacts affects economic opportunities by reducing performance of investments in income generating activities and availability of employment opportunities. This affects livelihoods diversification by limiting the available income sources.13% of the respondents said that change in local climatic patterns had led to reduction in income levels.

Negative effects of climate variability especially poverty erodes the societal moral fabric driving people to engage in social ills including crime, prostitution, early marriages among girls in an attempt to cope with the harsh conditions.Climate variability affects local people's culture and lifestyles as people change their behaviors to cope and as lack of resources effects engagement in traditional cultural events e.g. rites of passage.

Climate variability has negative impacts on human health. This occurs due to the resultant food and nutritional insecurity which causes diseases such as kwashiorkor, marasmus, eczema, scabies and stunting among children. Water scarcity causes water borne and hygienic related diseases e.g. typhoid, dysentery and skin diseases. Dry season's hence dusty conditions due to low vegetation cover cause respiratory and eye infections. Snake bites also increase during the dry season as snakes encroach human settlements in search of water. Increase in social ills due to impacts of drought lead to increase in sexually transmitted diseases. Stress due to climate variability impacts lead to depression. People also suffer from heat related stress during droughts. Extreme rainfall events may also lead to escalation of diseases that occur then e.g. pneumonia. Decrease in incomes due to economic losses reduces the ability of people to pay for healthcare services.

88.3% of the respondents said that climate variability has an impact on health status of their household members. Of those who said climate variability had an impact on household's health status, 40% said it led to exposure to diseases such as airborne and water borne diseases while 37.4% said it caused lack of proper diet hence malnutrition. 8.6% said climate variability increased risk of disease due to extreme heat with 3.6% saying it led to heat stress.

More frequent and prolonged droughts lead to acute scarcity in quality and quantity of water resources. This is caused by increasing pressure on water catchment and riparian areas which reduces water recharge and increased evapotranspiration; unsustainable use as pressure on the scarcely available water increases; drying of rivers, boreholes and dams. Lack of water has a negative impact of economic productivity of local people especially women since they have to invest more efforts, time and money to access water. Drying up of rivers and other water sources leads to failure of irrigation projects hence heavy financial losses.

Climate variability leads to increase in outmigration especially rural to urban migration as people leave to seek for alternative livelihood opportunities. This reduces the human resource capacity in rural areas as it's mainly the able bodied, knowledgeable and skilled people who leave. The less empowered people are left behind which enhances marginalization and underdevelopment.Harsh living conditions caused by climate variability e.g. low incomes and food insecurity was also observed to be discouraging people from having big families hence reduction in population growth rate and family sizes in the area.

Scarcity of resources especially pasture and water due to climate variability causes resource conflicts between upstream and downstream users and between local people and encroaching pastoralists from other areas. Human wildlife conflicts are also becoming more rampant especially near main wildlife habitats as wildlife move into human settled areas or humans encroach wildlife habitats in search of water and pasture.

Negative impacts of climate variability cause stresses that may lead to family disputes which at times escalate into family break ups.

Climate variability negatively impacts access to education due to low income levels which means parents have difficulties in paying school fees and for other school expenses. This istrue especially for post primary education that have greater financial requirements. Inability of parents to pay hinders local schools from investing in quality educational facilities and modern/digital methods and models of pedagogy which affects the quality of learning. Poverty also sometimes hinders people from pursuing their preferred career paths as they opt for cheaper options or are hindered from pursuing higher education levels due to rising needs occasioned by high dependency. Famine often leads to drop out or absence from schools, low concentration in class and health problems which cause poor educational performance. Migration of households in response to impacts of climate variability may force children to abandon or not attend schools, shift schools frequently or be left alone without the parental support needed to ensure proper school attendance.

Negative impacts of climate variability on moral values also negatively impacts education access through school drop outs, poor attendance hence poor performance as school going children engage in criminal and immoral activities hence reduced focus on education, early pregnancies or marriages. Climate variability by affecting school attendance leads to the problem of over age school children who are more vulnerable to early pregnancies, early marriages, child labour and negative peer pressure to engage in social ills such as prostitution, crime and drug abuse.

When asked whether climate variability had an impact on household's access to education with 86.8% of the respondents saying that climate variability had an impact on their household's access to education. Among those who said that climate variability had an impact on access to education, 52.1% said that this impact was in form lack of money to cater for education school expenses. An additional 27.6% were also of the observation that climate variability also led to lack of school fees. 32.3% said that climate variability led to lack of food which interferes with access to education while 1.6% said it caused absenteeism from school due to illnesses caused by harsh climatic conditions.

Climate variability has a negative effect development initiatives as people strive to cope hence focusing attention and commit their time, money and efforts on their immediate survival needs.Climate variability at times leads to damage of the local infrastructure such as roads, buildings and dams. This could manifest due to extreme rainfall events leading to occurrence of flash floods. Flash floods damage and cut off roads hence interfering with transport services, damage building including homesteads leading to heavy financial losses.

Response to impacts of climate variability on local livelihoods

Local people are undertaking various responses to impacts of climate variability including diversification of livelihoods by leveraging on diverse existing and emerging income generating opportunities. 8.9% of the respondents said they operated business activities while 9.6% said they engaged in traditional handicraft income generating activities such as basketry to cushion themselves against the impacts of climate variability. In addition, 8.2% of the respondents said they respond by seeking manual jobs while 0.1% said they seek salaried jobs in response to impacts of climate variability.Local people also lease out or sell assets such as land and pasture during severe drought periods as a coping strategy. 0.1% said they sell assets to get their basic needs as a coping mechanism to impacts of climate variability.Local people also diversify their production systems by growing and raising diverse livestock and crops species and varieties.

Capacity building to improve knowledge and skills that help in resilience building activities including on entrepreneurship, climate smart agriculture and health is done through training and extension services. This also involves access to information including on markets, weather, production technologies through shared learning and media platforms. There is also sensitization and capacity building to enhance climate variability awareness and resilience building at community level and in schools through environmental clubs.

Developing water harvesting structures such as check dams along rivers, water pans, sand dams, rock water harvesting and roof water harvesting systems to increase water storage and availability. Boreholes are also developed at strategic locations to provide water especially during drought seasons. 1.9% of the respondents said they were engaging in water harvesting activities as a response to impacts of climate variability.The community members have also developed committees charged with the role of managing these water facilities.In worst case scenarios there is roll out of water relief services using water boozers. Communities also buy water for domestic and livestock use during periods of severe water scarcity. 2.3% of the respondents said they purchase water for livestock as a response measure.

Practicing climate smart agriculture and planting of resistant crop varieties. 0.3% of the respondents said they had adopted the growing of drought resistant crops as a way of addressing the impacts of climate variability. 0.1% said they practiced early planting as a response measure so as to make full use of the often inadequate rainfall amounts.Soil and water conservation measures on farms are also being employed with 0.1%

of the respondents saying they engaged in soil erosion control through establishment of barriers as a response mechanism.

Local people are establishing sustainable irrigation projects through groups to engage in irrigation farming thus reducing impacts of drought through reduced reliance on rain fed agriculture. 2.1% of the respondents said they used irrigation in response to impacts of climate variability. There is also investment in better inputs including agrochemicals, fertilizers and manure and improved seeds. Communities also establish seed banks to preserve local crop varieties. The community is also receives supports for farm inputs e.g. the government led e-voucher system that provides farm inputs to promote commercial farming and subsidization of inputs prices by the government.

In livestock production resilience is built by keeping improved local breeds; introduction of hardy exotic breeds such as Sahiwal, Fleckvieh and Jersey cattle; provision of subsidized artificial insemination services by the county government; community led grass reseeding programs; planting of fodder trees; fodder preservation methods e.g. hay and silage making; providing supplementary feeds; use of farm left overs as fodder; provision of fodder relief e.g. grass cubes and water relief for livestock during worse case scenarios and leasing of grazing areas.2.7% of the respondents alluded to having leased out their grazing lands during droughts while 0.4% said they purchased animal fodder in response to drought impacts.

Local people also undertake livestock offtake at onset of droughtsto minimize related negative impacts. 0.6% of the respondents said that they addressed the impacts of climate variability by reducing the number of livestock kept while 4.9% said they sell their livestock at the onset of droughts.Livestock pests and diseases are also controlled through treatment and vaccination campaigns; controlled animal movement through permitting systems; and use of various pest control methods such as tsetse traps.

Local people respond to impact of climate variability on nutritional and food insecurity by screening people especially children for malnutrition and giving of nutrient supplements e.g. vitamin A supplement and balanced diet food packs.There is roll out of food relief services and programs by government and non-government agencies in worse case scenarios to enable communities cope to and survive severe drought periods.

Communities also adjust food consumption patterns based on prevailing conditions by e.g. skipping some meals, reduction of food rations and adults foregoing meals to allow children to eat.1.0% of respondents said they ration food by changing consumption patterns to copewith the impacts of climate variability.Households have food storage facilities e.g. granaries for safe storage of food to be used during harsh conditions and to sell when good prices prevail. 1.2% of the respondents said they addressed the impacts by storing food for future use during harsh times. They also buy food from markets during famines. 2.7% of the respondents said they respond by buying food from the market.

Local people respond to impacts of climate variability on access to education in various ways including: implementation of education support programs through fee sponsorships to vulnerable children, school feeding programs, food for fees programs and school gardening projects.There is also capacity building of school management boards and teaching staff on disaster management, establishment of boarding schools where children learn better cushioned against negative impacts and easing fees payment through phased payment or payment in kind.

There are also human health response actions that are being undertaken. This includes support initiatives targeting specific diseases that make people more vulnerable e.g. HIV/AIDS support groups. Free medical clinics are also organized mainly targeting specific diseases. There are also programs that offer free medication against epidemics and highly prevalent diseases. Health services outreach is being enhanced through Community Health Workers. Community led sanitation initiatives have been initiated to ensure all households have a toilet or latrine to avoid open defecation which leads to diseases especially during the rainy season. Health sensitization is being done through community meetings and schools. These include nutrition health sensitization programs.Communities are being supported with water treatment chemicals to avoid water borne diseases. Support programs for breast feeding mothers have been initiated to ensure children are well breastfed to avoid child mortality. Local people also join and contribute to health insurance schemes such as National Health Insurance Fund to help them address health related risks.

Regular climate and drought monitoring is being done to establish early warning systems and develop climate and weather advisories that are disseminated through various media. In addition to scientific forecasting, the community also uses traditional forecasting methods although their effectiveness is being affected by change in climatic patterns. This information serves to inform preparedness to extreme climate events and response actions.

Community based forest and catchment areas conservation initiatives including tree seedlings production and tree growing activities through agroforestry and social forestry are being undertaken. 3.9% of the respondents said they engage in tree planting to address impacts of climate variability. There is engagement in non-timber forest products enterprises e.g. honey production and promotion of sustainable use of tree products e.g. hygienic pollarding of branches rather than lopping among others.Environmental degradation including forests destruction is being controlled through enforcement of government legislations and community bylaws that curtail such activities.

Water resources are also being regulated using resource allocation plans and enforcement of government legislations. This includes regulation on the time for irrigation, acreage of irrigated land, water use permitting systems and controlling water intake points. There is continuous monitoring of rivers and water use to inform management actions. Water resource management plans are being participatorily developed and implemented to guide management efforts.

Management of local natural resources is also being achieved by leveraging on community based governance systems and structuresincluding local bylaws, taboos and resource users groups andassociations. The management capacity of community based natural resource users associations such as community forest associations and water resources users associations is being enhanced to enable them to effectively undertakeenvironmental and natural resources conservation and management activities.

Local communities use social networks to cope with impacts of climate variability. In doing this they support each other to cope with negative impacts through social welfare and reciprocity mechanisms and receiving remittances from relatives and friends.0.6% said they relied on help from their relatives while 1% sought relief from well-wishers as a way of coping with impacts of climate variability. Such networks also help people to cope with negative impacts through emotional support as people share and discuss their problems.These social networks or social capital are mainly accessed through community based groups.

Community based groups are being leveraged on to enhance resilience to climate variability. This includes through cheaper access to foodstuffs, crop and livestock production inputs and other capital assets by purchasing in bulk thus gaining from economics of scale. They also enable easier access to trainings, donor support and funding to help cope with impacts of climate variability. Community based production groups are also helping to improvemarketing of local products. This is by members of such groups bulkingtheir produce to increase their bargaining power, mobilizing resources to invest in value addition initiatives andtaking advantages of their organized structures to engage in more profitable production schemes e.g. contract farming and tenderpreneurship.

The community is also leveraging on emerging technologies e.g. mobile telephony to reinforce their resilience to climate variability. This is because they enable better access to market information,new innovations, weather forecasts and advisories. Users are also able to access information and knowledge that builds their capacity to undertake entrepreneurship and production activities. These technologies improve communication thus increasing efficiency in carrying out production and business activities.Mobile phone services also provide short term loans which support coping strategies for response to impacts of climate variability. They also help in coordination hence enhancing effectiveness of disaster response action.

Measuring climate variability resilience based on accessto livelihood assets and livelihood strategies

Local people's resilience to climate variability was measured based on access to livelihood assets and livelihood strategies. This was measured using household'sexpenditureon access to education and health care and access to inputs of crop and livestock production.

The households were found to be making substantial investment on education. The total household's expenditure on access to education in the last one year across the respondent's households was KShs 27,918,510 with an average expenditure per household being KShs 72,516. The household's expenditure on education ranged between KShs 600 to KShs 2,000,000.

Households were also investing in access to health care services. The total amount of household's expenditure on access to health care in the last one year was KShs 6,960,340 with an average of KShs 18079 per household. Thehousehold's expenditure on health care ranged between KShs 200 to KShs 200,000.

Household's expenditure on inputs of crop and livestock production was also looked at. The total expenditure on access to inputs of crop production across the respondent's households in the last one year was KShs 5,504,925 with an average of KShs 14,299 per household. This ranged between KShs 250 to KShs 160,500. The expenditure was on various inputs of crop production as shown in table 4.

Table 4: Total expenditure on crop production

Total expenditure on crop production			
Input	**% who purchased /paid for input**	**% who didn't purchased /paid for input**	**Total expenditure on input (KShs)**
Fertilizer	9.4	90.6	68,720
Manure	4.9	96.1	49,600
Planting seeds/materials	76.6	23.4	941,105
Pesticides/ herbicides	84.9	15.1	1,089,820
Irrigation water	15.6	84.4	88,560
Granary/store	9.1	99.9	487,700

Farming land	22.6	77.4	643,800
Labour	44.2	55.8	1,517,000
Tools	40.5	59.5	386,900
Marketing costs	48.6	51.4	304,360
Total expenditure			**5,504,925**

The total expenditure across the respondent's households on inputs of livestock production in the last one year was found to be KShs 4,576,450 with an average expenditure of KShs 11,887 per household. This ranged between KShs 100 to KShs 280,000. This expenditure was on various inputs of livestock production as shown in table 5.

Table 5: Total expenditure on livestock production

Total expenditure on livestock production			
Input	**% who purchased /paid for input**	**% who didn't purchased / paid for input**	**Total expenditure on input (KShs)**
Fodder	13.5	86.5	482,450
Supplementary feeds	12.7	87.3	65,320
Lease of grazing land	41.0	59.0	1,012,550
Medicine/pesticides	75.6	24.4	506,060
Insemination/breeding services	2.3	97,7	3,950
Water	37.7	62.3	761,160
Livestock shelter	32.2	67.8	282,610
Tools	16.4	83.6	169,100
Labour	14.0	86,0	1,070,690
Marketing costs	38.4	61.6	168,930
Total expenditure			**5,504,925**

Calculation ofhousehold's resilience to climate variability index

A resilience index was calculated to measure household's level of resilience to climate variability based on the sustainable livelihoods frameworks. The indicators used in calculating the household's resilience index wereexpenditure on access to capital assets and expenditure on livelihood strategies. The indicators included household's expenditure on access to education and access to health care, and expenditure on inputs of crop production and inputs of livestock production.

These indicators were allocated weights based on the pairwise ranking matrix as shown in table 6.

Table 6: Weighting of indicators through pairwise ranking matrix

Weighting of indicators through pairwise ranking matrix			
#	**Indicator**	**Rank**	**Weight**
1	Expenditure on health care	1	4
2	Expenditure on education	2	3
3	Expenditure on crop production	3	2
4	Expenditure on livestock production	4	1

The household's resilience composite index was then developed as per the study methodology. The household's resilience index arrived at was then tested for accuracy and robustness using uncertainty analysis. An uncertainty of 2.9% was arrived at giving an indication of very high certainty. Sensitivity analysis was also done to test the household's resilience index for accuracy robustness. A coefficient of determination (R^2) of 1.00 was arrived at meaning the variation in the composite index is largely explained by the model's components which is an indication of very high sensitivity.

The household's resilience was categorized based on the household's resilience index. This categorized the levels of resilience as shown in table 7.

Table 7: Categorization of household's resilience to climate variability based on household's resilience index

Categorization of household's resilience to climate variability based on household's resilience index	
Index range	**Definition**
0 – 0.25	Very low household resilience
>0.25 – 0.5	Low household resilience
>0.5 – 0.75	High household resilience
>0.75 – 1.00	Very high household resilience

The local household's resilience index was then subjected to descriptive analysis to determine the percentage of households lying at various levels of resilience in the study area as in table 8.

Table 8:Categorization of household's resilience to climate variability based on household's resilience index in Tharaka South

Categorization of household's resilience to climate variability based on household's resilience index in Tharaka South			
Index range	**Definition**	**Frequency**	**Percentage**
0 – 0.25	Very low household resilience	304	79.0
>0.25 – 0.5	Low household resilience	61	15.8
>0.5 – 0.75	High household resilience	17	4.4
>0.75 – 1.00	Very high household resilience	3	0.8

Most of the household's i.e. 79.0% were found to have a very low resilience to climate variability. In addition, 15.8% of the households had a low resilience to climate variability. 4.4% were observed to have a high resilience to climate variability while only 0.8% were found to have a very high resilience. This means that households in Tharaka South Subcounty are marked by very low levels of resilience to climate variability.

VII. Discussion

Climate variability was observed in Tharaka South Subcounty across all timescales. This is depicted by positive trends in monthly climate variability for all months along the study period. There is also a positive trend in intraseasonal climate variability for all the four seasons under study. A similar positive trend is observed in the case of intra annual climate variability.These trends are non-significant and marked by highly fluctuating nonlinear patterns which indicates that climatic patterns are highly unpredictable.

This observation is confirmed by trends of rainfall amounts across all timescales along the study period. Monthly rainfalls show a negative trend for all months except for the months of January, February and November which show a positive trend. This means that monthly rainfall amounts are generally on the decline. A positive trend in the normally dry months of January and February is an indicator of the increasingly erratic thus unpredictable nature of local climate conditions.A similar scenario is observed for seasonal rainfall where by negative highly fluctuating rainfall trendsare observed for the MAM short rains,OND long rains season. A positive rainfall trend is however observed in the JF dry seasonand theJJAS dry season which indicates the increasingly unpredictable climatic patterns as rainfall amounts increase in these normally dry seasons. The annual total rainfall trends also depict a negative nonlinear trend meaning rainfall amounts are generally decreasing and becoming more erratic and unpredictable along the years.This unpredictability is observed even for shorttimescales which makes it hard to forecastclimatic conditions.

The study area also shows a generally increasing trend in drought severity along the years as depicted by the general negative trend of percentage of annual precipitation. This observation was made across all timescales. All months in the study period show a negative trend in percentage of normal precipitation except for January, February and Novemberwhich have a positive trend in percentage of normal precipitation. The positive trend in percentage of normal precipitation especially in the normally dry months of January and February gives an indication of climate variability in the study area.A negative trend in percentage of normal precipitation was also observed for seasonal rainfall for the MAM and OND wet seasons.A positive trend was however observed for the JFdry season and theJJAS dry season which have a positive trend in percentage of normal precipitation. Again a positive trend in percentage of normal precipitation for thesetwo normally dry month is an indicator of climate variability. As appertains to the annual scale, the percentage of normal precipitation shows a negative trend over the years. These trends are mainly non-significant and nonlinear in nature depicting that the local climatic conditions are highly unpredictable.

The intra annual climate variability in thestudy area has a negative relationship with total annual rainfall amount meaning rainfall amounts are generally decreasing as the climate becomes more variable. A negative relationship is also observed between climate variability andannual percentage of normal precipitation meaning droughts are becoming more severe as climate variability increases.

A similar relationship is observed for the MAM and OND rainfall seasons whereby the intraseasonal climate variability for these two wet seasons is observed to have a negative relationship with seasonal rainfall amountsand seasonal percentage of annual precipitation.However, the JF and JJAS dry seasons show a positive relationship intraseasonal climate variability and seasonal rainfall amounts. There is also a positive relationship between intraseasonal climate variability and seasonal percentage of normal precipitation for the JF and JJAS dry seasons. This observation is as opposed to the expected scenario for these dry seasons which again depicts the highly unpredictable nature of local climatic conditions.

The annual NDVI is found to have a negative relationship with climate variability meaning an increase in climate variability leads to a decrease in NDVI. On the other hand, NDVI has a positive relationship with rainfall amounts and percentage of normal precipitation. This means NDVI increases with an increase in rainfall and a decrease in drought severity.

The NDVI in the study area was found to have a nonlinear trend meaning the vegetation condition is not predictable. The NDVI trend is however observed to have a general significant positive trend along the study period. This indicates the local vegetation condition to be improving along the years from 1981-2018. This is despite the fact that rainfall amount has a declining trend while drought severity has an increasing trend along the years as climate becomes more variable. This means NDVI in the study area is not solely influenced by climatic factors. The NDVI could also be influenced by anthropogenic factors especially the nature of land use and environmental management activities. This includes the nature of crop production, irrigation agriculture, agroforestry and afforestation which have could be having a significant influence on vegetation conditions in the study area

Local people in Tharaka South Sub County have perceived climate variability. This is confirmed by 86.5% of the respondents who said the local climatic conditions have changed to a high extent over time.This has mainly been perceived through the increasing unpredictability of local climatic patterns, more frequent and prolonged droughts and erratic rainfall seasons. They mainly attribute the observed climate variability on environmental degradation and its drivers which causevariation in local patterns ofclimate elements away from the norm henceclimate variability.

Climate variability has negative impacts on local people's livelihoods. This involves negative impacts on access to capital assets hence also on livelihood strategies. Climate variability has a negative impact on the local natural resources base including forests and water resourcesdue to increase in human pressure hence unsustainable use andeffects of severe drought on vegetation growth, restoration efforts and condition. The resultant resource scarcity has negative multiplier effects including loss of incomes and resource conflicts.Climate variability decreases the quantity and quality of crop and livestock production due to negative effects on growth conditions, the resource base and lack of adequate inputs as income levels decrease. This results in food and nutritional insecurity and increased poverty.

Climate variability also negatively affects the societal moral fabric as people are forced to engage social ills due to rising poverty. There is change in local lifestyles as people adjust to cope and adapt. There is also an impact on the population structure as more able people out-migrate in search of alternative livelihood sourcesand fertility rates drop in response to harsh climatic conditions. Climate variability has a negative impact on access to and performance in education. This is due to lack of financial capacity to invest in education and conditions that hinder access and good performance including food insecurity, poor health andincrease in social ills. Health is also impacted negatively as climate variabilitycreates the right conditions for higher disease prevalence and reduce the financial capacity to pay for health care services.

The local community is responding to climate variability through diversification of livelihood strategies including income generation and production activities. This diversification is also enabled by improved knowledge and skills for resilience building attained through trainings and information sharing networks.Initiatives have also been put in place to address impacts of climate variability on access to education including school feeding and education sponsorship programs. Impacts on health are being addressed through sensitization, disease prevention and community based outreach initiatives.

Communities are also coping and adapting to impacts of climate variability through reciprocity mechanisms created by social networks e.g. community based groups. Thesesocial networks also avenues for emotional support and knowledge sharing which increases resilience. Community members collectively engage production and business activities through these networks hence improving market participation and efficiency through the increased bargaining power and economies of scale. They also provide financial capital through informal microfinance institutions hence enhancingaccess to capital assets and livelihood strategies.

Local communities are also improving their crop and livestock production to better cope and adapt to impacts of climate variability through various climate smart agriculture practices, inputs subsidization and support initiatives, and reduction of dependence on rain fed agriculture through water harvesting and sustainable irrigation projects. This is helping to address effects of climate variability on food and nutritional security. Food relief programs, increased capacity to purchase foodstuffs through enhancement of livelihood strategies and change in consumption patterns also contribute to increasedfood and nutritional security.

Resilience to climate variability is also being enhanced through ecosystem based approaches including sustainable natural resources management and environmental restoration activities especially through community based approaches. Environmental monitoring is also done on a regular basis to establish early warning systems and inform management actions.

The resilience of local households to climate variability was found to be mainly very low. This is because upon developing and calculating a household's resilience index based on the sustainable livelihoods framework. Most of the household's i.e. 79.0% exhibited a very low resilience to climate variability as per the established criteria. This means although the community is undertaking various responses to impacts of climate variability, they are not being undertaken at a level that s makes the households sufficiently resilient.

VIII. Conclusion

Local climate patterns in Tharaka South Subcounty are becoming increasingly variable as witnessed by positive trends in climate variability for monthly, seasonal and annual timescales. Climate variability locally is associated with decreasing rainfall amounts and increasing drought severity for the wet seasons with the opposite being true for the dry seasons whose rainfall and drought severity levels have a negative relationship with climate variability. Climatic patterns are thus becoming more erratic and unpredictable as confirmed by local people perception of climate patterns over time. Climate variability is largely attributed to environmental degradation and its drivers which have caused changes in the local climate systems. Climate variability has been observed to have negative impacts on local people's livelihoods by affecting access to livelihood assets which in turn affects livelihood strategies hence outcomes. Local people are however leveraging on existing institutional structures and processes to build resilience to climate variability. However, despite efforts geared towards responding to impacts of climate variability, most local households still have very low resilience levels. Therefore there is need to intensify climate variability resilience building through adaptation and mitigation mechanisms that enhance access to assets and thus improve livelihood strategies.

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